COURSE CURRICULUM FOR Ph.D. COURSE WORK

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

SAMBALPUR UNIVERSITY

INSTITUTE OF INFORMATIONTECHNOLOGY

JYOTI VIHAR, BURLA

Sept-2020

Programme Educational Objectives

PEO1	Understand the nature and basic concepts relating to the Ph.D. Degree in Electrical & Electronics Engineering
PEO2	Analyse the relationships among different concepts
PEO3	Perform procedures as laid down in the areas of study
PEO4	Apply the Basic Concepts learned to execute them

Programme Outcome

PO-1	**Critical Thinking:** Take informed actions after identifying the assumptions that frame our thinking and actions
PO-2	**Effective Communication:** Will be able to speak, read, write and listen clearly inperson and through electronic media in English and in one Indian Language
PO-3	**Social Interaction (Interpersonal Relation):** Elicit views of others, mediate disagreements and prepared to work in team
PO-4	**Entrepreneurship Capability:**Demonstrate qualities to be prepared to become anentrepreneurship
PO-5	**Ethics:**Recognize different value systems including your own, understand the moral dimensions and accept responsibility for them
PO-6	**Environment and Sustainability:** Understand the issues of environmental contextsand sustainable development
PO-7	**Life-Long Learning:**Acquire the ability to engage in independent and life-long learning in the context of socio-technological changes

Rules and Regulations

A PhD scholar who hasregistered for Ph.D. program in Electrical and Electronics Engineering (EEE) in Sambalpur University, Burla, Odisha needs to choose **two branch specific papers** from the following papers given in Table.2 according to his/her specialization/interest. This is in addition to Research Methodology which is common to all branches and Power System Management (Core Course). The detailed course structure for pre Ph.D coursework is mentioned in Table1.

Table1. Detailed Structure for PhD Course Work in EEE

Course Code	**Name of Course**	**Contact Hours (L T P)**	**Credits**
EEPH01	Power System Management	4-0-0	4
	Research Methodology	4-0-0	4
	Research and Publication Ethics	2-0-0	2
	Paper-1 (Elective)	4-0-0	4
	Paper-2 (Elective)	4-0-0	4
EEPHS04	Seminar		2
EEPHR05	Research Review Report		2
Total Credit			22

Table 2. Specialization papers (Electives) for Electrical and Electronics Engineering

Sl. No.	Course Code	Course Title	Credit
1	EEPH02	**Power System Analysis**	4
2	EEPH03	**Distribution system Engineering**	4
3	EEPH04	**Power Electronics Control of Drives**	4
4	EEPH05	**Power QualityProblems and Mitigation**	4
5	EEPH06	**Power System Reliability**	4
6	EEPH07	**Advanced Control System**	4
7	EEPH08	**Dynamics of Electrical Machines**	4
8	EEPH09	**Renewable Energy Sources**	4
9	ECPH10	**Advanced Communication Theory**	4

10	ECPH11	**Advanced Image Processing**	4
11	ECPH12	**Advanced signal processing**	4

POWER SYSTEM MANAGEMENT

<table>
<tr><td colspan="2"></td><td>L-P-T:Cr.</td><td>4-0-0: 4</td></tr>
<tr><td>Objective:</td><td colspan="3">The objectives of this subject are:
1. To provide knowledge of load density calculation in an area and forecasting of load in advance using different methods.
2. To understand the power system economics and planning.
3. To train the students to analyze various types of electricity market operation and control issues under congestion management.
4. To understand the procedure of power system financing.</td></tr>
<tr><td rowspan="4">Course Outcomes:</td><td>CO-1</td><td colspan="2">Remember and understand the basic concepts/principles of Power system Management.</td></tr>
<tr><td>CO-2</td><td colspan="2">Analyze the various concepts to understand them through case studies.</td></tr>
<tr><td>CO-3</td><td colspan="2">Apply knowledge in understanding practical problems.</td></tr>
<tr><td>CO-4</td><td colspan="2">Execute/create the projects or field assignment as per knowledge gained in the course.</td></tr>
</table>

Module-I:

Load characteristics and load forecast Basic definitions- load definitions, load factor definitions,diversity principle in distribution systems, Load Forecast- factors affecting load forecasting methods, small areas load forecasting, spatial load forecasting methods, simulation, trending and mixed load forecasting methods.

