APJ Abdul Kalam Technological University

Cluster 4: Kottayam

M. Tech Program in Electrical Engineering (Power Systems and Renewable Energy)

Scheme of Instruction and Syllabus: 2020 Admissions

Compiled By

Rajiv Gandhi Institute of Technology, Kottayam

November 2020

SCHEME AND SYLLABI FOR M. TECH DEGREE WITH SPECIALIZATION IN POWER SYSTEMS AND RENEWABLE ENERGY

Creditrequirements : 67 credits(22+19+14+12)
NormalDuration : Regular: 4 semesters; External Registration: 6 semesters;
Maximumduration : Regular: 6 semesters; External Registration: 7 semesters.
Courses: Core Courses: Either 4 or 3 credit courses; Elective courses: All of 3 credits
Allotment of credits and examinationscheme: -

Semester1 (Credits: 22)

Exam Slot	Course No:	Name	L- T - P	Internal Marks	End Semester Exam		Credits (22)
					Marks	Duration (hrs)	
A	04EE6801	Computational Techniques	3-0-0	40	60	3	3
B	04EE6501	Non – Conventional Energy Sources	4-0-0	40	60	3	4
C	04EE6803	Computer Aided Power System Analysis	4-0-0	40	60	3	4
D	04EE6805	Power Electronics for Renewable Energy Systems	3-0-0	40	60	3	3
E	04 EE 6XXX*	Elective – I	3-0-0	40	60	3	3
	04 GN 6001	Research Methodology	0-2-0	100	0	0	2
	04 EE 6813	Seminar – I	0-0-2	100	0	0	2
	04 EE 6815	Power Systems and Power Electronics Lab	0-0-2	100	0	0	1
		Total	**23**				**22**

**See List of Electives-I for slot E*

List of Elective - I Courses

Exam Slot	COURSE NO.	COURSE TITLE
E	04EE6807	Energy Management and Audit
E	04EE6809	Conventional and Alternative Energy Storage Technology
E	04EE6103	System Theory
E	04EE6811	Electric Drive System

Semester 2 (Credits: 19)

Exam Slot	Course No:	Name	L- T - P	Internal Marks	End Semester Exam		Credits (19)
					Marks	Duration (hrs)	
A	04EE6802	Analysis, Design and Grid Integration of Renewable Energy Systems	4-0-0	40	60	3	4
B	04EE6804	Smart Grid Technologies and Application	3-0-0	40	60	3	3
C	**04EE6418**	Power System Dynamics and Stability	3-0-0	40	60	3	3
D	04EE6XXX*	Elective - II	3-0-0	40	60	3	3
E	04EE6XXX^	Elective - III	3-0-0	40	60	3	3
	04 EE 6892	Mini Project	0-0-4	100	0	0	2
	04 EE 6824	Advanced Power Systems and Renewable Energy Lab	0-0-2	100	0	0	1
		Total	**22**				**19**

**See List of Electives -II forslotD* *^See List of Electives -III for slotE*

List of Elective - II Courses

Exam Slot	COURSE NO.	COURSE TITLE
D	04 EE 6806	Energy System Modeling and Analysis
D	04 EE 6808	Electric and Hybrid Vehicles
D	04 EE 6810	Energy Resource Economics and Environment
D	04 EE 6812	Power System Planning

List of Elective - III Courses

Exam Slot	COURSE NO.	COURSE TITLE
E	04 EE 6814	Power System Restructuring and Deregulation
E	04 EE 6816	SCADA and Applications
E	04 EE 6818	FACTS and HVDC
E	04 EE 6820	ICT Enabled Power System Protection and Computer Relaying
E	04EE 6822	Power System Operation and Control

M. Tech (Power Systems and Renewable Energy)

Summer Break

Exam Slot	Course No:	Name	L- T - P	Internal Marks	End Semester Exam		Credits (0)
					Marks	Duration (hrs)	
NA	04 EE 7800	Industrial Training	0-0-4	NA	NA	NA	Pass /Fail
		Total	4				0

Semester 3 (Credits: 14)

Exam Slot	Course No:	Name	L- T - P	Internal Marks	End Semester Exam		Credits (14)
					Marks	Duration (hrs)	
A	04 EE 7XXX*	Elective - IV	3-0-0	40	60	3	3
B	04 EE 7XXX^	Elective - V	3-0-0	40	60	3	3
	04 EE 7291	Seminar - II	0-0-2	100	0	0	2
	04 EE 7293	Project (Phase - I)	0-0-12	50	0	0	6
		Total	20				14

**See List of Electives-IV forslotA* ^*See List of Electives-V for slotB*

List of Elective - IV Courses

Exam Slot	COURSE NO.	COURSE TITLE
A	04 EE 7801	Embedded System Controllers for Renewable energy Systems
A	04 EE 7803	Machine Learning and Data Analytics
A	04 EE 7501	Energy and climate
A	04 EE 7103	Optimal Control Theory

List of Elective - V Courses

Exam Slot	COURSE NO.	COURSE TITLE
B	04 EE 7805	Artificial Intelligence application in power systems
B	04 EE 7001	Bio-inspired algorithms
B	04 EE 7807	Power Quality
B	04 EE 7809	Nanomaterials for solar application

Semester 4 (Credits: 12)

Exam Slot	Course No:	Name	L- T - P	Internal Marks	External Evaluation Marks	Credits (12)
NA	04 EE 7810	Project (Phase -II)	0-0-21	70	30	12
		Total	**21**			**12**

Total: 67

COURSE No.:	COURSE TITLE	L-T-P: Credits	YEAR
04EE6801	COMPUTATIONAL TECHNIQUES	3-0-0: 3	2020

Course Prerequisites

- Basic knowledge of engineering mathematics at UG level.
- Knowledge of a programming language preferably MATLAB or OCTAVE or SCILAB

Course Objectives

- To equip the student with mathematical techniques necessary for computing applications in engineering systems

Syllabus

Introduction to numerical techniques. Numerical, analytical solution of ordinary differential equations and partial differential equations. Stability of the numerical methods. Iterative solutions. Matrix equations. Ill conditioning and norms. Linear and unconstrained optimization. Simplex methods.

Expected Outcomes

Upon the completion of this course, students will have the ability:

- To solve equations using numerical iteration techniques including Newton's method,interpolation methods
- To solve equations using numerical iteration techniques including Triangularization techniques, Eigen values etc.
- To apply numerical techniques for the solution of differential equation of dynamicsystems
- To use MATLAB/Octave/Scilab platforms for the solution of equations
- To apply numerical techniques for the solution of partial differential equation
- To acquire knowledge of various unconstrained optimization.

Text book:

1. Erwin Kreyszig, Advanced Engineering Mathematics 9th Edition, Wiley International Edition
2. William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery, Numerical Recipes for scientific computing, Cambridge University Press
3. Igor Grivia, Stephen G Nash, ArielaSofer, Linear and Nonlinear Optimization, Second Edition, SIAM

Course plan

COURSE NO.:	COURSE TITLE	L-T-P: 3-0-0	
04EE6801	COMPUTATIONAL TECHNIQUES	CREDITS: 3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 Numerical Analysis: Solution of equations by iterations - Fixed point iteration – Bisection - Newton's method – secant method Interpolation – Lagrange interpolation – Newton's divided difference, forward difference, backward difference equations – spline interpolation Numeric integration – Trapezoidal rule, Simpson's rule – Numerical differentiation		7	15
MODULE: 2 Numerical Linear Algebra: Gaussian elimination – LU factorization – Doolittle's method, Cholesky's method - Matrix inversion Gauss-Siedel iteration for system of equations – Ill conditioning and norms Curve fitting – least squares method – eigen value problems – power method for eigen values – Tridiagonalization and QR factorization		8	15
FIRST INTERNAL TEST			
MODULE: 3 Numerical Solution of ODE: Euler's forward difference, backward difference and symmetric methods – stability of Euler's methods – RungeKutta methods – multistep methods, Euler method for systems – Runge Kutta Methods for systems		8	15
MODULE: 4 Numerical Solution of PDE: Elliptic PDE – Difference equations for Laplace and Poisson equations – Liebmann's method – ADI method – Boundary conditions, Parabolic PDE – Crank Nicholson Method -Hyperbolic PDE – Explicit method		7	15
SECOND INTERNAL TEST			
MODULE: 5 Geometry of Linear Programming – Standard form – Extreme points – Optimality, Simplex Method – Tableaus – Solution – Degeneracy and Termination		6	20
MODULE: 6 Dual Problems – Dual Simplex Method – Parametric Linear Programming, Enhancements of Simplex Method – Basis – Numerical stability		6	20
END SEMESTER EXAM			

Internal Continuous Assessment: 40 marks
Internal continuous assessment is in the form of periodical tests, assignments, seminars or a combination of all whichever suits best. There will be a minimum of two tests per subject. The assessment details are to be announced to students' right at the beginning of the semester by the teacher.
Two internal tests, each having 15 marks each summing to a total of 30 marks
All modules should have programming demonstrations which is counted as assignments – 10 marks
Cluster level end-semester examination:60 marks

COURSE No.:	COURSE TITLE	L- T - P: Credits	YEAR
04 EE 6501	NON – CONVENTIONAL ENERGY SOURCES	4-0-0	2020

Pre-requisites: Nil

Objectives:

- To introduce concepts of solar energy conversion and the various ways of storing the solar energy
- To understand the principles of wind energy conversion devices, types of wind turbines and generators.
- To study about Geothermal energy, ocean energy, wave energy, tidal energy, fuel cell, hydrogen energy, biomass and its conversion technologies

Syllabus

Solar radiation outside the Earth's atmosphere and at the Earth's surface – Instruments for Solarradiation measurement– Solar radiation geometry – Solar Photovoltaic Systems - Solar thermal energycollectors – types and applications, Wind Energy: Basic principles of wind energy conversion – windspeed measurement - classification of wind turbine – types of rotors – aerodynamic operation of windturbine – wind power equation – Betz limit – Wind characteristics, Small Hydropower system,Geothermal resources – power generation – Vapour/liquid dominating systems, Methods of oceanthermal electric power generation – open cycle and closed cycle OTEC system, Power in Waves – waveenergy technology, Tidal Energy- tidal energy conversion scheme, Principles of operation of fuel cellclassification, Hydrogen energy – hydrogen production and utilization, Biomass conversion technologiesBiogas production.

Course Outcome:

Students will be able to explain the concepts behind various type of new and renewable energy resources.

Text Books:

1. J. Twidell and T. Weir, Renewable Energy Resources, E&FN Spon Ltd, London, 1986.
2. S. P. Sukatme, Solar Energy – Principles of thermal collection and storage, second edition, Tata McGraw Hill, 1991.

References:

1. G. D. Rai, Non Conventional Energy Sources, Khanna Publishers, 2010.
2. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, second edition, John Wiley,New York, 1991.
3. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.
4. L. L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
5. L. Monition, M. Lenir and J. Roux, Micro Hydro Electric Power Station,John Wiley and Sons,England,1984.
6. K. M. Mittal, Non-conventional Energy Systems – Principles, Progress and Prospects, Wheeler Publications, 1997.
7. D. D. Hall and R. P. Grover, Bio-Mass Regenerable Energy, John Wiley, New York, 1987.
8. B. H. Khan, Non Conventional Energy Resources, 2nd edition, TMH 2013.
9. D. P. Kothari, K. C. Singhal, Rakesh Rajan, Renewable energy sources and emerging technologies, 2nd edition, 2013.
10. C. S. Solanki, Solar Photovoltaic Fundamentals, Technologies and Applications, PHI Learning, New Delhi, 2012.

Course plan

COURSE NO.	COURSE TITLE		L- T – P: 4-0-0
04 EE 6501	NON – CONVENTIONAL ENERGY SOURCES		CREDITS: 4
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 Solar Radiation: Solar radiation outside the Earth's atmosphere and at the Earth's surface – Instruments for Solar radiation measurement, Solar radiation data – Solar radiation geometry – Empirical equations – Solar radiation on a tilted surface – Problems.		8	15
MODULE: 2 Solar Photovoltaic Systems – PV Cell fundamentals – equivalent circuit – cell characteristics – I-V equation-series parallel combination of P V Cells-classification of solar cell. Solar thermal energy collectors – types - Liquid flat plate collector - concentrating collectors –parabolic collector - central receiver collector– applications – solar water heating systems. - Overview of Solar thermal electric power generation		9	15
FIRST INTERNAL TEST			
MODULE: 3 Wind Energy: Basic principles of wind energy conversion – wind speed measurement - classification of wind turbine – types of rotors – aerodynamic operation of wind turbine – wind power equation – Betz limit – Wind characteristics – Problems – types of generators – site selection		10	15
MODULE: 4 Small Hydro: Basic concepts – site selection – types of turbines. Geothermal energy: Geothermal resources – power generation – Vapour/liquid dominating systems – block diagram – hot dry rock and hydrothermal resources – applications – Environmental considerations Energy from biomass: Biomass conversion technologies - Biogas production – classification of biogas plants		10	15
SECOND INTERNAL TEST			
MODULE: 5 Ocean Energy: Methods of ocean thermal electric power generation –open cycle and closed cycle OTEC system - Environmental impacts. Wave Energy: Power in Waves – wave energy technology – Heaving float type – pitching type – Heaving and pitching type – oscillating water column type – surge devices - Environmental impacts - Tidal Energy: Limitations of tidal energy – tidal range powers – problems – tidal energy conversion scheme – single basin and double basin types		9	20
MODULE: 6 Hydrogen energy: Introduction – hydrogen production – electrolysis – thermo chemical methods – hydrogen storage – utilization of hydrogen gas. Fuel cell: Principles of operation of fuel cell – classification – conversion efficiency and losses – types of electrodes – work output and emf – applications		10	20
END SEMESTER EXAM			

Course No.:	COURSE TITLE	L-T-P: Credits	Year
04EE6803	COMPUTER AIDED POWER SYSTEM ANALYSIS	4-0-0: 4	2020

Pre-requisites:

Objectives:

1. To develop an idea about graph theory and building algorithm.
2. To identify and represent various power system components.
3. Learn to analyze power systems with different load flow studies and short circuit studies.

Syllabus

Elementary linear graph theory; Building algorithm for Bus impedance matrix; Load Flow Studies; Three phase Load Flow; Representation of power system components; Incorporation of FACTS devices in Load Flow; Types of faults-Short circuit study of a large power system; Unsymmetrical Faults; Short circuit calculations using Z bus.

Course Outcome:

The student will get acquainted with mathematical approach for load flow studies and fault calculations.

Text Books:

1. Singh L P, "Advanced Power Systems Analysis and Dynamics", New Age Intl. Publishers, 1983.
2. Stagg and EL Abiad , "Computer Methods in Power system Analysis
3. Kusic G L, "Computer Aided Power System Analysis", Prentice Hall, 1986.