Module-II:

Basics of Power System Economics & Short-term Operation Planning of Power System, Loadcurves and load duration curves, Economic load dispatch- concept of marginal cost and KuhnTucker'scondition of optimum in power dispatch, participation factors Classical method to calculate loss coefficients, Loss coefficient calculation using Y-Bus, Loss coefficients using sensitivity factors, Transmission loss coefficients, Transmission loss formula.

Module-III:

Power Pools & Electricity Markets Inter-area transactions, multi-area power interchanges, Energy brokerage systems, Market design and auction mechanism, Pool versus bilateral markets and price formation, Role of independent generators and system operator.

Module-IV:

Power Sector Financing Time value of money, utility economic evaluation, Capacity planning issues and methods- Levelizing and levelized bus-bar analysis, Screening curve analysis, Horizon-year generation additions analysis, Capacity planning in competitive environment.

Text Books:

1. H G Stoll, **Least Cost Electric Utility Planning,** Wiley-Indersceice, 1989
2. K Bhattacharya, M H J Bollen, J E Daalder, **Operation of restructured power system**, Kluwer Academic Publisher, 2001.

Reference Books:

1. D.P. Kothari, J.S. Dillon, **Power System Optimization**, PHI, 2011.

POWER SYSTEM ANALYSIS

		L-P-T:Cr.	4-0-0: 4
Objective:	1. To understand the concepts of per-unit system and modeling of power system 2. To learn the concepts of power flow analysis 3. To implement the concepts of unit commitment and hydro-thermal coordination in real time problems. 4. To analyze the concepts of state estimation and contingency analysis		
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Power system analysis.**	
	CO-2	Analyze the various concepts to understand them through case studies.	
	CO-3	Apply knowledge in understanding practical problems.	
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.	

Module-I (10 Hours)

Power Systems Review: Review of basic concepts- per unit systems, ac circuits, phasors, power system structure and topology; System Modeling: From Detailed to Approximate Including their Controls: Automatic Voltage Regulator (AVR): Exciter types, Exciter Modeling, Generator Modeling, and Static and Dynamic analysis of the AVR Loop, AVR Root Loci, Stability Compensation, and Effect of Generator Loading. Automatic Load Frequency Control (ALFC): Steady state and dynamic analysis in frequency domain for multi-area power system. Transmission systems: transformers and lines, including distributed parameter models Loads: RL, motor drives and aggregated models.

Module-II (10 Hours)

Power flow analysis, Optimal power flow, Solution of OPF by Gradient method, Newton's method, LP method, Security constrained OPF, Continuation power flow, Sparse matrix techniques for large scale system problems.

Module-III (10 Hours)

Unit commitment of generators, Hydro-thermal coordination- hydrological coupling between hydro power stations, power balance and discharge equations, formulation of the operational planning problem, pumped storage units and their scheduling, Generation with limited energy supply, Probabilistic production simulation.

Module-IV (10 Hours)

Power System Security, Contingency analysis, sensitivity factors, preventive & corrective measures, State Estimation in Power Systems, Weighted lest square estimation, Estimation in AC network, Orthogonal decomposition.

Text Books

1. Hadi Saadat, **Power Systems Analysis**, Tata McGraw Hill
2. John J Grainger, William D Stevenson, **Power System Analysis,** McGraw Hill
3. P Kundur, **Power System Stability and Control**, McGraw Hill
4. Olle I. Elgerd, **Electric Energy Systems Theory and Introduction,** McGraw Hill

Reference Books:

1. Stagg G W, El Abiad A H, **Computer methods in power system analysis,** McGraw Hill

DISTRIBUTION SYSTEM ENGINEERING

<table>
<tr><td colspan="2"></td><td>L-P-T:Cr.</td><td>4-0-0: 4</td></tr>
<tr><td>Objective:</td><td colspan="3">The objectives of this subject are:
1. Provide a generalized concept of distribution system configuration.
2. Planning for the distribution system and to understand the need of automation and control of distribution system.
3. Design of sub-transmission system, primary and secondary system.
4. Understand the voltage drop, voltage regulation and power loss calculations.</td></tr>
<tr><td rowspan="4">Course Outcomes:</td><td>CO-1</td><td colspan="2">Remember and understand the basic concepts/principles of Distribution system engineering.</td></tr>
<tr><td>CO-2</td><td colspan="2">Analyze the various concepts to understand them through case studies.</td></tr>
<tr><td>CO-3</td><td colspan="2">Apply knowledge in understanding practical problems.</td></tr>
<tr><td>CO-4</td><td colspan="2">Execute/create the projects or field assignment as per knowledge gained in the course.</td></tr>
</table>

Module-I (10 Hours)

Distribution system planning Short term planning, Long term planning, Dynamic planning, Subtransmission and substation design, Sub-transmission networks configurations, Substation bus schemes, Distribution substations ratings, Service areas calculations, Substation application curves.

Module-II (10 Hours)

Distributed Generation Standards, DG potential, Definitions and terminologies; current status and future trends, Technical and economic impacts, Definitions and terminologies; current status and future trends, Technical and economic impacts DG Technologies, DG from renewable energy sources, DG from non-renewable energy sources, distributed generation applications, Operating Modes, Base load; peaking; peak shaving and emergency power, Isolated, momentary parallel and grid connection.

Module-III (10 Hours)

Primary and secondary system design considerations Primary circuit configurations, Primary feeder loading, secondary networks design Economic design of secondaries, Unbalance loads and voltage considerations.

Module-IV (10 Hours)

Distribution system performance and operation Distribution automation and control, Voltage drop calculation for distribution networks, Power loss Calculation, Application of capacitors to distribution systems, Application of voltage regulators to distribution systems.

Text Books

1. Anthony J Pansini, **Electrical Distribution Engineering,** CRC Press
2. H Lee Willis, **Distributed Power Generation Planning and Evaluation**, CRC Press
3. James A Momoh, **Electric Power Distribution Automation Protection and Control,** CRC Press

Reference Books:

1. James J Burke, **Power Distribution Engineering: Fundamentals and Applications,** CRC Press
2. T Gonen, **Electric Power Distribution System Engineering**, McGraw Hill

POWER ELECTRONICS CONTRL OF DRIVES

		L-P-T:Cr.	**4-0-0: 4**
Objective:	The objectives of this subject are: 1. To understand the concepts of modeling of power system and power electronics. 2. To learn the concepts of electrical drives. 3. To analyze the concepts of converter and chopper controlled dc drive. 4. To understand the applications of induction motor and synchronous motor AC drive.		
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Power electronics control of drives.**	
	CO-2	Analyze the various concepts to understand them through case studies.	
	CO-3	Apply knowledge in understanding practical problems.	
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.	

Module-I

Introduction to AC and DC drives, Basic power electronic drive system, components of Electric Drives, Different types of loads, motor shaft, load coupling systems, Requirements of electrical drives, size and rating of motors (short time, intermittent, continuous), Heating and cooling of motors, Classes and duty and selection of motors.

Module-II

DC Drives: Evaluation of a dc drive performance, Chopper-fed dc motor drives, Features of a Chopper-fed separately-excited dc motor, Current limit control, Steady-state performance of a dc motor fed from chopper and phase-controlled rectifiers, Dual converters, Three-phase dc motor drives Principles of adjustable-speed ac drives: Selecting an adjustable-speed drive, Constant volts/hertz operation, Generation of adjustable-frequency ac power, Adjustable frequency operation of ac motors.