References:

1. Hadi Saadat, "Power System Analysis", McGraw Hill
2. Arriliga J and Watson N R, "Computer Modeling of Electrical Power Systems", Wiley, 2001.
3. Nagrath J J and Kothari D P, "Modern Power system Analysis", Tata McGraw Hill, 1980.
4. Kothari D P, "Modern Power system Analysis", Tata McGraw Hill, 1980.
5. John J. Grainger, William D. Stevenson, Jr., "Power System Analysis", - Tata McGraw-Hill Series in ECE.
6. Jos Arrillaga, Bruce C. Smith, Neville R. Watson, Alan Wood, "Power System Harmonic Analysis", - John Wiley and Son, 1997
7. S A Soman, S A Khaparde, ShubhaPandit, "Computational methods for large sparse power systems analysis",: An object oriented approach, Kluwer academic publishers

Course Plan

Course No.:	COURSE TITLE	L-T-P: 4-0-0	
04EE6803	COMPUTER AIDED POWER SYSTEM ANALYSIS	Credits: 4	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE:1 **Elementary linear graph theory** Incidence and Network matrices- Development of network matrices from Graph theoretic approach- Building algorithm for Bus impedance matrix- Modification of Z_{Bus}matrix due to changes in primitive network.			**15**
MODULE:2 **Load Flow Studies** Overview of Gauss- Seidel and Newton - Raphson Methods- Decoupled Newton Load Flow- Fast Decoupled Load Flow-AC/DC load flow- Three phase Load Flow – Sparsity techniques – Triangular factorization – Optimal ordering – Optimal load flow in power Systems.			**15**
FIRST INTERNAL TEST			
MODULE: 3 **Power system componentsand their representation** Representation of Synchronous machine, transmission system, three phase power networks. Incorporation of FACTS devices in Load Flow: Static Tap Changing, Phase Shifting (PS), Static Var Compensator (SVC), Thyristor Controlled Series Compensator (TCSC) and Unified power Flow Controller.			**15**
MODULE: 4 **Short circuit studies** Types of faults-Short circuit study of a large power system-Algorithm for calculating system conditions after fault-Three phase short circuit, three phase to ground, double line to ground, line to line and single line to ground fault-Short circuit calculations using Z bus –Short circuit calculations for balanced and unbalanced three phase network using Z-bus.			**15**
SECOND INTERNAL TEST			

MODULE: 5 **State Estimationsof Power system** State estimation – least square and weighted least square estimation methods for linear and non-linearsystems. Static state estimation of power systems- injections only and line only algorithms, Treatment of bad data – detection, identification and suppression of bad data.		**20**
MODULE: 6 **Contingency Analysis** Contingency Analysis- adding and removing multiple lines, Analysis of single and multiple contingencies, Contingency Analysis by DC model, System reduction for contingency and fault studies		**20**
END SEMESTER EXAM		

Course No.:	COURSE TITLE	L- T – P: Credits	Year
04EE6805	Power Electronics for Renewable Energy Systems	3-0-0: 3	2020

Pre-requisites: Nil
Objectives

- To lay a foundation in the fundamentals of power electronic devices
- To study the operation and analysis of various converters used for renewable energy applications.
- To study various strategies used for the control of power electronic converters used for renewable energy applications.

Syllabus

Ideal and Real switches,Overview of solid-state devices ,Controlled rectifiers for renewable energy systems PWM rectifiers,Dc-dc converters for renewable energy systems ,Resonant DC-DC converters, Inverters for grid connection,Multilevel inverters, Current Control of inverters.

Text Books

1. Joseph Vithayathil, Power Electronics: Principles and Applications, Tata McGraw Hill 2010.
2. Mohan, Undeland, Robbins, Power Electronics; Converters, Applications and Design. -3rd edition, John Wiley and Sons, 2003.
3. Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education, 2013.

Reference Books

1. Krein P. T., Elements of Power Electronics, Oxford University Press, 1998.
2. L. Umanand, Power Electronics – Essentials & Applications, Wiley-India, 2009.
3. M H Rashid (Ed), Power Electronics Handbook: Devices, Circuits and Applications, Academic Press 2010.
4. José Rodríguez, *et al,* Multilevel Inverters: A Survey of Topologies, Controls, and Applications, IEEE Transactions on Industrial Electronics, vol. 49, no. 4, August 2002.

Course No.:	Course Title	L- T – P: 3-0-0	
04EE6805	**Power Electronics for Renewable Energy**	**Credits: 3**	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 **Overview of solid-state devices** Ideal and Real switches, Power diodes, Power Transistors, Power MOSFETS, IGBTs, Thyristor, GTO, TRIAC; Static and Dynamic Performance, Driver circuits and Snubbers for Power MOSFET and IGBT.		6	15
MODULE: 2 **Controlled rectifiers for renewable energy systems:** Single phase and three phase – fully controlled and semi-controlled – analysis with RL and RLE load – inversion mode of operation **PWM rectifiers**: Power factor improvement of rectifier circuits – Single phase PWM rectifier – topologies and control		7	15
FIRST INTERNAL TEST			
MODULE: 3 **Dc-dc converters for renewable energy systems** DC-DC converters: DC steady state principles, Analysis of Buck, boost, buck-boost, Ćuk converters under continuous and discontinuous conduction mode operation Basic operation of Forward, fly-back and push-pull converter circuits, half bridge, full bridge converters.		9	15
MODULE: 4 **Resonant DC-DC converters** Concept of soft switching, Operating principle, waveforms of Resonant switch converter – Zero voltage switching and Zero current switching DC-DC Converter control: PWM, closed loop control, feed forward and current mode control		6	15
SECOND INTERNAL TEST			
Module: 5 **Inverters for grid connection** Operation and analysis of single phase and three phase inverters RL load, PWM inverter modulation strategies, unipolar and bipolar switching scheme, sine wave PWM.		6	20
Module: 6 **Multilevel inverters**: Types and Operation - Diode-clamped multilevel inverter - Flying-capacitors multilevel inverter – cascaded multilevel inverter **Current Control of inverters** - Current Regulated PWM Voltage Source Inverters – Hysteresis band control - Fixed Switching Frequency Current Control Methods.		7	20
END SEMESTER EXAM			

COURSE NO.:	COURSE TITLE	L-T-P: Credits	YEAR
04EE6811	**ELECTRIC DRIVE SYSTEM**	**3-0-0-3**	**2020**

Pre-requisites: Nil

Course Objectives:

To enable the students

- To evaluate and select a suitable drive for a particular application.
- To analyse the basic drive system dynamics and arrive at operating point characteristics.
- To develop the basic design of an electric drive system.

Syllabus

Electric Drive System- Dynamics and steady state stability - dc motor drives -closed loop control of dc drives - AC induction motor drives -PWM converter-fed Induction Motor drives - Synchronous motor drives - Converter-fed Synchronous Motor Drives.

Course Outcome:

- Students will be able to select a suitable drive for a particular application.
- Students will be able to develop basic design of an electric drive system, analyse its steady state stability.

Text Books:

R. Krishnan, Electrical Motor Drives, PHI-2003

References:

1. G.K.Dubey, Power semiconductor controlled drives, Prentice Hall- 1989
2. G.K.Dubey, Fundamentals of Electrical Drives, Narosa- 1995
3. S.A. Nasar, Boldea , Electrical Drives, Second Edition, CRC Press - 2006
4. M. A. ElSharkawi , Fundamentals of Electrical Drives , Thomson Learning -2000
5. W. Leohnard, Control of Electric Drives,-Springer- 2001
6. Murphy and Turnbull, Power Electronic Control of AC motors, Pergamon Press
7. Vedam Subrahmaniam, Electric Drives, TMH-1994

COURSE PLAN

COURSE NO.:	COURSE TITLE	L- T – P: 3-0-0	
04EE6811	ELECTRIC DRIVE SYSTEM	CREDITS: 3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 Components of electrical Drives – electric machines, power converter, controllers - dynamics of electric drive - torque equation - equivalent values of drive parameters- components of load torques types of load – four-quadrant operation of a motor – steady state stability – load equalization – classes of motor duty- determination of motor rating.		8	15
MODULE 2: DC motor drives – dc motors & their performance (shunt, series, compound, permanent magnet motor, universal motor, dc servomotor) – braking – regenerative, dynamic braking, plugging –Transient analysis of separately excited motor – converter control of dc motors – analysis of separately excited & series motor with 1-phase and 3-phase converters – dual converter –analysis of chopper controlled dc drives – converter ratings and closed loop control – transfer function of self, separately excited DC motors – linear transfer function model of power converters – sensing and feeds back elements – current and speed loops, P, PI and PID controllers – response comparison – simulation of converter and chopper fed DC drive		8	15
FIRST INTERNAL TEST			
MODULE: 3 Induction motor drives – stator voltage control of induction motor – torque-slip characteristics – operation with different types of loads – operation with unbalanced source voltages and single phasing – analysis of induction motor fed from non-sinusoidal voltage supply – stator frequency control – variable frequency operation – V/F control, controlled current and controlled slip operation – effect of harmonics and control of harmonics.		7	15
MODULE 4: PWM inverter drives for Induction Motors – multi quadrant drives – rotor resistance control – slip torque characteristic – torque equations, constant torque operation – slip power recovery scheme – torque equation – torque slip characteristics – power factor – methods of improving power factor – limited sub synchronous speed operation – super synchronous speed operation.		7	15
SECOND INTERNAL TEST			
MODULE 5: Synchronous motor drives – speed control of synchronous motors – adjustable frequency operation of synchronous motors – principles of synchronous motor		6	20

control – voltage source inverter drive with open loop control –		
MODULE: 6 Self-controlled synchronous motor with electronic commutation – self-controlled synchronous motor drive using load commutated thyristor inverter.	6	20
END SEMESTER EXAM		

COURSE NO.:	COURSE TITLE	L-T-P: Credits	YEAR
04EE6807	ENERGY MANAGEMENT AND AUDIT	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

To give the Student:-

- Acquainted with the basic principles of Energy conservation management
- Knowledge on Energy management of different electrical loads
- In depth knowledge in energy efficiency analysis of HVAC systems and turbines.
- An overview in energy economics.

Syllabus

Energy conservation management; General principles of energy management and energy management planning; Energy audit report; Energy management; Computer-aided energy management; Cogeneration; Energy efficiency; Energy efficiency analysis; Energy efficiency of turbines; Energy Economics.

Course Outcome:

The student will be able to understand major principles of energy conservation and identify energy management opportunities in various applications .

Text Books:

1. Charles M Gottschalk, “Industrial energy conservation”, John Wiley & Sons, 1996.
2. Craig B Smit, “Energy management principles”, Pergamon Press

References:

1. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE std 739 – 1995 (Bronze book).
2. Rajan G. G., “Optimizing energy efficiencies in industry”,Tata McGraw Hill, Pub. Co., 2001.
3. Paul O. Callaghan, “Energy management”,McGraw Hill Book Co.
4. Wayne C. Turner, “Energy management Hand Book”,The Fairmount Press, Inc, 1997.
5. Rao S. & Parulekar B B, “Energy Technology”,Khanna Publishers, 1999.

COURSE PLAN

COURSE NO.:	COURSE TITLE	L-T-P: 3-0-0	
04EE6807	ENERGY MANAGEMENT AND AUDIT	CREDITS: 3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments- ECO assessment and Economic methods specific energy analysis-Minimum energy paths-consumption models-Case study.		6	15
MODULE: 2 Electric motors-Energy efficient controls and starting efficiency-Motor Efficiency and Load Analysis Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors. Variable speed drives; Pumps and Fans-Efficient Control strategies-Optimal selection and sizing – Optimal operation and Storage; Case study		8	15
FIRST INTERNAL TEST			
MODULE: 3 Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study. Reactive Power Management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement- Maintenance, case study.		6	15
MODULE: 4 Peak Demand controls- Methodologies-Types of Industrial Loads-Optimal Load scheduling-case study. Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes Electronic Ballast-Power quality issues-Luminaries, case study.		8	15
SECOND INTERNAL TEST			
MODULE: 5 Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study; Electric loads of Air conditioning & Refrigeration-Energy conservation measures-Cool storage. Types-Optimal operation case study; Electric water heating-Geysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls- software-EMS		6	20
MODULE: 6 Economic analysis methods-cash flow model, time value of money, evaluation of proposals, pay-back method, average rate of return method, internal rate of return method, present value method, life cycle costing approach, Case studies.		8	20
END SEMESTER EXAM			

COURSE CODE	COURSE NAME	L-T-P: Credits	YEAR
04EE6809	CONVENTIONAL AND ALTERNATIVE ENERGY STORAGE TECHNOLOGY	3-0-0	2020

Pre-requisites: Nil

Course Objectives:

- To introduce and analyse energy storage for power systems

Syllabus

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

Overview on Energy storage technologies: Potential energy (Pumped hydro, Compressed Air,) - Kinetic energy (Mechanical- Flywheel) - Thermal energy without phase change passive (adobe) and active (water) - Thermal energy with phase change (ice, molten salts, steam) – Chemical energy (hydrogen, methane,) - Electrochemical energy (Batteries, Fuel cells) – Electrostatic energy (Super Capacitors), Electromagnetic energy (Super conducting Magnetic Energy Storage) - Different Types of Energy Storage Systems comparative analysis, Comparison of environmental impacts for different technologies.

Energy storage Applications: Renewable energy generation- Solar energy, Wind Energy, pumped hydro energy, fuel cells, battery Storage- types, charging methodologies, SoC, SoH estimation techniques, Hydrogen production methods and storage.

Smart Grid, Smart Microgrid, Smart House, Mobile storage system: Electric vehicles -G2V, V2G, Management and control hierarchy of storage systems - Aggregating EES systems and distributed generation (Virtual Power Plant Energy Management with storage systems, Battery SCADA, Hybrid Energy storage systems: configurations and applications

Course Outcome:

Student will be able to explain concepts behind various type of new and conventional energy storage technology resources.

Text Books:

1. A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN - 978-1-84919-219-4),2011.

2. Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt," Energy Storage in Power Systems" Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016.

3. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN -13:9789380090122), 2011.

References:

1. Electric Power Research Institute (USA), "Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits" (1020676),December 2010.

2. Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation", National Renewable Energy Laboratory (NREL) - A National Laboratory of the U.S. Department of Energy - Technical Report NREL/ TP6A2-47187, January 2010

M. Tech (Power Systems and Renewable Energy)

COURSE NO.:	COURSE TITLE	L-T-P: 3-0-0	
04 EE 6501	CONVENTIONAL AND ALTERNATIVE ENERGY STORAGE TECHNOLOGY	CREDITS :3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 Introduction to energy storage for power systems: Need and role of energy storage systems in power system, General considerations, Energy and power balance in a storage unit, Mathematical model of storage, Econometric model of storage		8	15
MODULE: 2 Overview on Energy storage technologies: Potential energy (Pumped hydro, Compressed Air,) - Kinetic energy (Mechanical- Flywheel) - Thermal energy without phase change passive (adobe) and active (water) - Thermal energy with phase change (ice, molten salts, steam) - Chemical energy (hydrogen, methane,)		9	15
FIRST INTERNAL TEST			
MODULE: 3 Electrochemical energy (Batteries, Fuel cells) - Electrostatic energy (Super Capacitors), Electromagnetic energy (Super conducting Magnetic Energy Storage) - Different Types of Energy Storage Systems comparative analysis, Comparison of environmental impacts for different technologies.		10	15
MODULE: 4 Energy storage Applications: Renewable energy generation- Solar energy, Wind Energy, pumped hydro energy, fuel cells, battery Storage- types, charging methodologies, SoC, SoH estimation techniques, Hydrogen production methods and storage		10	15
SECOND INTERNAL TEST			
MODULE: 5 Smart Grid, Smart Microgrid, Smart House, Mobile storage system:Electric vehicles - G2V, V2G, Management and control hierarchy of storage systems		9	20
MODULE: 6 Aggregating EES systems and distributed generation (Virtual Power Plant Energy Management with storage systems, Battery SCADA, Hybrid Energy storage systems: configurations and applications		10	20
END SEMESTER EXAM			

COURSE NO.	COURSE TITLE	L-T-P: C	YEAR
04EE6103	SYSTEM THEORY	3-0-0: 3	2020

Pre-requisites: Nil

Course Objectives:

To give students

- A foundation in state space representation of systems.
- An ability to design observers.
- The ability to analyse the stability of linear and non linear systems.
- An introduction to the basic concepts of optimal control;

Syllabus

State space analysis and design of linear systems, Design of observers, Stability analysis using lyapnov stability criterion, Introduction to Optimal Control and dynamic programming.

Course Outcome:

At the end of the course students will be able to

1. Use state space method to represent and analyse a system
2. Analyse the stability of a nonlinear system.
3. Describe the basic concepts of optimal control.

References:

1. Benjamin C. Kuo, Control Systems, Tata McGraw-Hill, 2002.
2. M. Gopal, Modern Control System Theory, Tata McGraw-Hill.
3. Thomas Kailath, Linear System, Prentice Hall Inc., Eaglewood Clis, NJ, 1998
4. D. E. Kirk, Optimal Control Theory, Prentice-Hall. 1970

COURSE PLAN

COURSE NO.	COURSE TITLE	L-T-P: 3-0-0	
04 EE 6103	SYSTEM THEORY	Credits: 3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 State Space Analysis and Design -Analysis of stabilization by pole cancellation - reachability and constructability - stabilizability - controllability - observability - grammians. - Linear state variable feedback for SISO systems, Analysis of stabilization by output feedback-modal controllability-formulae for feedback gain		6	15
MODULE: 2 Significance of controllable Canonical form-Ackermann's formula - feedback gains in terms of Eigen values - Mayne-Murdoch formula state feedback and zeros of the transfer function - non controllable realizations and stabilizability -controllable and uncontrollable modes.		7	15
FIRST INTERNAL TEST			
MODULE: 3 Observers -Asymptotic observers for state measurement-open loop observer-closed loop observer formulae for observer gain - implementation of the observer - full order and reduced order observers - separation principle - combined observer -controller optimality criterion for choosing observer poles.		7	15
MODULE: 4 Observer Design -Direct transfer function design procedures- Design using polynomial equations - Direct analysis of the Diophantine equation.		6	15
SECOND INTERNAL TEST			
MODULE: 5 Lyapunov Stability - definition of stability, asymptotic stability and instability - Lyapunov's second method. Lyapunov's stability		8	20

analysis of LTI continuous time and discrete time systems , stability analysis of non linear system – Krasovski's theorem - variable gradient method.		
MODULE: 6 Introduction to Optimal Control- Pontryagin's maximum principle- theory- application to minimum time, energy and control effort problems, terminal control problem. Dynamic programming- Bellman's principle of optimality, multistage decision processes. Linear regulator problem: matrix Riccati equation and its solution.	8	20
END SEMESTER EXAM		

COURSE CODE	COURSE NAME	Credits	YEAR
04 EE 6815	POWER SYSTEMS AND POWER ELECTRONICS LABORATORY	0-0-2-1	2020

Pre-requisites:Nil

Course Objectives:

To carry out experimental/simulation studies on Power System problems.

To enable the students:

- To carry out simulation studies on Power System problems.
- To design, simulate, develop and troubleshoot Power Electronic Circuits.
- To develop experimental skills for independent research.

Course Outcome:

- The student will be able to design and setup basic power electronic circuits and carry out simulation studies of Power System Problems.

Syllabus

1. Formation of Bus Admittance Matrix and Bus Impedance Matrix using MATLAB
2. Formation of Jacobian for a system not exceeding 4 buses (no PV Buses) in polar co-ordinates using MATLAB/PSS/E
3. Sequence Components of Power System Network with Single Line to Ground Fault using MATLAB SIMULINK
4. Modeling of Single Machine Power System
5. Short circuit studies of power system
6. Power System dynamic studies
7. Load flow analysis using Gauss Seidel Method, Newton Raphson Method
8. Fast De-coupled for both PQ and PV Buses
9. DC Load flow analysis.
10. Modeling of Automatic Generation Control for a two area network
11. Single Phase Semi-converter with R-L and R-L-E loads for continuous and discontinuous conduction modes.
12. Single phase full- converter with R-L and R-L-E loads for continuous and discontinuous conduction modes.
13. Three phase full-converter with R-L-E load.
14. Controlled and Uncontrolled rectifier with different types of filters-continuous and discontinuous modes of operation.
15. IGBT and MOSFET based inverters.
16. Simulation of single-phase Semi-converter and Fully controlled converters with R, RL and RLE Load.
17. Simulation of Three-phase fully controlled converter.
18. Simulation of Single-phase full bridge inverter.
19. Simulation of Three-phase full bridge inverter.
20. Simulation of PWM inverters.

(**At least 12 experiments in the list are to be conducted in the laboratory. Additional experiments and simulation assignments can also be given by the department**)

COURSE CODE	COURSE NAME	L-T-P-C	YEAR
04 GN 6001	RESEARCH METHODOLOGY	0-2-0:2	2020

Pre-requisites:Nil

Course Objectives:

To enable the students:

- To get introduced to research philosophy and processes in general.
- To formulate the research problem and prepare research plan
- To apply various numerical /quantitative techniques for data analysis
- To communicate the research findings effectively

Syllabus

Introduction to the Concepts of Research Methodology, Research Proposals, Research Design, Data Collection and Analysis, Quantitative Techniques and Mathematical Modeling, Report Writing.

Course Outcome:

Students who successfully complete this course would learn the fundamental concepts of Research Methodology, apply the basic aspects of the Research methodology to formulate a research problem and its plan. They would also be able to deploy numerical/quantitative techniques for data analysis. They would be equipped with good technical writing and presentation skills.

Text Books:

1. Research Methodology: Methods and Techniques', by Dr. C. R. Kothari, New Age International Publisher, 2004
2. Research Methodology: A Step by Step Guide for Beginners' by Ranjit Kumar, SAGE Publications Ltd; Third Edition

References:

1. Research Methodology: An Introduction for Science & Engineering Students', by Stuart Melville and Wayne Goddard, Juta and Company Ltd, 2004
2. Research Methodology: An Introduction' by Wayne Goddard and Stuart Melville, Juta and Company Ltd, 2004
3. Research Methodology, G.C. Ramamurthy, Dream Tech Press, New Delhi
4. Management Research Methodology' by K. N. Krishnaswamy et al, Pearson Education

COURSE No.:	COURSE TITLE	L-T-P: 0-2-0	
04 GN 6001	**RESEARCH METHODOLOGY**	**CREDITS: 2**	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 Introduction to Research Methodology: Concepts of Research, Meaning and 2 Objectives of Research, Research Process, Types of Research, Type of research: Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, and Conceptual vs. Empirical		5	15
MODULE :2 Criteria of Good Research, Research Problem, Selection of a problem, Techniques involved in definition of a problem, Research Proposals – Types, contents, Ethical aspects, IPR issues like patenting, copyrights.		4	15
FIRST INTERNAL TEST			
MODULE: 3 **Research Design:** Meaning, Need and Types of research design, Literature Survey and Review, Identifying gap areas from literature review, Research Design Process, Sampling fundamentals, Measurement and scaling techniques, Data Collection – concept, types and methods, Design of Experiments.		5	15
MODULE 4: **Quantitative Techniques:** Probability distributions, Fundamentals of Statistical analysis, Data Analysis with Statistical Packages, Multivariate methods, Concepts of correlation and regression - Fundamentals of time series analysis and spectral analysis.		5	15
SECOND INTERNAL TEST			
MODULE: 5 **Report Writing:** Principles of Thesis Writing, Guidelines for writing reports & papers, Methods of giving references and appendices, Reproduction of published material, Plagiarism, Citation and acknowledgement.		5	20
MODULE: 6 Documentation and presentation tools – LaTeX, Office software with basic presentations skills, Use of Internet and advanced search techniques.		4	20
END SEMESTER EXAM			

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE6802	ANALYSIS, DESIGN AND GRID INTEGRATION OF RENEWABLE ENERGY SYSTEMS	4-0-0-4	2020

Pre-requisites: Nil

Course Objectives:

- To analyze grid integrated Solar PV System and WECS
- To learn about power controls in GIRES

Syllabus

Review of DC-DC converters; Maximum power point tracking (MPPT) in solar PV systems; Partial shading of PV systems; MPPT methods for shaded PV system; Grid connected PV systems; Anti-islanding and protection scheme; Line of protective equipment in solar PV system; Earthing scheme of PV installations; Wind Energy Conversion System; power speed characteristics and torque speed characteristics; control Development of Wind Power Generation; Power Converters for Wind Turbines; Controls and Grid Requirements for Modern Wind Turbines; DFIG based WECS; Methods of improving stability.

Course Outcome:

Upon the completion of this course, students will have the ability:

- to explain the dynamics of grid connected Solar PV system.
- to analyze the Wind Energy Conversion System.

Text Books:

1. Haitham Abu-R, Mariusz Malinowski and Kamal Al-Haddad,"power electronics for renewable energy systems, transportation and industrial applications", IEEE Press and John Wiley & Sons Ltd.
2. S. N. Bhadra, D. Kastha, S. Banerjee, "Wind Electrical System", Oxford higher Education.
3. L. L. Freris, "Wind Energy Conversion Systems", Prentice Hall, 1990.

References:

1. D. A. Spera, "Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering", ASME Press.
2. Paul Gipe, "Wind Energy Comes of Age", John Wiley & Sons Inc.
3. T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, "Wind energy Handbook", John Wiley & Sons,2001.
4. Mathew Sathyajith, Wind Energy: Fundamentals,"Resource Analysis and Economics", Springer, 2006.
5. Mathew Sathyajith, Geetha Susan Philip, "Advances in Wind Energy Conversion Technology", Springer, 2011.
6. G. L. Johnson, "Wind Energy Systems", Prentice Hall, 1985.
7. Anna Mani, "Wind Energy Data for India", Department of Non-conventional Energy Sources, Govt. of India, New Delhi, 1995.

COURSE PLAN

COURSE NO:	COURSE TITLE	CREDITS	
04EE6802	ANALYSIS, DESIGN AND GRID INTEGRATION OF RENEWABLE ENERGY SYSTEMS	4-0-0:4	
MODULES		Contact hours	Sem. Exam Marks %
MODULE: 1 Review of DC-DC converters: Buck, Boost, Buck Boost topologies. Bidirectional DC-DC converters- design and component selection. Maximum power point tracking (MPPT) in solar PV systems – Conventional Methods - Perturb & Observe method, Incremental conductance method. Solar charge controllers – PWM based and MPPT based solar charge controllers. Design of Off- grid PV systems.		2	15
Module: 2 Partial shading of PV systems- Cause and effect – Hot spot formation. Mitigation methods- Bypass diode and analysis of shaded PV system with and without bypass diodes. I-V and P-V curves of partially shaded PV system. Blocking diodes and its function. MPPT methods for shaded PV system- Global maximum power point (GMPP) tracking.		10	15
FIRST INTERNAL TEST			
Module: 3 Grid connected PV systems- Block diagram – Specifications of Grid Interactive Inverter (GII) - Point of common coupling (PCC) - Comparison with Off grid systems. Anti-islanding and protection schemes. Power flow control in grid connected PV system- Active and reactive power control in α-β and d-q frame. Line of protective equipment in solar PV system – fuse, MCB, string combiner box and string monitoring box- Earthing scheme of PV installations.		7	15
Module: 4 Wind Energy Conversion System: Introduction, Fundamentals of wind turbine-power contained in wind-types-tip speed ratio- power coefficient- specific rated capacity- Aerodynamics of wind rotor- power speed characteristics and torque speed characteristics wind turbine control system – pitch - stall- yaw and power electronic control Development of Wind Power Generation, Wind Power Conversion -Basic Control Variables for Wind Turbines-Wind Turbine Concepts.		8	15

SECOND INTERNAL TEST		
Module: 5 Power Converters for Wind Turbines: Two-Level, Multilevel, Multi-cell Converter. Power Semiconductors for Wind Power Converter. Controls and Grid Requirements for Modern Wind Turbines: Active Power Control-Reactive Power Control- THD, Fault Ride-Through Capability. Emerging Reliability Issues for Wind Power System.	6	20
Module: 6 DFIG Based Grid Integrated Wind Energy Conversion System Properties and Control of a Doubly Fed Induction Machine: Introduction. Basic principles of DFIM-Structure of the Machine and Electric configuration –Steady State Equivalent Circuit-Dynamic Modeling. Vector Control of DFIM Using an AC/DC/AC Converter-Grid Connection Operation-Rotor Position Observers- Stand-alone Operation DFIM-Based Wind Energy Conversion Systems:Wind Turbine Aerodynamic-Turbine Control Zones-Turbine Control-Typical Dimensioning of DFIM-Based Wind Turbines-Steady-State Performance of the Wind Turbine Based on DFIM - Analysis of DFIM-Based Wind Turbines during Voltage Dips Methods of improving stability: transient stability enhancement – different techniques. Small Signal Stability Enhancement: Using Power System Stabilizers-Supplementary control of Static VAR Compensators.	10	20
END SEMESTER EXAM		

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE6418	POWER SYSTEM DYNAMICS AND STABILITY	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To understand and work with the modelling of main power system elements like, synchronous machines, excitation systems, prime mover and its governing mechanism and power system load.
- To understand and work with the linearization of power system elements and its small signal stability analysis.
- To understand and work with power system stabilizer, voltage stability and its analysis
- To understand and work with different power system stability enhancements.

Syllabus

Fundamental concepts and overview; Types of Stability; Mathematical description of a synchronous Machine. Modeling of other power system components-Excitation and Turbine and Load Modeling. Small signal Stability analysis, Power system stabilizer and its Multi Machine system. Voltage stability aspects and its analysis including continuation power flow analysis. Enhancement of stability-Transient and its techniques, small signal using PSS-Supplementary control of Static VAR Compensators.

Course Outcome:

- Candidate should be able to work with the modelling of main power system elements like, synchronous machines, excitation systems, prime mover and its governing mechanism and power system load.
- Candidate should be able to work with the linearization of power system elements and its small signal stability analysis.
- Candidate should be able to work with power system stabilizer, voltage stability and its analysis
- Candidate should be able to work with different power system stability enhancements.

Text Books:

1. Kundur P, "Power System Stability and Control", TMH
2. Anderson and Fouad, "Power System Control and Stability", Galgotia Publications, Compensation 1981.

References:

1. Ramanujam R, "Power System Dynamics- Analysis & Simulation", PHI learning Private Limited.
2. Padiyar K R, "Power System Dynamics", 2nd Edition, B.S. Publishers, 2003.
3. Sauer P W & Pai M A," Power System Dynamics and Stability", Pearson, 2003.
4. Olle I Elgerd, "Electric Energy Systems Theory an Introduction", 2nd Edition, McGraw-Hill, 1983.
5. Kimbark E W, "Power System Stability", McGraw-Hill Inc., 1994, Wiley & IEEE Press, 1995.
6. Yao-Nan-Yu, "Electric Power Systems Dynamics", Academic Press, 1983.