Module-III

Variable frequency operation of three–phase symmetrical induction machine, Scalar control methods for constant power an constant torque modes, Vector control of induction machine, Methods of field sensing and estimation, Field orientation methods: Implementation of IRFO scheme using current controlled PWM, VSI and implementation of DSFO scheme using CSI, Performance of vector controlled permanent magnet machine.

Module-IV

Adjustable-frequency Synchronous Motor Drives: Types of synchronous machine and their steady-state theory of operation, Adjustable frequency operation. Vector control of synchronous motor, switched reluctance motor drive, brushless DC motor drive, Permanent magnet drive.

Text Books:

1. Vedam Subrahmanyam, **Electric Drives: Concepts and Applications**, Tata McGraw Hills
2. Gopal K Dubey, **Fundamentals of Electric Drives**, Narosa
3. Bimal K Bose, **Modern Power Electronics and AC Drives**, Pearson
4. J M D Murphy, F G Turnbull, **Power Electronic Control of AC Drives**, Pergamon Press

Reference Books:

1. Ned Mohan, **Electric Machines and Drives: A First Course,** Wiley
2. N K De and P K Sen, **Electric Drives**, PHI

POWER QUALITY PROBLEMS AND MITIGATIONS

		L-P-T:Cr.	4-0-0: 4
Objectives:	1. To study the various issues of Power Quality and their effect on power system, 2. To analyze the origin of power quality disturbances like sag and interruptions, 3. To understand themitigation techniques for power quality disturbances.		
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Power quality problems and mitigations.**	
	CO-2	Analyze the various concepts to understand them through case studies.	
	CO-3	Apply knowledge in understanding practical problems.	
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.	

Module-I (10 Hours)

Overview of Power Quality and Power Quality Standard, Interest in Power Quality, Power Quality, Voltage Quality, Overview of Power Quality Phenomena, Power Quality and EMC Standards,Long Interruptions and Reliability Evaluation, Introduction, Observation of System Performance, Standards and Regulations, Overview of Reliability Evaluation,Basic Reliability Evaluation Technique, Costs of Interruptions

Module-II (10 Hours)

Short Interruptions: Introduction, Terminology,Origin of Short Interruptions, Monitoring of Short Interruptions,Influence of Equipment, Single Phase Tripping, Stochastic Prediction of Short Interruptions

Module-III (10 Hours)

Voltage Sags Characterization: Introduction, Voltage sag Magnitude, Voltage sag Duration, Three Phase Unbalance, Phase Angle Jumps,Magnitude and Phase-Angle Jumps for three phase Unbalanced Sags, Other Characteristics of Load Influence on Voltage Sags, Sags due to Starting of Induction Motors

Module-IV (10 Hours)

Mitigation of Interruptions and Voltage Sags: Overview of Mitigation Methods, Power System Design Redundancy Through Switching, Power System Design, Redundancy through Parallel Operation, The System – Equipment Interface: Voltage –Source Converter, Series voltage controllers, Shunt Voltage Controllers, Cascade Connected Voltage controllers

Text Books

1. Math H.J Bollen, **Understanding Power Quality Problems: Voltage Sags and Interruptions,** IEEE Press
2. Roger C. Dugan, Mark F. Mcgranaghan, Surya Santoso, H. Wayne Beaty, **Electrical Power Systems Quality**, McGraw Hill Education.
3. Allan Greenwood, **Electrical Transients in Power Systems**, Wiley
4. C S Indulkar, **Power System Transients: A Statistical Approach,** PHI
5. Bhim Singh, Ambarish Chandra, Kamal Al-Haddad, **Power Quality Problems and Mitigation Techniques**, Wiley

Reference Books

1. C Sankaran, **Power Quality**, CRC Press
2. A Moreno Munoz, **Power Quality: Mitigation Technologies in a Distributed Environment,** Springer
3. Surajit Chattopadhyay, Madhuchanda Mitra, Samarjit Sengupta, **Electric Power Quality**, Springer

POWER SYSTEM RELIABILITY

		L-P-T:Cr.	**4-0-0: 4**
Objectives:	The objective of this subject are: 1. To understand the importance of maintaining reliability of power system components. 2. To apply the probabilistic and other methods for evaluating the reliability of generation, transmission and distribution systems. 3. To evaluate the reliability of composite system. 4. To estimate the reliability of various other components such as sub-station, breakers etc.		
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Power system reliability.**	
	CO-2	Analyze the various concepts to understand them through case studies.	
	CO-3	Apply knowledge in understanding practical problems.	
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.	