COURSE PLAN

COURSE NO:	COURSE TITLE:	CREDITS	
04EE6418	POWER SYSTEM DYNAMICS AND STABILITY	3-0-0:3	
MODULES		Contact hours	Sem. Exam Marks; %
MODULE: 1 **Power System Stability:** Structure of power System and its controls. Concept of Power system stability-Types of stability.		2	15
MODULE: 2 **Modelling Power System Components:** Synchronous machine modelling: Synchronous Machine Mathematical Description of a Synchronous Machine - Basic equations of a synchronous machine. dq0 Transformation- per unit representation- equivalent circuits for direct and quadrature axes. Excitation System Modelling -Static Excitation System only- Hydraulic turbine modelling- Load modelling concepts.		10	15
FIRST INTERNAL TEST			
MODULE : 3 **Small Signal Analysis** Fundamental Concepts of Stability of Dynamic Systems: State-space representation- stability of dynamic system - Linearization, Eigen properties of the state matrix – Eigen value and stability. Small Signal Stability of Single Machine Infinite Bus (SMIB) System. Swing Equation, H-constant calculation - Representation in system studies-		7	15
MODULE : 4 **Effects of K constants on small signal stability:** Generator represented by the classical model. Effect of field flux variation on system stability-Effects of Excitation System - Block diagram representation with exciter and AVR- Effect of AVR on synchronizing and damping torque components.		8	15
SECOND INTERNAL TEST			
MODULE : 5 **Voltage Stability:** Voltage stability – generation aspects - transmission system aspects – load aspects. PV curve – QV curve – PQ curve – analysis with static loads. Load ability limit - sensitivity analysis-continuation power flow analysis.		7	20
MODULE : 6 **Enhancement of Stability** Methods of improving stability – transient stability enhancement – different techniques. Small Signal Stability Enhancement: Using Power System Stabilizers-Supplementary control of Static VAR Compensators.		8	20
END SEMESTER EXAM			

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE6804	SMART GRID TECHNOLOGIES AND APPLICATION	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To understand various aspects of the smart grid, including technologies, components, architectures and applications.
- To understand various Smart grid control elements required to monitor and control the grid, such as smart meters, sensors and phasor measurement units.

Syllabus

Evolution of Electric Grid; Concept, Need, functions, Opportunities & Barriers of Smart Grid; Resilient & Self-Healing Grid; Smart Meters; Automatic Meter Reading(AMR);Outage Management System(OMS); Plug in Hybrid Electric Vehicles(PHEV);Home & Building Automation; Smart Substations; Geographic Information System (GIS);Intelligent Electronic Devices(IED); Smart storage; Wide Area Measurement System(WAMS); Phase Measurement Unit(PMU); Smart energy efficient end use devices; Load Curves; Load Frequency Control (LFC) in Micro Grid System; Reactive Power Control in Smart Grid.

Course Outcome:

- Candidate should be able to describe the smart grid technologies, components, architectures and applications.
- Candidate should be able to categorize various Smart grid control elements required to monitor and control.
- Candidate should be able to explain the smart grid applications within the industry, and design criteria.
- Candidate should be able to Learn the need of Load Frequency Control and reactive power control

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press.

References:

1. Janaka Ekanayake, Kithsiri Liyanage,Jianzhong.Wu, AkihikoYokoyama, Nick Jenkins, "Smart Grid: Technology and Applications"- Wiley
2. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell
3. Peter S. Fox-Penner, "Smart Power: Climate Change, the Smart Grid, and the Future of Electric

Utilities”
4. James Momoh, “Smart Grid: Fundamentals of Design and Analysis”-Wiley, IEEE Press, 2012.

COURSE PLAN

COURSE NO:	COURSE TITLE:	CREDITS	
04EE6804	SMART GRID TECHNOLOGIES AND APPLICATION	3-0-0:3	
MODULES		Contact Hours	Sem. Exam Marks; %
MODULE : 1 Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and Benefits. Present development & International policies in Smart Grid. Indian Smart Grid. Components and Architecture of Smart Grid Design		5	15
MODULE : 2 Introduction to Smart Meters, Real Time Pricing- Models, Smart Appliances, Automatic Meter Reading(AMR), Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation.		5	15
FIRST INTERNAL TEST			
MODULE : 3 Smart Substations, Substation Automation, Introduction to IEC 61850, Feeder Automation. Geographic Information System (GIS). Intelligent Electronic Devices (IED) & their application for monitoring & protection, Wide Area Measurement System (WAMS). Phase Measurement Units (PMU).		8	15
MODULE : 4 Smart energy efficient end use devices-Smart distributed energy resources-Energy management-Role of technology in demand response- Demand Side Management. Load Curves -Load Shaping Objectives-Methodologies-Barriers. Peak load saving-Constraints-Problem formulation- Case study.		9	15
SECOND INTERNAL TEST			

MODULE : 5 Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System. Reactive Power Control in Smart Grid	6	20
MODULE : 6 Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Bluetooth, Zig-Bee, GPS, Wi-Fi, Wi-Max based communication. Cloud computing in smart grid. Private, public and Hybrid cloud. Cloud architecture of smart grid	9	20
END SEMESTER EXAM		

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE6808	ELECTRIC AND HYBRID VEHICLES	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To understand and work with the modelling of main power system elements like, synchronous machines, excitation systems, prime mover and its governing mechanism and power system load.
- To understand and work with the linearization of power system elements and its small signal stability analysis.
- To understand and work with power system stabilizer, voltage stability and its analysis
- To understand and work with different power system stability enhancements.

Syllabus

Fundamental concepts and overview; Types of Stability; Mathematical description of a synchronous Machine. Modeling of other power system components-Excitation and Turbine and Load Modeling. Small signal Stability analysis, Power system stabilizer and its Multi Machine system. Voltage stability aspects and its analysis including continuation power flow analysis. Enhancement of stability- Transient and its techniques, small signal using PSS-Supplementary control of Static VAR Compensators.

Course Outcome:

Upon successful completion of this course, the student will be able to:

- understand about basics of hybrid electric vehicle
- Understand about drives and control.
- select battery and apply the concept of battery management system
- design battery charger for an EV
- understand about E-Mobility
- describe the latest trends in E–vehicle networking.

Text Books:

1. Iqbal Hussain, Electric & Hybrid Vehicles – Design Fundamentals, CRC Press, 2011
2. Rand D.A.J, Woods, R & Dell RM Batteries for Electric vehicles, research studies press, UK, 1998.

References:

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electrical and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

COURSE PLAN

COURSE NO:	COURSE TITLE	CREDITS	
04EE6808	ELECTRIC AND HYBRID VEHICLES	3-0-0:3	
MODULES		Contact hours	Sem. Exam Marks; %
MODULE: 1 **Introduction to Hybrid and Electric Vehicle** : Review of Conventional Vehicle. Introduction to Hybrid Electric Vehicles and Electric Vehicles. Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving.		2	15
MODULE: 2 **Electric Drives:** Electric Drives-Energy consumption Concept of Hybrid Electric Drive Trains, Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, Electric Propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, switched reluctance motor.		10	15
FIRST INTERNAL TEST			
MODULE: 3 **Energy Storage:** Energy Storage System Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles:- Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system.		7	15
MODULE 4 **Energy Management System** Battery Management System. Requirement of Battery Monitoring, Battery State of Charge Estimation methods, Battery Cell equalization problem, thermal control, protection interface, SOC Estimation, Energy & Power **estimation**, Battery thermal management system, EV charging standards, V2G, G2V, V2B, V2H		8	15
SECOND INTERNAL TEST			

MODULE: 5 **E-Mobility and Connectors** Connected Mobility and Autonomous Mobility- case study E mobility Indian Roadmap Perspective. Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs. Connectors- Types of EV charging connector, North American EV Plug Standards, DC Fast Charge CCS (Combined Charging System), Tesla, European EV Plug Standards,	7	20
MODULE: 6 **VEHICULAR NETWORKS AND COMMUNICATION** Vehicular Communications: Intelligent Transportation Systems: IEEE 802.11p-ITS-IVC: Inter Vehicle Communications- Mobile Wireless Communications And Networks- Architecture Layers- Communication Regime.V2V, V2I-VANET-WAVE; DSRC. Information In The Vehicle Network Routing-Physical Layer Technologies-Medium Access For Vehicular Communications- Security Applications and Case Studies.	8	20
END SEMESTER EXAM		

COURSE NO.	COURSE TITLE	L-T-P-C	YEAR
04EE6810	ENERGY RESOURCE ECONOMICS AND ENVIRONMENT	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To understand the World and Indian energy reserves, energy usage patterns and to study and develop various future energy scenarios
- To understand the concepts of Energy conservation and related energy economics by using various tools
- To study about various pollutants to the eco system, its production, harmful effects, methods of reduction relevant into the areas of air and water pollution and to understand the concepts of Global warming caused by Green house Gases, , and the mitigation and adaptation concepts.

Syllabus

Overview of World and India's energy scenario – energy reserves and security - country annual energy balances – trends in energy use patterns, Energy chain - primary energy analysis – life cycle energy assessment – energy and development linkage – Energy Scenarios –need of scenarios, Energy Economics:- Need for economic analysis - Simple payback period - Time value of money - Return on Investment – Internal Rate of Return – Capital Recovery Factor - Net Present Value, Life cycle costing – cost of saved energy – cost of energy generated – simple problems about economics of renewable energy systems and energy conservation systems, Environmental impacts of energy use – Air pollution - Indoor air quality – SOx – NOx – CO –Volatile Organic Compounds – Particulate matter, Sources of emissions - Motor vehicle emissions - exhaust emission test – control of automobile emissions,

Stationery sources of emissions – Coal power plants – control of emissions from coal power plants, Environmental impact assessment - environmental audit, Climate change from green house gases – CO_2 emissions – Global warming - Green house gases and Global warming potential, Radiative forcing of Climate change - mitigation and adaptation measures - IPCC Assessment –Stabilizing Greenhouse gases, Kyoto Protocol – Carbon credits

Course Outcome:

- Ability to understand energy reserves, various energy scenarios, impacts of energy usage on environment and energy economics.

Text Books:

1. G. M. Masters, W.P. Ela, Introduction to Environmental Engineering and Science, Third Edition, PHI, 2008.

2. Frank Kreith, Jan F. Kreider, Principles of Sustainable Energy, CRC Press, 2011.

References:

1. Energy and the Challenge of Sustainability, World energy assessment, UNDP, United Nations Publications, New York, 2000.
2. General Aspects of Energy Management and Energy Audit (Book -1of Guide books), Revision II, Bureau of Energy Efficiency, India.
3. A. K. N. Reddy, R. H. Williams, T. B. Johansson, Energy after Rio – Prospects and challenges, UNDP, United Nations Publications, New York, 1997.
4. Nebojsa Nakicenovic, Arnulf Grubler, Alan McDonald, Global energy perspectives, Cambridge University Press, 1998.
5. J. M. Fowler, Energy and the environment, 2nd Edition, McGraw Hill, New York, 1984.

COURSE PLAN

COURSE NO.:	COURSE TITLE	CREDITS	
04EE6810	ENERGY RESOURCE ECONOMICS AND ENVIRONMENT	3-0-0:3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 Overview of World and India's energy scenario – energy reserves and security - Disaggregation by end-use and supply – country annual energy balances – examples – trends in energy use patterns – annual electrical energy usage pattern in India.		8	15
MODULE: 2 Energy chain - primary energy analysis – life cycle energy assessment – energy and development linkage – Energy Scenarios –need of scenarios - simple problems with development of energy use scenarios.		8	15
FIRST INTERNAL TEST			
MODULE: 3 Energy Economics: Need for economic analysis - Simple payback period - advantages and limitations - Time value of money - Return on Investment – Internal Rate of Return – Capital Recovery Factor - Net Present Value.		10	15
MODULE: 4 Life cycle costing – cost of saved energy – cost of energy generated – simple problems about economics of renewable energy systems and energy conservation systems.		10	15
SECOND INTERNAL TEST			
MODULE: 5 Environmental impacts of energy use – Air pollution - Indoor air quality – SOx – NOx – CO –Volatile Organic Compounds – Particulate matter, Sources of emissions - Motor vehicle emissions - exhaust emission test – control of automobile emissions, Stationery sources of emissions – Coal power plants – control of emissions from coal power plants, Environmental impact assessment - environmental audit		10	20

MODULE: 6 Climate change from greenhouse gases – CO_2 emissions – Global warming - Greenhouse gases and Global warming potential, Radiative forcing of Climate change - mitigation and adaptation measures - IPCC Assessment –Stabilizing Greenhouse gases, Kyoto Protocol– Carbon credits.	10	20
END SEMESTER EXAM		

COURSE NO.	COURSE TITLE	L-T-P-C	YEAR
04EE6806	ENERGY SYSTEM MODELING AND ANALYSIS	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To understand the various mathematical methods for energy system modelling
- To study the various economic models and convergence solution

Syllabus

Modelling Overview: Levels of analysis – steps in model development - examples of models – quantitative techniques – interpolation – polynomial– Lagrangian – curve fitting – regression analysis – solution of transcendental equations, Systems Simulation: Information flow diagram – solution of set of nonlinear algebraic equations – successive substitution – Newton Raphson – examples of energy systems simulation, Optimization: Objectives/constraints – problem formulation – unconstrained problems – necessary and sufficiency conditions, Constrained optimization, Lagrange multipliers – constrained variations – Kuhn-Tucker conditions – linear programming – simplex tableau – pivoting – sensitivity analysis, Dynamic Programming: Search Techniques – univariate / multivariate – case studies of optimization in energy systems, Dealing with uncertainty- probabilistic techniques – Trade-offs between capital and energy using Pinch analysis, Energy- Economy Models: Scenario generation – input output model, Numerical solution of differential equations – overview – convergence – accuracy – transient analysis – application examples.

Course Outcome:

- The student will be able to mathematically model and optimize an energy system

Text Books:

1. W. F. Stoecker, Design of Thermal Systems, McGraw Hill, 1981.
2. S. S. Rao, Optimization theory and applications, Wiley Eastern, 1990.

References:

1. S. S. Sastry, Introductory methods of numerical analysis, Prentice Hall 1988.
2. S. C. Chapra, R. P. Canale, Numerical methods for Engineers, Tata McGraw Hill New Delhi, 2007.

COURSE PLAN

COURSE NO.:	COURSE TITLE	CREDITS	
04EE6806	ENERGY SYSTEM MODELLING AND ANALYSIS	3-0-0 : 3	
MODULES		Contact Hours	Sem. Exam Marks, (%)
MODULE: 1 Modelling Overview: Levels of analysis – steps in model development - examples of models – quantitative techniques – interpolation – polynomial– Lagrangian – curve fitting – regression analysis – solution of transcendental equations.		7	15
MODULE: 2 Systems Simulation: Information flow diagram – solution of set of nonlinear algebraic equations – successive substitution – Newton Raphson – examples of energy systems simulation.		6	15
FIRST INTERNAL TEST			
MODULE: 3 Optimization: Objectives/constraints – problem formulation – unconstrained problems – necessary and sufficiency conditions, Constrained optimization		6	15
MODULE: 4 Lagrange multipliers – constrained variations – Kuhn-Tucker conditions – linear programming – simplex tableau – pivoting – sensitivity analysis		6	15
SECOND INTERNAL TEST			
MODULE: 5 Dynamic Programming: Search Techniques – univariate / multivariate – case studies of optimization in energy systems Dealing with uncertainty- probabilistic techniques – Trade-offs between capital and energy using Pinch analysis		8	20
MODULE: 6 Energy- Economy Models: Scenario generation – input output model, Numerical solution of differential equations – overview – convergence – accuracy – transient analysis – application examples		9	20
END SEMESTER EXAM			

COURSE NO.	COURSE TITLE	L-T-P-C	YEAR
04EE6812	POWER SYSTEM PLANNING	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To understand the Indian power system practical aspects
- To understand power interchanges and production in power system
- To understand the cost models and various power plants

Syllabus

Overview of Indian power sector– load duration curve – energy load curve – maximum demand – demand factor – diversity factor – coincidence factor – contribution factor – load factor – plant capacity factor, Plant use factor – utilization factor power factor and economics of power factor correction – Interchange of Power and Energy - Energy broker system– availability based tariff, Production cost models - Outages considered, Probabilistic Production Cost Programs : Probabilistic production cost computation - simulating economic scheduling with the Unserved Load Method, The Expected Cost Method - A discussion of some practical Problems - Steam power plants: Rankine cycle - Nuclear power plants-Gas power plants- Diesel power plants- Hydroelectric power plants.

Course Outcome:

- The student will understand the power system practical aspects, power interchanges and production in power system, cost models and various power plants.

Text Books:

1. J. Wood, B. F. Wollenberg, Power Generation, Operation and Control, Willey India, 2007.
2. P.K. Nag, Power plant engineering, Tata Mc Graw Hill, 2002.
3. D. P. Kothari and I. J. Nagrath, Power System Engineering, Tata McGraw Hill.

References:

1. P. K. Nag, Engineering Thermodynamics, Tata Mc Graw Hill, 2005.
2. P.S. Pabla, Electric Power Distribution, Tata McGraw Hill.
3. K. Bhattacharya, M. H. J. Bollen, J. E. Daalder, Operation of Restructured Power Systems, Kluwer Academic Publishers, 2001.
4. V. Kamaraju, Electrical Power Distribution Systems, Tata McGraw Hill.
5. M. V. Deshpande, Elements of Electrical Power Station Design, PHI.
6. Lucas M. Faulkenberry, Walter Coffer, Electrical power Distribution and Transmission, Pearson Education.
7. C. L. Wadhwa, Electrical Power System, New age International.
8. Indian Electricity Act - 2003, Govt. of India.

COURSE PLAN

COURSE NO:	COURSE TITLE	L-T-P: 3-0-0	
04EE6812	POWER SYSTEM PLANNING	CREDITS : 3	
MODULES		Contac Hours	Sem. Exam Marks, (%)
MODULE 1: Overview of Indian power sector – installed capacity and generation – duties and functions of govt. agencies for energy (India) – CEA, CERC, Ministry of Power, Ministry of New and Renewable Energy – Ministry of Petroleum and Natural Gas – State electricity agencies of India (KSEB) – Load Dispatch Centers – SLDC – RLDC – NLDC, Overview of Indian Electricity Act-2003. Load Curve – load duration curve – energy load curve – maximum demand – demand factor – diversity factor – coincidence factor – contribution factor – load factor – plant capacity factor.		7	15
MODULE 2: Plant use factor – utilization factor power factor and economics of power factor correction - Numericals Interchange of Power and Energy: Economy interchange between interconnected utilities – interutility economy energy evaluation Interchange evaluation with unit commitment – multiple utility interchange transactions – capacity interchange – diversity interchange – energy banking – emergency power interchange –inadvertent power exchange – Power pools		9	15
FIRST INTERNAL TEST			
MODULE 3: Energy broker system – allocating pool savings –transmission effects and issues – transfer limitations – wheeling –transactions involving nonutility parties – availability based tariff.		6	15
MODULE 4: Production cost models: Introduction - Uses and types of production cost program - production costing using load duration curves - Outages considered Probabilistic Production Cost Programs : Probabilistic production cost computation - simulating economic scheduling with the Unserved Load Method		9	15
SECOND INTERNAL TEST			

MODULE 5: The Expected Cost Method - A discussion of some practical Problems Sample Computation and Exercise : No Forced Outages - Forced Outages Included Probability methods and uses in generation planning	6	20
MODULE 6: Steam power plants: Rankine cycle (ideal, actual and reheat) – layout – components – alternators – excitation system – governing system of steam turbine – simple problems. Nuclear power plants: Layout – components – pressurized water reactor – boiling water reactor – heavy water reactor – gas cooled reactor – fast breeder reactor. Gas power plants: Gas turbine cycle – layout – open cycle, closed cycle and combined cycle gas power plants. Diesel power plants: Thermal cycle – diesel plant equipment. Hydroelectric power plants: Selection of site – mass curve – flow duration curve – hydrograph – classification of hydro plants – layout – components – classification of hydro turbines.	8	20
END SEMESTER EXAM		

COURSE CODE	COURSE NAME	L-T-P-C	YEAR
04EE6818	FACTS AND HVDC	3-0-0-3	2020

Pre-requisites: Power Electronics, Power Systems

Course Objectives:

- To understand the fundamentals of FACTS Controllers,
- To know the importance of controllable parameters and types of FACTS controllers & their benefits
- To study HVDC Transmission system
- To understand the control aspects of HVDC System

Syllabus

Facts concepts; basic types of FACTS controllers; Static shunt and series compensators; SVC, STATCOM, SVC and STATCOM comparison; thyristor switched series capacitors (TCSC), static series synchronous compensator (SSSC); Combined compensators; . Interline power flow controller (IPFC); HVDC Transmission system; Control of HVDC system; Voltage Source Converter based HVDC systems

Course Outcome:

Students will be able to

- Explain methods for economic load dispatch and Module commitment.
- Apply control and compensations schemes on a power system.
- Adopt contingency analysis and selection methods to improve system security.

Text Books:

1. K. R. Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International
2. Allen J Wood, Bruce F Wollenberg, "Power Generation, Operation and Control", John Wiley& Sons, New York, II Edition, 1984.
3. Kundur P, "Power System Stability and Control", McGraw Hill, 2006
4. N.G. Hingorani & Laszlo Gyugyi , "Understanding FACTS" , IEEE Press, 2000
5. Rao S, "EHV AC & HVDC Transmission Systems", Khanna Publishers.

References:

1. Nagrath J J and Kothari D P, "Modern Power system Analysis", Tata McGraw Hill, 1980.
2. Singh L P, "Advanced Power Systems Analysis and Dynamics", New Age Intl. Publishers, 1983.
3. Arrilaga,J., `High Voltage Direct current transmission',Peter Pereginver Ltd., London,UK.,1983
4. HVDC Transmission system', Wiley Eastern Limited .,NewDelhi,1992.

COURSE NO:	COURSE TITLE:	L-T-P: 3-0-0	
04EE6818	**FACTS AND HVDC**	**CREDITS : 3**	
MODULES		**Contact hours**	**Sem. Exam Marks; %**
MODULE 1 Facts concepts: Reactive power control in electrical power transmission, principles of conventional reactive power compensators. Introduction to FACTS, flow of power in AC parallel paths, meshed systems, basic types of FACTS controllers, definitions of FACTS controllers, brief description of FACTS controllers.		10	15
MODULE 2 Static shunt and series compensators: Shunt compensation – objectives of shunt compensation, methods of controllable VAR generation, static VAR compensators – SVC, STATCOM, SVC and STATCOM comparison. Series compensation – objectives of series compensation, thyristor switched series capacitors (TCSC), static series synchronous compensator (SSSC), power angle characteristics, and basic operating control schemes.		6	15
FIRST INTERNAL TEST			
MODULE 3 Combined compensators: Unified power flow controller (UPFC) – Introduction, operating principle, independent real and reactive power flow controller and control structure. Interline power flow controller (IPFC), Introduction to Active power filtering, Concepts relating to Reactive power compensation and harmonic current compensation using Active power filters.		6	15
MODULE 4 HVDC transmission: HVDC Transmission system: Introduction, comparison of AC and DC systems, applications of DC transmission, types of DClinks, Layout of HVDC Converter station and various equipments. HVDC Converters, analysis of bridge converters with and without overlap, inverter operation, equivalent circuit representation of rectifier and inverter configurations		10	15

SECOND INTERNAL TEST		
MODULE 5 Control of HVDC system: Principles of control, desired features of control, converter control characteristics, power reversal, Ignition angle control, current and extinction angle control. Harmonics introduction, generation, ac filters and dc filters.	9	20
MODULE 6 Introduction to multi-terminal DC systems and applications, comparison of series and parallel MTDC systems, Voltage Source Converter based HVDC systems	7	20
END SEMESTER EXAM		

COURSE No.:	COURSE NAME	Credits	YEAR
04 EE 6820	ICT ENABLED POWER SYSTEM PROTECTION AND COMPUTER RELAYING	3-1-0:3	2020

Pre-requisites: Nil Course

Course Objectives:
To enable the students:

- A comprehensive study of ICT enabled power system protection

Syllabus:

Protection standards and Review of protection schemes. Data Acquisition Systems, RTU, IED, Synchrophasor based Wide Area Monitoring Systems. Wide Area Measurement Systems. Wide Area Measurement - A Generic PMU. Protection in DG and smart grid. ICT enabled algorithms. Modelling of PMU for simulation studies

Course Outcome:

Students who successfully complete this course will have an ability to understand different protection standards schemes of DG and SG; Wide Area Measurement, ICT enabled algorithms. Modelling of PMU for simulation studies

Text Books:

1. Arun G Phadke, James S Thorp, Synchronised Phasor Measurments and Their Applications, Springer, 2008.
2. Arun G Phadke, James S Thorp, Computer Relaying for Power Systems, second edition, John Wiley & Sons Publications, 2009.
3. Miroslav M. Begovic (Editor) Electrical Transmission Systems and Smart Grids, Springer, New York in 2012. T.S.M. Rao “Digital/Numerical Relays” Tata McGraw-Hill Education, 01-Jul-2005.
4. Badari Ram and D. N. Viswakarma, “Power System Protection and Switchgear”, Tata McGraw Hill, 2011.
5. **T.S.M. Rao “Digital/Numerical Relays” Tata McGraw-Hill Education, 01-Jul-2005**

References:

6. Mladen Kezunovic , Sakis Meliopoulos, Vaithianathan Venkatasubramanian, Vijay Vittal, Application of Time-Synchronized Measurements in Power System Transmission Networks , Springer, 2014.
7. Alfredo Vaccaro (Editor), Wide Area Monitoring, Protection and Control Systems: The enabler for smarter grids, IET Power and Energy Series, 2016.
8. Rahman, Waheed Ur, Muhammad Ali, Amjad Ullah, Hafeez Ur Rahman, Majid Iqbal, Haseeb Ahmad, Adnan Zeb, Zeeshan Ali, M. Ahsan Shahzad, and Beenish Taj. "Advancement in Wide Area Monitoring Protection and Control Using PMU’s Model in MATLAB/SIMULINK." Smart Grid and Renewable Energy, vol.3, no. 04, pp. 294-307,2012.
9. P. K. Nayak, A. K. Pradhan, and P. Bajpai. "Wide area measurement-based backup protection for power network with series compensation." IEEE Transactions on Power Delivery, vol. 29, no. 4, pp. 1970-1977, August 2014.
10. V. K. Agrawal etal., “Operational Experience of the First Synchrophasor Pilot Project in Northern India” Power System Operation Corporation, CBIP- 5th International Conference on Power System Protection and Automation, 6-9 Dec 2010.
11. Bhuvanesh A. Oza, “Power System Protection and Switchgear”, Tata McGraw Hill,2010.
12. Y.G. Paithankar and S.R Bhide, “Fundamentals of Power System Protection”, PrenticeHall of India, 2003.

COURSE PLAN

COURSE No.:	COURSE NAME:	L-T-P: **3-1-0**	
04 EE 6820	**ICT ENABLED POWER SYSTEM PROTECTION AND COMPUTER RELAYING**	**Credits :3**	
MODULES		Contact Hours	Sem. Exam Marks (%)
Module 1 Protection standards and Review of protection schemes IEEE Protection Standards & Guides, Protection Characteristics: Reliability, Security, Speed, Selectivity, And Economics, Review of protection schemes: Over-current protection, Differential Protection, Distance protection, quadrilateral relay, elliptical relay, Numerical relay: principles		9	15
Module 2 **WAMS** Data Acquisition Systems, RTU, IED, Synchrophasor based Wide Area Monitoring Systems(WAMS): Wide Area Measurement Systems (WAMS), WAMS architecture, applications. Phasor representation of sinusoids, Fourier series and Fourier transforms, sampled data and aliasing, DFT and phasor representation, leakage phenomena - **Phasor Estimation** : Phasor estimation of nominal frequency inputs- phasors of nominal frequency signals, formula for updating phasors, effect of signal noise and window length, phasor estimation with fractional cycle data window. Frequency estimation of balanced and unbalanced inputs. PMU, Data Sampling and signal conditioning,		11	15
FIRST INTERNAL TEST			
Module 3 **WAMS structure** Wide Area Measurement - A Generic PMU - Hierarchy for phasor measurement systems - Communication options for PMUs. Functional requirements of PMUs and PDCs. The “Synchrophasor” and file structure standards-PDC files.		8	15
Module 4: Protection in DG and smart grid Protection in Distributed Generators (DGs), micro grids and smart grids. Power system protection testing: automatic testing, test methods, maintenance and field testing of relays.		8	15

SECOND INTERNAL TEST		
Module 5 **ICT enabled algorithms** Use of FFT, DFT, Wavelet for protection algorithms. Fault location and identification. Information and Communication Technology application to protective systems: ICT functions, ICT control of network for protection coordination, Common Format for Transient Data Exchange(COMTRADE).	8	20
Module 6 **Modelling of PMU for simulation studies** Protection of series compensated transmission line: Issues, challenges in protection of FACTS compensated transmission lines. Faulty area identification based on fault voltage component distribution. Fault voltage ratio coefficient (FVRC), Effect of fault resistance, fault position and line impedance on FVRC. Faulty zone identification based on sequence currents. Faulty line identification techniques Trends in PMU based technology: PMU projects in India and other countries. Modelling of PMU: Wide Area Monitoring Protection and Control Using PMU's Model in MATLAB/SIMULINK- signal processing tools in PMU data analysis.	11	20
END SEMESTER EXAM		

COURSE CODE	COURSE NAME	Credits	YEAR
04 EE 6814	POWER SYSTEM RESTRUCTURING AND DEREGULATION	3-1-0:3	2020

Pre-requisites: Nil

Course Objectives:

- To give the Student the basic knowledge of the power system restructuring, market structure, relation between demand and supply costs and Electricity price.
- To study factors affecting the electricity price in the restructured market and generation capacity evaluation.
- To impart the basic concepts and an overview of transmission pricing and congestion management.

Syllabus:

Power system restructuring- deregulation of power industry- Reasons and objectives of deregulation of various power systems across the world- Market Structure and operation- Costs relationship between short run and long run costs- Monopolistic and Oligopolistic- Determination of market price- Electricity price- automatic generation control and its pricing- Generation assets valuation and risk analysis.- Transmission Congestion Management and Pricing- Role of FACTS devices in competitive power market- Available Transfer Capability, Distributed Generation in restructured markets- Reactive power requirements under steady state voltage stability and dynamic voltage stability- System losses and loss reduction methods, Power tariffs –Market Forces shaping of reactive power-reactive power requirement of the utilities.

Course Outcome:

Students will be able to

- Explain basics of the power system restructuring, market structure, relation between demand and supply costs and Electricity price, factors affecting the electricity price in the restructured market and generation capacity evaluation.
- Outline the concept of transmission pricing and congestion management, stability and impact of reactive power in power tariff in restructured markets

References:

1. "Maket Operations in Electric Power Systems" Mohammad Shahidehpour,Hatim Yamin, Zuyi Li ,A John Wiley & Sons, Inc., Publications , 2002
2. Understanding electric utilities and de-regulation, Lorrin Philipson, H. Lee Willis, Marcel Dekker Pub., 1998.
3. Power system economics: designing markets for electricity by Steven Stoft, John Wiley & Sons, 2002.
4. "Operation of restructured power systems" K. Bhattacharya, J. E. Daadler, M. H.J. Boolen, Kluwer Academic Pub., 2001.
5. Restructured electrical power systems: operation, trading and volatility by Mohammad Shahidehpour, M. Alomoush , CRC Press , 2001
6. Power System Restructuring and Deregulation by Loi Lei Lai, John Wiley & Sons Ltd.
7. "Power System Restructuring Engineering & Economics" Marija llic by Francisco Galiana and Lestor Fink, Kulwer Academic Publisher, USA.