Module I

Generating Capacity Basic Probability Methods: The generation system model, Loss of load indices, Equivalent forced outage rate, Capacity expansion analysis, scheduled outages, Evaluation methods on period basis, Load forecast uncertainty, Forced outage rate uncertainty, Loss of energy indices. Generating Capacity Frequency & Duration Method*:* The generation model, System risk indices.

Module II

Interconnected Systems: Probability error method in two interconnected systems, Equivalent assisting unit approach to two interconnected systems, Factors affecting the emergency assistance available through the interconnections, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected systems, multi connected system, Frequency & duration approach. Operating Reserve: General concepts, PJM method, Extension to PJM method, Modified PJM method, Postponable outages, Security function approach, Response risk, Interconnected systems.

Module III

Composite Generation & Transmission Systems: Radial configurations, Conditional probability approach, Network configurations, State selection, System & load point indices, Application to practical systems, Data requirements for composite system reliability. Generating plant availability, Derated states & auxiliary systems, Allocation & effect of spares, Protection systems, HVDC systems.

Module IV

Distribution Systems Basic Techniques & Radial Networks: Evaluation techniques, additional interruption indices, Application to radial systems, effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, effect of transferring loads, Probability distributions of reliability indices. Distribution Systems-Parallel & Meshed Networks: Basic evaluation techniques, Inclusion of busbar failures, Inclusion of scheduled maintenance, Temporary & transient failures, Inclusion of weather effects, Common modes failures, Common mode failures & weather effects, Inclusion of breaker failures.

Text Books

1. Roy Billiton and Ronald N. Allan**, Reliability Evaluation of Power Systems,** Plenum
2. Roy Billiton and Wenyuan Li, **Reliability Assessment of Electric Power Systems Using Monte Carlo Methods**, Plenum Press
3. Ronald N Allan, Roy Billinton, **Reliability Assessment of Large Electric Power Systems**, Kluwer Academic Press

References Books

1. Richard E. Brown, **Electric Power Distribution Reliability**, CRC Press
2. Allen J Wood, **Power System Reliability Calculations**, MIT Press
3. Mohammad Shahidehpour, Hatim Yamin, Zuyi Li, **Market Operations in Electric Power Systems: Forecasting, Scheduling and Risk Management,** Wiley

ADVANCED CONTROL SYSTEM

<table>
<tr><td colspan="2"></td><td>L-P-T:Cr.</td><td>4-0-0: 4</td></tr>
<tr><td>Objectives:</td><td colspan="3">The objectives of this subject are:
1. The purpose of this course is to introduce the key concepts in advanced control systems for SISO as well as MIMO systems.
2. Digital control techniques are to be described
3. The students should be able to characterize and tune different adaptive controllers
4. The purpose is to give up-to-date knowledge for designing controllers for various systems.</td></tr>
<tr><td rowspan="4">Course Outcomes:</td><td>CO-1</td><td colspan="2">Remember and understand the basic concepts/principles of Advanced control system.</td></tr>
<tr><td>CO-2</td><td colspan="2">Analyze the various concepts to understand them through case studies.</td></tr>
<tr><td>CO-3</td><td colspan="2">Apply knowledge in understanding practical problems.</td></tr>
<tr><td>CO-4</td><td colspan="2">Execute/create the projects or field assignment as per knowledge gained in the course.</td></tr>
</table>

MODULE-I(10 Hours)

Review of matrix algebra, state variable modeling of continuous and discrete time systems, linearization of state equations, Solutions of state equation in LTI and time varying system.