COURSE NO:	COURSE TITLE:	L-T-P:CREDITS	
04 EE 6814	POWER SYSTEM RESTRUCTURING AND DEREGULATION	3-0-0:3	
MODULES		Contact hours	Sem. Exam Marks; %
MODULE : 1 Power system restructuring& Deregulation - Introduction, Reasons for restructuring / deregulation of power industry ,Understanding the restructuring process, Introduction to issues involved in deregulation, Reasons and objectives of deregulation of various power systems across the world		5	15
MODULE : 2 Market Structure and operation:- Objective of market operation, Electricity market models, Power market types, Market power, Key components in market operation. Demand and supply, Demand analysis - theory of demand, Elasticity of demand, Demand forecasting types- techniques of forecasting.		6	15
FIRST INTERNAL TEST			
MODULE : 3 Costs: short run –long run- relationship between short run and long run costs, perfect competition-Monopoly- Monopolistic and Oligopolistic, Determination of market price, Price discrimination		6	15
MODULE : 4 Electricity price: price volatility, ancillary services in electricity power market, automatic generation control and its pricing, Generation assets valuation and risk analysis.-introduction, VaR for Generation Asset Valuation, Generation Capacity Valuation		8	15
SECOND INTERNAL TEST			
MODULE: 5 Transmission Congestion Management and Pricing transmission cost allocation methods, LMP, FTR and Congestion Management. Role of FACTS devices in competitive power market, Available Transfer Capability, Distributed Generation in restructured markets.		9	20
MODULE : 6 Reactive power requirements- Reactive power requirements under steady state voltage stability and dynamic voltage stability, reactive power requirements to cover transient voltage stability, System losses and loss reduction methods, Power tariffs and Market Forces shaping of reactive power, reactive power requirement of the utilities.		8	20
END SEMESTER EXAM			

COURSE NO.	**COURSE TITLE**	**L-T-P-C**	**YEAR**
04 EE 6816	**SCADA AND APPLICATIONS**	**3-0-0-3**	**2020**

Pre-requisites: Nil Course

Objectives:

To introduce SCADA systems, its components, architecture, communication and applications

Syllabus:

Introduction to SCADA systems, Fundamental Principle of Modern SCADA Systems, Monitoring and supervisory functions, Application area of SCADA system, SCADA System Components, Remote Terminal Unit-(RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems. SCADA Architecture: Various SCADA architectures, advantageous and disadvantageous, SCADA Communication: Various industrial communication, Open standard communication protocols, Operation and control of interconnected power system, Automatic substation control, SCADA configuration, Energy management system, System operating states, System security, state estimation, SCADA Applications, Case studies, Implementation. Simulation exercises.

Course Outcome:

Upon successful completion of this course, students will be able to:

- Use SCADA systems in different engineering applications such as utility, communication, automation, control, monitoring etc.

Text Books:.

Reference

1. Stuart A Boyer. *SCADA-Supervisory Control and Data Acquisition*', Instrument Society of America Publications. USA. 1999.
2. Gordan Clarke, Deon RzynAzvs, *Practical Modern SCADA Protocols:* DNP3, 60870J and Related Systems', Newnes Publications, Oxford, UK,2004
3. David Bailey, Edwin Wright*, Practical SCADA for Industry*, Newnes (an imprint of Elsevier), 2003
4. KLS Sharma, *Overview of Industrial Process Automation*, Elsevier Publication

COURSE PLAN

COURSE NO.:	COURSE TITLE	L-T-P: 3-0-0	
04 EE 6816	SCADA AND APPLICATIONS	CREDITS: 3	
MODULES		Contac Hours	Sem. Exam Marks (%)
MODULE 1 Introduction to SCADA systems: -Evolution of SCADA -Fundamental Principle of Modern SCADA Systems, -Monitoring and supervisory functions -Application area of SCADA Consideration and benefits of SCADA systeM		7	15
MODULE 2 SCADA System Components: Remote Terminal Unit-(RTU), Intelligent Electronic Devices (IED) -PLC: Block diagram, programming languages, Ladder diagram, Functional block diagram, Applications, Interfacing of PLC with SCADA. -Communication Network -SCADA Server, SCADA/HMI Systems		9	15
FIRST INTERNAL TEST			
MODULE 3 SCADA Architecture: -Various SCADA architectures, advantages and disadvantages of each system -Single unified standard architecture, IEC 61850 SCADA / HMI Systems		6	15
MODULE 4 SCADA Communication: -Various industrial communication technologies -wired and wireless methods and fiber optics Open standard communication protocols		9	15
SECOND INTERNAL TEST			
MODULE 5: Operation and control of interconnected power system -Automatic substation control, SCADA configuration-Energy management system -System operating states System security, state estimation		6	20
MODULE 6: SCADA Applications: Utility applications Transmission and Distribution sector operations, monitoring, analysis and improvement. -Industries - oil, gas and water. -Case studies: -Implementation. Simulation Exercises		8	20
END SEMESTER EXAM			

COURSE CODE	COURSE NAME	Credits	YEAR
04EE6822	POWER SYSTEM OPERATION AND CONTROL	3-1-0:4	2020

Pre-requisites: Nil

Course Objectives:

- To know the general concepts of load forecasting, economic operation, unit commitment and solution method.
- To impart the concepts of hydro thermal scheduling, automatic generation control and AGC implementation.
- To study the concept of voltage control using compensation devices.
- To gain the knowledge about power system security.

Syllabus

Active Power and Frequency control, Reactive Power &Voltage control, Power transmission problems and emergence of facts solutions, Economic operation, Hydro thermal Co-ordination, Power system security

Course Outcome:

Students will be able to

- Explain methods for economic load dispatch and unit commitment.
- Apply control and compensations schemes on a power system.
- Adopt contingency analysis and selection methods to improve system security.

Text Books:

6. Allen J Wood, Bruce F Wollenberg, "Power Generation, Operation and Control", John Wiley& Sons, New York, II Edition, 1984.
7. Kundur P, "Power System Stability and Control", McGraw Hill, 2006
8. N.G. Hingorani & Laszlo Gyugyi , "Understanding FACTS" , IEEE Press, 2000

References:

5. Nagrath J J and Kothari D P, "Modern Power system Analysis", Tata McGraw Hill, 1980.
6. Singh L P, "Advanced Power Systems Analysis and Dynamics", New Age Intl. Publishers, 1983.
7. Stagg and EL Abiad , "Computer Methods in Power system Analysis", McGraw Hill, 1968.

COURSE NO:	COURSE TITLE:	CREDITS	
04 EE 6301	Power system Operation and control	4-0-0:4	
MODULES		Contact hours	Sem. Exam Marks; %
Module 1: Active Power and Frequency control:- Fundamentals of speed governing-Control of Generating unit power output-composite regulating characteristic of Power system-Responds rates of turbine-Governing systems-Fundamentals of Automatic Generation control (AGC) - implementation of AGC		10	
Module 2: Reactive Power &Voltage control Production and absorption of Reactive power-Methods of voltage Control-Shunt reactors-Shunt capacitors-series capacitors-synchronous condensers - Static Var systems-Principles of transmission system compensation.		6	
FIRST INTERNAL TEST			
Module 3: Power transmission problems and emergence of FACTS solutions Fundamentals of ac power transmission, transmission problems and needs, emergence of FACTS- FACTS controllers- SVC and STATCOM		6	
Module 4. Economic operation Economic operation: Load forecasting-classification-method of Least Squares Curve fit-Unit Commitment-constraints in Unit Commitment solution methods- Economic Dispatch problem of thermal units-Gradient method-Newtons method-Base point and participation factor method-Unit Commitment versus Economic Dispatch.		10	
SECOND INTERNAL TEST			

MODULE 5:Hydro thermal Co-ordination Hydro electric plant models- scheduling problems- short term hydro thermal scheduling problem-Gradient approach-Hydro units in series-Pumped storage hydro plants- Dynamic programming solution to hydro thermal scheduling problem	9	
MODULE 6: Power system security:- System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis – Corrective controls (preventive, emergency, and restorative) – Islanding scheme.	7	

COURSE CODE	COURSE NAME	Credits	YEAR
04 EE 6824	ADVANCED POWER SYSTEMS AND RENEWABLE ENERGY LAB	0-0-2-1	2020

Pre-requisites: Nil
Course Objectives:

To enable the students:

1. To carry out experiment and simulation studies on PV and wind energy conversion systems.
2. To develop experimental skills for independent research.

Syllabus/List of Experiments:

PART A

1. Simulation of solar PV generator.
2. Effect of tilt angle on solar PV system.
3. Effect of bypass diode and blocking diode for a solar PV panel.
4. Analysis of effect of shading and temperature on Solar PV Module.
5. Introduction to solar PV simulation
6. Design and of Implementation of DC-DC converter for solar application.
7. Hardware implementation of PO MPPT algorithm.
8. Hardware implementation of INC MPPT algorithm.
9. Design and implementation of charge Controllers.
10. OFF grid PV system with Li ion battery
11. Experiments on Wind Energy Emulator
12. Simulation of modeling of wind energy conversion systems.
13. Simulation of MPPT in wind energy conversion systems.
14. Simulation of reactive power compensation by variable speed wind energy conversion systems.
15. Study of battery management system and condition monitoring of storage devices

PART B

16. Real time simulation of power system and power electronic systems under Hardware – in –loop platform
17. Measurement of Power Quality and Energy Loss of inverters, Motor & Power System
18. Analysis of Static Var Compensators.
19. Analysis of STATCOM.
20. Load forecasting using ANN Tool/ETAP
21. Power Quality studies using PSCAD/PSS/E
22. Substation layout using AutoCAD Electrical
23. Transient Stability Analysis and formation of Swing Curves using MATLAB/SIMULINK
24. Modelling of Surge Arresters using PSCAD
25. Modelling of FACTS devices using SIMULINK
26. Transformer Tests using SIMULINK /ETAP
27. Fault Analysis of a synchronous Generator using PSCAD
28. Execute optimal power flow problem using ETAP/PSCAD.
29. Analysis of voltage stability of a SLIB (Single Load Infinite Bus) system while delivering maximum power using MATLAB/PSS-E.
30. Continuation Power Flow (CPF) analysis using MATLAB

(**At least 5 experiments from each part in the list are to be conducted in the laboratory. Additional experiments and simulation assignments can also be given by the department**)

COURSE NO.	COURSE TITLE	L-T-P:C	YEAR
04 EE 7001	BIO INSPIRED ALGORITHMS	3-0-0:3	2020

Pre-requisites: Nil

Course Objectives:

To enable the student to apply fuzzy logic based analysis tools in optimization of power systems and power electronic problems.

Syllabus:

Fuzzy Logic-concepts-set theory -operations-membership function-fuzzy rules-fuzzy reasoning-fuzzy inference systemsMamdani and Sugeno type-defuzzification- fuzzy controllers-applications in electric drives, power system **Genetic Algorithm Application :** Modern Heuristic Search Techniques Genetic Algorithm-Introduction- -Encoding-Fitness Function, Premature Convergence, Slow Finishing,Basic Operators, Selection-Tournament Selection, Truncation Selection, Linear Ranking Selection, Exponential Ranking Selection, Elitist Selection, Proportional Selection-Crossover, Mutation, Control Parameters Estimation, Niching Methods, Parallel Genetic Algorithms-Application in Drives.- Tunning of membership function using genetic algorithm. Application of GA to neural network.- Tunning of controllers.

Swarm Intelligence: Ant Colony Optimization

Swarm intelligence general characteristics, Ant Colony Optimization: Basic Concepts- The Ant Colony System-Ants' Foraging Behaviour and Optimization,- The Max-Min Ant System Minimum Cost Paths, Combinatorial Optimization, Major Characteristics of Ant Colony Search Algorithms- Positive Feedback-Rapid Discovery of Good Solution - Use of Greedy Search and Constructive Heuristic Information- Ant Colony Optimization Algorithms Applications.

Particle swarm optimization and Firefly Algorithm

Particle swarm optimization: Application and Implementation. **Fire Fly Algorithm** – Basic Concepts- Application in optimization, power electronics and power system problems.

Course Outcome:

Students who successfully complete this course will have demonstrated an ability to apply optimization techniques in engineering applications.

Text Books:

1. Leandro Nunes de Castro," Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications". Chapman & Hall/CRC, 2006.
2. G. Rozenberg, T. Bäck, J. N. Kok ,"Handbook of Natural Computing", Springer Verlag- 2010.

References:

1. Melanie Mitchell, “ An Introduction to Genetic Algorithms”, MIT Press- 1996.
2. Mohamed E. El-Hawary, “Modern Heuristic Optimisation technique –Theory and application to power system”,IEEE Press.
3. Xin-She Yang, “Nature-Inspired Metaheuristic Algorithms”, Luniver Press 2010.
4. J. R. Koza: “ Genetic Programming: On the programming of computers by means of natural selection”, MIT Press- 1992 .

COURSE PLAN

COURSE NO:	Course Title		CREDITS
04 EE 7001	**BIO INSPIRED ALGORITHMS**		**3-0-0:3**
MODULES		**Contact hours**	**Sem. Exam Marks;%**
MODULE : 1 Fuzzy Logic-concepts-set theory -operations-membership function-fuzzy rules-fuzzy reasoning-fuzzy inference systemsMamdani and Sugeno type-defuzzification- fuzzy controllers-applications in electric drives, power system.		10	15
MODULE : 2 **Genetic Algorithm Application :** Modern Heuristic Search Techniques Genetic Algorithm-Introduction- -Encoding-Fitness Function, Premature Convergence, Slow Finishing, Basic Operators, Selection-Tournament Selection, Truncation Selection, Linear Ranking Selection, Exponential Ranking Selection, Elitist Selection, Proportional Selection-Crossover, Mutation, Control Parameters Estimation, Niching Methods, Parallel Genetic Algorithms-Application in Drives.- Tuning of membership function using genetic algorithm. Application of GA to neural network.- Tuning of controllers.		8	15
FIRST INTERNAL TEST			
MODULE : 3 **Swarm Intelligence: Ant Colony Optimization** Swarm intelligence general characteristics, Ant Colony Optimization: Basic Concepts- The Ant Colony System- Ants' Foraging Behavior and Optimization,- The Max-Min Ant System Minimum Cost Paths, Combinatorial Optimization.		6	15
MODULE : 4 Major Characteristics of Ant Colony Search Algorithms- Positive Feedback-		8	15

Rapid Discovery of Good Solution - Use of Greedy Search and Constructive Heuristic Information- Ant Colony Optimization Algorithms Applications.		
SECOND INTERNAL TEST		
MODULE : 5 Particle swarm optimization: -Fundamentals- Concepts of PSO-Comparison with Genetic Algorithm-Application and Implementation.	5	20
MODULE : 6 **Firefly Algorithm** –Basic Concepts-Application in optimization, power electronics and power system problems.	5	20
END SEMESTER EXAMINATION		

COURSE NO.	COURSE TITLE	L-T-P:C	YEAR
04 EE 7801	EMBEDDED SYSTEM CONTROLLERS FOR RENEWABLE ENERGY SYSTEMS	3-0-0:3	2020

Pre-requisites: Nil

Course Objectives:

Upon the completion of the course the student will be able to

- To describe the differences between the general computing system and the embedded system, also recognize the classification of embedded systems
- To become aware of the architecture of the AVR processor and its programming aspects (Assembly Level)
- To acquire knowledge on key board interfacing, conversion from ADC and DAC
- To equipped to design and develop control of drives using embedded system programming

Syllabus:

Introduction to Embedded System: An embedded system, processor, hardware unit, software embedded into a system, Example of an embedded system, Real time and embedded OS. Structural unit in a processor selection for embedded systems. AVR system –AVR family processors, Architecture, Addressing modes, Instruction overview, Branch, Call, and Time Delay Loop, AVR I/O Port Programming. Assembly level programming Higher level language programming, AVR Programming in C, Timer Programming, Interrupt Programming. Real world interfacing: Interfacing LED, push button, LCD and Keyboard, ADC, DAC, and different Sensor Interfacing, Relay, Opt isolator interface. Stepper Motor Interfacing, Servo motor interfacing, PWM Programming, RTC, PC interface, data acquisition system. Case studies DC motor control, Induction Motor control (VSI and CSI fed) , BLDC motor control. Concept of smart card sized computers-Programming of smart card sized controllers- AVR based single board microcomputers for data acquisition and PWM signal generation.

Course Outcome:

- Students who successfully complete this course will be able to describe the differences between the general computing system and the embedded system, also recognize the classification of embedded systems
- To become aware of the architecture of the AVR processor and its programming aspects (Assembly Level)
- To acquire knowledge on key board interfacing, conversion from ADC and DAC
- To equipped to design and develop control of drives using embedded system programming

Text Books:

- M A Mazidi, S Naimi “AVR Microcontroller and Embedded Systems: Using Assembly and C“
- Rajkamal “Embedded System Architecture: Programming & Design”, TMH Edition, 2007.
- J. W. Valvano“, Embedded Microcomputer System: Real time interfacing”, Cengage Engineering, 1st Edition, 2000.

COURSE PLAN

COURSE NO.	COURSE TITLE	L-T-P:C	
04 EE 7801	**EMBEDDED SYSTEM CONTROLLERS FOR RENEWABLE ENERGY SYSTEMS**	**3-0-0:3**	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE 1 Introduction to Embedded System: An embedded system, processor, hardware unit, software embedded into a system, Example of an embedded system, Real time and embedded OS. Structural unit in a processor selection for embedded systems.		8	15
MODULE 2 AVR system –AVR family processors, Architecture, Addressing modes, Instruction overview, Branch, Call, and Time Delay Loop, AVR I/O Port Programming. Assembly level programming		8	15
FIRST INTERNAL TEST			
MODULE 3 Higher level language programming, AVR Programming in C, Timer Programming, Interrupt Programming.		7	15
MODULE 4 Real world interfacing: Interfacing LED, push button, LCD and Keyboard, ADC, DAC, and different Sensor Interfacing, Relay, Opt isolator interface.		8	15
SECOND INTERNAL TEST			
MODULE 5 Stepper Motor Interfacing, Servo motor interfacing, PWM Programming, RTC, PC interface, data acquisition system. Case studies DC motor control, Induction Motor control (VSI and CSI fed) , BLDC motor control.		9	20
MODULE 6 Concept of smart card sized computers- Programming of smart card sized controllers- AVR based single board microcomputers for data acquisition and PWM signal generation.		8	20
END SEMESTER EXAM			

COURSE NO.	COURSE TITLE	L-T-P-C	YEAR
04 EE 7501	ENERGY AND CLIMATE	3-0-0-3	2020

Pre-requisites: Nil Course Objectives:

To introduce the impact of various energy extraction strategies on climate

Syllabus:

Current energy scenario of World, USA and India – Energy terms – Fossil energy vs renewable sources – Electricity – Future projections, Externalities of energy use. Cycles Water cycle – Oxygen cycle – Carbon cycle – Nitrogen cycle – Phosphorous cycle, Climate Science Research: Climate history – Greenhouse gas effect – Anthropogenic climate change – role of different gases, Impacts and adaptation – uncertainties – precautionary principle, Global problems – Integrated assessment models, Biodiversity – Environmental aspects of energy utilization – Public health issues related to environmental pollution, Carbon Sequestration: Biological pathways – physicochemical methods, CO capture from large point sources – pre, post and oxy-combustion technology, Transport– storage monitoring – feasibility – economics and public perceptions, Case studies, Climate Policy: Kyoto protocol – UNFCCC – IPCC – Geopolitics of GHG control, Carbon market – CDM and other emission trading mechanisms – Non-CO GHGs - Relevance for India.

Course Outcome:

Upon successful completion of this course, students will be able to understand the impact of various energy extraction strategies on climate

Text Books:.

1. The Energies, MIT Press, Cambridge, 1999.
2. J. Houghton, Global Warming, Cambridge University Press, New York, 1997.

References:

1. B. Metz, IPCC Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press, NY, 2005.
2. Various reports published by IPCC, http://www.ipcc.ch/, 1990 onwards.
3. CDM Country Guide for INDIA: Institute for Global Environmental Strategies (Ed), Ministry of the Environment, Japan, 2005.
4. F. Harris, Global Environmental Issues, John Wiley, Chichester, 2004.
5. E. J. Wilson and D. Gerard, Carbon Capture and Sequestration: Integrating Technology, Monitoring, and Regulation, edited by, Blackwell Publishing, Ames, Iowa, USA, 2007.

COURSE PLAN

COURSE NO.:	COURSE TITLE	L-T-P: 3-0-0	
04 EE 7501	ENERGY AND CLIMATE	CREDITS: 3	
MODULES		Contac Hours	Sem. Exam Marks (%)
MODULE: 1 **Current energy scenario of World, USA and India – Energy terms – Fossil energy vs renewable sources – Electricity – Future projections Externalities of energy use. Cycles Water cycle – Oxygen cycle – Carbon cycle – Nitrogen cycle – Phosphorous cycle**		7	15
MODULE: 2 **Climate Science Research: Climate history – Greenhouse gas effect – Anthropogenic climate change – role of different gases Impacts and adaptation – uncertainties – precautionary principle**		7	15
FIRST INTERNAL TEST			
MODULE: 3 **Global problems – Integrated assessment models Bio-diversity – Environmental aspects of energy utilization – Public health issues related to environmental pollution.**		6	15
MODULE: 4 **Carbon Sequestration: Biological pathways – physicochemical methods CO capture from large point sources – pre, post and oxy combustion technology**		9	15
SECOND INTERNAL TEST			
MODULE: 5 **Transport– storage – monitoring – feasibility – economics and public perceptions, Case studies**		6	20
MODULE: 6 **Climate Policy: Kyoto protocol – UNFCCC – IPCC – Geopolitics of GHG control, Carbon market – CDM and other emission trading mechanisms –Non-CO GHGs - Relevance for India**		7	20
END SEMESTER EXAM			

COURSE CODE	COURSE NAME	L-T-P: Credits	YEAR
04 EE 7809	NANO MATERIALS FOR SOLAR APPLICATION	3-0-0: 3	2020

Pre-requisites: Nil Course

Objectives:

To give the Student: -

- A comprehensive study of various nanomaterials and nanostructures for nano materials for solar application.

Syllabus:

The properties of nanomaterials and nanostructures. Nanomaterials in solar energy conversion devices and systems. The use of nanostructures and nanomaterials in solar energy storage. The use of nanomaterials in the fuel cell and hydrogen technology

Course outcome:

Students will be able to

- Student will be able to explain concepts behind various type of new and conventional energy storage technology
  resources.

Text Books:

1. Tsakalakos .L, "Nanotechnology for Photovoltaic"s, CRC, 2010.

References:

2. Garcia-Martinez .J, "Nano Technology for Energy Challenge", Wiley- H Weinheim, 2010.
3. Maheshwar Sharon, Madhuri Sharon, Carbon "Nano forms and Applications", McGraw-Hill, 2010.
4. Tsakalakos .L, "Nanotechnology for Photovoltaic"s, CRC, 2010.
5. Wiesner .M.R and Bottero .J.Y, "Environmental Nano Technology: Applications and Impacts of nanomaterials", Tata McGraw-Hill, 2007.
6. KarkareI .K , "Nanotechnology- Fundamentals and Applications", IK Intern.Publ.,2008.
7. Leite .E.R., "Nano Structured Materials for Electrochemical Energy Production and Storage", Springer, 2009.
8. Eftekhari .A, "Nano Structured Materials in Electrochemistry", Wiley-VCH, 2008.
9. Allhoff .F, "What is Nanotechnology", Wiley, 2010.

COURSE PLAN

COURSE NO.	COURSE TITLE	CREDITS	
04 EE 6501	NANOMATERIALS FOR SOLAR APPLICATION	3-0-0: 3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE 1 **INTRODUCTION TO NANO TECHNOLOGY** General Concepts in Nanotechnology, History of nanotechnology , Classification of different areas of nanotechnology ,Top-down Approach, Bottom-up Approach, The interdisciplinary nature of nanotechnology, nanotechnology for future, Nanotechnology and the Converging Technologies		8	15
MODULE 2 **PROPERTIES OF NANOMATERIALS** Introduction to nanomaterial, nano dimensional materials, classification of nanomaterials, bulk materials and nanomaterials – changes in bulk and nanomaterials of silicon, silver, gold. General methods of preparation of nanomaterials, thermal and thermo-electric properties of nano structures - modeling and metrology. Nanowires, nanostructures, nanocomposites.		9	15
FIRST INTERNAL TEST			
MODULE 3 NANOMATERIALS FOR SOLAR THERMAL CONVERSION Conversion of thermal energy - Nanostructures and nanomaterials, materials selection criteria, particle-scale effect. Phase compositions on nanoscale microstructures. Nanoparticles for conduction heat transfer, coatings on fins.		10	15
MODULE 4 NANO APPLICATIONS IN THERMAL ENERGY STORAGE Basics of thermal energy storage systems. Application of nanomaterials in solar thermal energy production and storage systems - Sensible, latent heat and chemical energy storages. Nano encapsulated phase change materials in cooling applications. Nanotechnology for electrochemical energy storage.		10	15
SECOND INTERNAL TEST			
MODULE 5 NANOMATERIALS FOR PHOTOVOLTAICS Photochemical solar cells, PV panels with nanostructures. Phase compositions on nanoscale microstructures – role of nanostructures and materials – nanomaterials in solar photovoltaic technology-band gap engineering and optical engineering – tandem structures - quantum well and quantum dot solar cells - photo-thermal cells – organic solar cells. Performance and reliability of nanomaterials based solar cells.		9	20
MODULE: 6 NANOMATERIALS IN FUEL CELL APPLICATIONS Use of nanostructures and nanomaterials in fuel cell technology - high and low temperature fuel cells, cathode and anode reactions, fuel cell catalysts, electrolytes, ceramic catalysts. Use of nano technology in hydrogen production and storage.		10	20
END SEMESTER EXAM			

COURSE CODE	COURSE NAME	L-T-P-C	YEAR
04EE7809	NANO MATERIALS FOR SOLAR APPLICATION	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To understand the properties of nanomaterials
- To familiarize the concepts of solar thermal and photovoltaic applications using nanomaterials.
- To gain knowledge about nanomaterial application in fuel cells

Syllabus

General Concepts in Nanotechnology; Properties of nanomaterials; Nanowires, nanostructures, nano-composites; Nanomaterials for Solar Thermal Conversion; Nanomaterials for Thermal energy storage; Nanomaterials for photovoltaic; The use of nanomaterials in the fuel cell and hydrogen technology

Course outcome:

Upon the completion of this course, students will have the ability:

- to explain concepts behind various type of Nanomaterials for solar and fuel cell application.

Text Books:

10. Tsakalakos .L, "Nanotechnology for Photovoltaic"s, CRC, 2010.

References:

1. Garcia-Martinez .J, "Nano Technology for Energy Challenge", Wiley- H Weinheim, 2010.
2. Maheshwar Sharon, Madhuri Sharon, Carbon "Nano forms and Applications", McGraw-Hill, 2010.
3. Tsakalakos .L, "Nanotechnology for Photovoltaic"s, CRC, 2010.
4. Wiesner .M.R and Bottero .J.Y, "Environmental Nano Technology: Applications and Impacts of nanomaterials", Tata McGraw-Hill, 2007.
5. KarkareI .K , "Nanotechnology- Fundamentals and Applications", IK Intern.Publ.,2008.
6. Leite .E.R., "Nano Structured Materials for Electrochemical Energy Production and Storage", Springer, 2009.
7. Eftekhari .A, "Nano Structured Materials in Electrochemistry", Wiley-VCH, 2008.
8. Allhoff .F, "What is Nanotechnology", Wiley, 2010.

COURSE PLAN

COURSE NO:	COURSE TITLE	CREDITS	
04EE7809	NANOMATERIALS FOR SOLAR APPLICATION	3-0-0: 3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE: 1 : **INTRODUCTION TO NANO TECHNOLOGY:** General Concepts in Nanotechnology, History of nanotechnology , Classification of different areas of nanotechnology ,Top-down Approach, Bottom-up Approach, The interdisciplinary nature of nanotechnology, nanotechnology for future, Nanotechnology and the Converging Technologies		**8**	**15**
MODULE: 2: PROPERTIES OF NANOMATERIALS: Introduction to nanomaterial, nano dimensional materials, classification of nanomaterials, bulk materials and nanomaterials – changes in bulk and nanomaterials of silicon, silver, gold. General methods of preparation of nanomaterials, thermal and thermo-electric properties of nano structures - modeling and metrology. Nanowires, nanostructures, nanocomposites.		**9**	**15**
FIRST INTERNAL TEST			
MODULE: 3 NANOMATERIALS FOR SOLAR THERMAL CONVERSION: Conversion of thermal energy - Nanostructures and nanomaterials, materials election criteria, particle-scale effect. Phase compositions on nanoscale microstructures. Nanoparticles for conduction heat transfer, coatings on fins.		**10**	**15**
MODULE: 4 NANO APPLICATIONS IN THERMAL ENERGY STORAGE: Basics of thermal energy storage systems. Application of nanomaterials in solar thermal energy production and storage systems - Sensible, latent heat and chemical energy storages. Nano encapsulated phase change materials in cooling applications. Nanotechnology for electrochemical energy storage.		**10**	**15**
SECOND INTERNAL TEST			
MODULE: 5 NANOMATERIALS FOR PHOTOVOLTAICS: Photochemical solar cells, PV panels with nanostructures. Phase compositions on nanoscale microstructures – role of nanostructures and materials – nanomaterials in solar photovoltaic technology- band gap engineering and optical engineering – tandem structures - quantum well and quantum dot solar cells - photo-thermal cells – organic solar cells. Performance and reliability of nanomaterials based solar cells.		**9**	**20**

MODULE: 6 NANOMATERIALS IN FUEL CELL APPLICATIONS: Use of nanostructures and nanomaterials in fuel cell technology - high and low temperature fuel cells, cathode and anode reactions, fuel cell catalysts, electrolytes, ceramic catalysts. Use of nano technology in hydrogen production and storage.	**10**	**20**
END SEMESTER EXAM		

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE7805	ARTIFICIAL INTELLIGENCE APPLICATION IN POWER SYSTEMS	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- Overview of artificial intelligence techniques
- To convey applications of AI techniques to power system problems

Syllabus

Introduction to AI; Artificial Neural Networks; Fuzzy Logic; Fuzzy Implication and Algorithms; Defuzzification Methods; Genetic Algorithms and Evolutionary Programming; Pattern Recognition; Statistical classifier design algorithms; increment-correction and LMSE algorithms; Application of AI techniques; Load forecasting, load flow studies, economic load dispatch.

Course Outcome:

Students who successfully complete this course be able to:

- understand various ANN configurations
- apply fuzzy logic controller for power system applications
- understand the concept and working of Evolutionary algorithms
- understand the concept of pattern recognition
- apply AI techniques for power system applications

Text Books:

[1]. N. P. Padhy, "Artificial Intelligence and Intelligent Systems," OXFORD University Press, New Delhi, 2005
[2]. Stamations V. Kartalopoulos, "Understanding Neural Networks and Fuzzy Logic: Basic concepts and Applications," Prentice Hall India Private Limited, New Delhi,2002.
[3]. Kevin Warwick, Arthur Ekwue and Raj Aggarwal, "Artificial Intelligence Techniques in Power Systems," IEE Power Engineering Series, UK, 1997.
[4]. Abhisek Ukil, "Intelligent Systems and Signal Processing in Power Engineering," Springer Berlin Heidelberg, New York
[5]. Simon Haykin, "Neural Networks: A Comprehensive Foundation," 2nd Edition, Pearson Education.
[6]. Zimmermann, H. J., "Fuzzy Set Theory and Its Applications," 2nd Edition, Kluwer Academic Publishers.
[7]. El Hawaray, "Electrical Power Applications with Fuzzy systems AIEEE Press.
[8]. D. P. Kothari, J. S. Dhillon, "Power System Optimisation," PHI
[9] M. Ganesh, "Introduction to fuzzy sets and fuzzy logic", Prentice Hall India.
[10] Kelvin Waruicke, Arthur Ekwlle, Raj Agarwal, "AI Techniques in Power System," IEE London
[11] S. Rajasekaran and G. A. V. Pai ,"Neural Networks, Fuzzy Logic & Genetic Algorithms, "- PHI, New Delhi, 2003.
[12]. P. D. Wasserman,Van Nostrand Reinhold, "Computing Theory & Practice," New York,1989.
[13]. Neural Network & Fuzzy System, Bart Kosko, Prentice Hall, 1992.
[14]. G. J. Klir and T. A. Folger, "Fuzzy sets, Uncertainty and Information," PHI, Pvt.Ltd,1994.
[15]. D.E.Goldberg, "Genetic Algorithms,", Addison Wesley 1999.

References:

5. Melanie Mitchell, “ An Introduction to Genetic Algorithms”, MIT Press- 1996.
6. Mohamed E. El-Hawary, “Modern Heuristic Optimisation technique –Theory and application to power system”,IEEE Press.
7. Xin-She Yang, “Nature-Inspired Metaheuristic Algorithms”, Luniver Press 2010.
8. J. R. Koza: “ Genetic Programming: On the programming of computers by means of natural selection”, MIT Press- 1992 .

COURSE PLAN

COURSE CODE	COURSE TITLE		CREDITS
04EE7805	ARTIFICIAL INTELLIGENCE APPLICATION IN POWER SYSTEMS		3-0-0:3
MODULES		Contact hours	Sem. Exam Marks; %
MODULE : 1 Introduction to AI: Definition, Applications, Components of an AI program; production system. Problem Characteristics. Overview of searching techniques. Knowledge representation: Knowledge representation issues; and overview. Representing knowledge using rules; procedural versus declarative knowledge. Logic programming, forward versus backward reasoning, matching. Control knowledge.		10	15
MODULE : 2 Artificial Neural Networks: Biological Neuron, Neural Net, use of neural 'nets, applications, Perception, idea of single layer and multilayer neural nets, back propagation, Hopfield nets, supervised and unsupervised learning		8	15
FIRST INTERNAL TEST			
MODULE : 3 Fuzzy Logic: Introduction, Foundation of Fuzzy Systems, Representing Fuzzy Elements, Basic Terms and Operations, Properties of Fuzzy Sets, Fuzzification, Arithmetic Operations of Fuzzy Numbers, The alpha cut method, The extension method, Linguistic Descriptions and their Analytical Forms, Fuzzy Linguistic Descriptions, Fuzzy Relation Inferences, Fuzzy Implication and Algorithms, Defuzzification Methods, Centre of Area Defuzzification, Centre of Sums Defuzzification.		6	15

MODULE : 4 Genetic Algorithms and Evolutionary Programming: Introduction, Genetic Algorithms, Procedure of Genetic Algorithms, Genetic Representations, Initialization and Selection, Genetic Operators, Mutation, The Working of Genetic Algorithms, Evolutionary Programming, The Working of Evolutionary Programming.	8	15
SECOND INTERNAL TEST		
MODULE : 5 Pattern Recognition: Introduction, automatic pattern recognition scheme. Design Concepts, Methodologies, Concepts of Classifier, concept of feature selection. Feature selection based on means and co-variances. Statistical classifier design algorithms; increment-correction and LMSE algorithms.	5	20
MODULE : 6 Application of AI techniques: Load forecasting, load flow studies, economic load dispatch, load frequency control, single area system and two area system, small signal stability (dynamic stability) reactive power control.	5	20
END SEMESTER EXAMINATION		

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE7103	OPTIMAL CONTROL THEORY	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

To enable the students:

- To apply the principles of optimal control to control problems
- To develop computational solutions to Control Problems

Syllabus

Optimality Problems in Control Theory - Mathematical models-selection of performance measures- constraints-classification of problem constraints-problem formulation-Dynamic Programming - Calculus of Variations - Basic Concepts-variation of functional – extremals-fundamental theorem in calculus of variation-Euler Equation-Piecewise Smooth extremals-constrained extrema- Hamiltonian-necessary condition for optimal control - Pontryagin's Minimum Principle - Minimum Time problem-Minimum Fuel problem-Minimum Energy problem. Case Studies.

Course Outcome:

Upon successful completion of this course, students will be able to:

- develop computational solutions to Control Problems.
- develop Optimal Controllers for Linear Regulator Problems.

Text Books:

1. Donald E. Kirk, "Optimal Control Theory", Dover Publications, Inc, New York.
2. Athans M. and P. L. Falb, Optimal control- An Introduction to the Theory and its Applications, McGraw Hill Inc., New York, 1966.

References:

1. Brian D. O. Anderson, John B. Moore, Optimal Control-Linear Quadratic Methods, Prentice-Hall Inc., New Delhi, 1991.
2. Sage A. P., Optimum Systems Control, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1968.
3. D. S. Naidu, Optimal Control Systems, CRC Press, New York Washington D. C., 2003.

COURSE PLAN

COURSE NO.:	COURSE TITLE	CREDITS	
04EE7103	OPTIMAL CONTROL THEORY	3-0-0 :3	
MODULES		Contact Hours	Sem. Exam Marks (%)
MODULE 1: Optimality Problems in Control Theory - Mathematical models - Performance measures for optimal control problems - selection of performance measures. Constraints-classification of problem constraints-problem formulation		6	15
MODULE 2: Dynamic Programming - The Optimal Control Law - Principle of OPtimality - Application of Principle of Optimality to Decision-Making Dynamic Programming Applied to a Routing Problem- Interpolation - A recurrence relation for Dynamic Programming –		8	15
INTERNAL TEST 1			
MODULE 3: Computational Procedure for Solving Control Problems - Characteristics of Dynamic Programming Solution. Analytical Results - Discrete Linear Regulator Problems.		8	15
MODULE 4: The Hamilton - Jacobi-Bellman Equation - Continuous Linear Regulator Problems Hamiltonian-necessary conditions for optimal control - Linear Regulator Problems		6	15
INTERNAL TEST 2			
MODULE 5: Calculus of Variations - Basic Concepts-Functionals of a single functions - variation of functional - functionals of several independent functions - Extremals- fundamental theorem in calculus of variation- Euler Equation-Piecewise Smooth extremals-constrained extrema.		8	20

MODULE 6: Pontryagin's Minimum Principle - Minimum Time problem-Minimum Fuel problem-Minimum Energy problem - Case Studies.	8	20
END SEMESTER EXAM		

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE7807	POWER QUALITY	3-0-0-3	2020

Pre-requisites: Nil

Course Objectives:

- To familiarize the various power quality characterizations, sources of power quality issues and recommend standards related to power quality
- To understand the effects of various power quality phenomena in various equipments.
- To understand and to provide solutions for power factor correction through various power factor correction techniques.
- To gain knowledge on active harmonic filtering and to provide solutions to grounding and wiring problems

Syllabus

Introduction; power quality; voltage quality; classification of power quality issues; power acceptability curves; Harmonics; effect of power system harmonics on power system equipment and loads; Modelling of networks and components under non-sinusoidal conditions; Power factor improvement; Active Harmonic Filtering; Dynamic Voltage Restorers; Grounding and wiring; NEC grounding requirements

Course Outcome:

Upon completion of course on Power quality the students:

- Will be able to identify and classify power quality disturbances.
- Will be able to analyze the causes of power quality issues caused by components in the system.
- Will be able to provide feasible solutions for power factor correction.
- Will be able to develop the harmonic mitigation methods.

Text Books:

1. Roger C Dugan, Mark. F. Mc Granánaghan, “Electrical Power Systems Quality”, 2nd Edition - McGraw Hill Publications.
2. Math H J Bollen “Understanding Power Quality Problems”, IEEE Press.

References:

1. Arrillaga J, “Power System Quality Assessment”, John wiley, 2000.
2. Arrillaga J, Smith B C, Watson N R & Wood A R, “Power System Harmonic Analysis”, Wiley, 1997.
3. Ashok S, “Selected Topics in Power Quality and Custom Power”, Course book for STTP, 2004,
4. Surya Santoso, Wayne Beaty H, Roger C. Dugan, Mark F. Mc Granaghan, “Electrical Power System Quality“, MC Graw Hill, 2002.

COURSE PLAN

<table>
<tr><th>COURSE NO:</th><th>COURSE TITLE</th><th colspan="2">CREDITS</th></tr>
<tr><td>04EE7807</td><td>POWER QUALITY</td><td colspan="2">3-0-0-3</td></tr>
<tr><td colspan="2">MODULES</td><td>Contact hours</td><td>Sem. Exam Marks; %</td></tr>
<tr><td colspan="2">MODULE : 1

Introduction-power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-power quality measures and standards-THD-TIF-DIN-C-message weights- flicker factor-transient phenomena-occurrence of power quality problems.</td><td>7</td><td>15</td></tr>
<tr><td colspan="2">MODULE : 2

Power acceptability curves-IEEE guides, standards and recommended practices.</td><td>5</td><td>15</td></tr>
<tr><td colspan="4">FIRST INTERNAL TEST</td></tr>
<tr><td colspan="2">MODULE : 3

Harmonics-individual and total harmonic distortion-RMS value of a harmonic waveform-triplex harmonics-important harmonic introducing devices-SMPS-Three phase power converters-arcing devices - saturable devices-harmonic distortion of fluorescent lamps-effect of power system harmonics on power system equipment and loads.</td><td>8</td><td>15</td></tr>
<tr><td colspan="2">MODULE : 4

Modelling of networks and components under non-sinusoidal conditions-transmission and distribution systems-shunt capacitors-transformers- electric machines-ground systems-loads that cause power quality problems-power quality problems created by drives and its impact on drives.</td><td>8</td><td>15</td></tr>
<tr><td colspan="4">SECOND INTERNAL TEST</td></tr>
<tr><td colspan="2">MODULE : 5

Power factor improvement- Passive Compensation. Passive Filtering. Harmonic Resonance. Impedance Scan Analysis.

Active Power Factor Corrected Single Phase Front End, Control Methods for Single Phase APFC, Three Phase APFC and Control Techniques, PFC

Based on Bilateral Single Phase and Three Phase Converter. static var compensators-SVC and STATCOM.</td><td>6</td><td>20</td></tr>
</table>

MODULE : 6 Active Harmonic Filtering-Shunt Injection Filter for single phase , three- phase three-wire and three-phase four-wire systems . d-q domain control of three phase shunt active filters uninterruptible power supplies- constant voltage transformers- series active power filtering techniques for harmonic cancellation and isolation .Dynamic Voltage Restorers for sag, swell and flicker problems. Grounding and wiring-introduction-NEC grounding requirements-reasons for grounding-typical grounding and wiring problems-solutions to grounding and wiring problems.	8	20
END SEMESTER EXAMINATION		

COURSE CODE	COURSE TITLE	L-T-P-C	YEAR
04EE7803	MACHINE LEARNING AND DATA ANALYTICS	3-0-0-3	2020

Pre-requisites: Basics of Linear Algebra and Probability Theory, Basic programming skills

Course Objectives:

To give the Student:-

- The basic concepts and techniques of Machine Learning.
- An understanding of the strengths and weaknesses of many popular machine learning approaches.
- Discuss simple Machine Learning applications in a range of real-world applications.

Syllabus

Mathematical base for studying Machine learning; Machine learning concepts and classification; Supervised Learning :ANN; Supervised Learning :Kernels and SVM; Supervised Learning : Decision Trees; Unsupervised Learning; Clustering, Mixture Models, Expectation Maximization, Spectral Clustering, Non-parametric density estimation, K-means, Fuzzy C-means.

Course Outcome:

Students who successfully complete this course will have:

- the ability to analyze the learning problems.
- the ability to apply the different machine learning algorithms in the learning problems.

Text Books:

1. E. Alpaydin, Introduction to Machine Learning, Prentice Hall of India, 2006.
2. Machine Learning, Tom Mitchell, McGraw Hill, 1997.

References:

1. Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning Data Mining,Inference,and Prediction
2. Richard O. Duda, Peter E. Hart, David G. Stork. Pattern classification, Wiley, New York, 2001.
3. Course material available on Swayam platform and NPTEL, for the course on Introduction to Machine Learning, conducted by Prof. Sudeshna Sarkar, IIT Kharagpur.
4. Course material available on, for the course on Introduction to Machine Learning, conducted by Prof. Balaraman Raveendran, IIT Madras
5. Michael Nielsen, Neural Networks and Deep Learning. Determination Press, 2015. [Free online]
6. Stuart J. Russell and Peter Norvig, Artificial Intelligence: A Modern Approach. Pearson, 3rd Edition, 2010.

COURSE PLAN

COURSE NO:	COURSE TITLE:	CREDITS	
04EE7803	MACHINE LEARNING AND DATA ANALYTICS	3-0-0: 3	
MODULES		Contact hours	Sem. Exam Marks; %
MODULE : 1 – Mathematical foundation for Machine Learning Revision of mathematical tools for machine learning -Probability Theory, Linear Algebra, Convex Optimization		8	15
MODULE : 2 – Fundamentals of Machine Learning Introduction to machine learning: Programs vs learning algorithms, What is learning, learning objectives and data needed. Tasks, Models, Features of Learning. Examples		8	15
FIRST INTERNAL TEST			
MODULE : 3 Supervised Learning :ANN Artificial Neural Networks, Perceptron, Multilayer networks and Back propagation algorithm, Introduction to Deep Neural networks, Recurrent Neural Networks (RNNs) and Convolutional Neural Networks (CNNs), Reinforcement Learning, Feature selection for SL.		10	15
MODULE : 4 Supervised Learning :Kernels and SVM Kernels, Support Vector Machines, Classification, Instance based learning, K-Nearest-Neighbor, Locally weighted linear Regression, Logistic Regression		10	15
SECOND INTERNAL TEST			
MODULE : 5 - Supervised Learning : Decision Trees Decision Trees and Rule-Based Models- Entropy, Information Gain, Tree construction, The problem of Missing Attributes, Gain Ratio, Classification by Regression (CART)		10	20

MODULE : 6 – **Unsupervised Learning** Clustering, Mixture Models, Expectation Maximization, Spectral Clustering, Non-parametric density estimation, K-means, Fuzzy C-means	10	20
END SEMESTER EXAM		