Review of linear algebra, matrix decomposition, LU, LDU, QR, Cholesky factorization, SVD, Numerical solution of linear system.

MODULE-II(10 Hours)

Analysis of SISO Control Loops, Classical PID Control, Synthesis of SISO Controllers, Fundamental Limitations in SISO Control, Model error Limitations, Structural Limitations, Frequency Domain design limitations, Architectural Issues in SISO Control, Internal Model Principle, Feed forward and Cascade Control, Anti-wind-up scheme, Introduction to Model Predictive Control

MODULE-III(10 Hours)

Digital Computer Control, Models for sampled Data Systems, Sample Data Design, Internal Model Principle for Digital Control, Models for hybrid Control, Systems, Analysis of Intersample behaviour.

Overview of nonlinear control, type of nonlinearities, Lyapunov stability criteria, Passivity analysis, Feedback linearization and backstepping control, sliding mode control and chattering effects of sliding mode control, different variants of sliding mode control, higher order sliding mode control

MODULE-IV(10 Hours)

MIMO Control Essentials, Analysis of MIMO Control Loops, Exploiting SISO Techniques in MIMO Control, MIMO Control Design: Design via Optimal control techniques, Model Predictive Control MIMO Controller Parameterizations, Decoupling.

Text Books:

1. Graham C. Goodwin, Stefan F.Graebe, Mario E.Salgado, **Control System Design**, PHI-2002.
2. Sigurd Skogestad, Ian Postlethwaite, **Multivariable Feedback Control Analysis and Design**, Wiley
3. Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, Francis J. Doyle III, **Process Dynamics and Control,** Wiley
4. Hassan K Khalil, **Nonlinear Systems,** Pearson
5. Jinkun Liu, **Sliding mode control using MATLAB**, AP

Reference Books:

1. B.W Bequette, **Process Control: Modelling, Design and Simulation**, PHI-2006
2. D.R. Coughanour, **Process System Analysis and Control**, Mc Graw Hills.
3. Arun K Tangirala, **Principles of System Identification Theory and Practice**, CRC Press

DYNAMICS OF ELECTRICAL MACHINES

		L-P-T:Cr.	4-0-0: 4
Objectives:	The objectives of this subject are: 1. To provide knowledge about the fundamentals of electrical machines by using transformation theory based mathematical modelling. 2. To impart knowledge about principle of operation and performance of DC, Synchronous, Induction machines and transformers. 3. To analyze the steady state and dynamic state operation of DC, Synchronous, Induction machines and transformers.		
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Dynamics of electrical machines.**	
	CO-2	Analyze the various concepts to understand them through case studies.	
	CO-3	Apply knowledge in understanding practical problems.	
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.	

MODULE-I

Singly excited circuits, Coupled circuits, Solution of Electro-dynamical Equations by Euler'smethod and Runge-Kutta method. Linearization of the Dynamic Equations and Small Signal Stability. Elementary DC Machine, Voltage and torque equations, Basic types of DC machines, Dynamic characteristics of DC motors, time-domain block diagrams and state equations, solution of dynamic characteristics by Laplace transformation.

MODULE-II

The basis of General Theory and Generalized Equation of A.C machines, Equation in terms of phases variable park's transformation, Various reference frames, Derivation of two-axis equation, Torque equation, Field and damper windings, Equivalent circuits, Operational impedances and frequency response loci, Modified equation with more accurate coupling between field and damper windings.

MODULE-III

Synchronous Generator short circuit and system faults: Symmetrical short circuit of unloaded generator, Analysis of short circuit oscillograms, short circuit of loaded synchronous generator, Unsymmetrical short of synchronous generator, system fault calculation, Sudden load changes, Equivalent circuit under transient condition, Constant flux linkage theorem, Simplified phasor diagram for transient changes.

MODULE-IV

Induction machines: General equation of the induction motor (equation), Application of equation in primary and secondary reference frames and complex form of equation, Short circuit and fault current due to the induction motor, fault calculation. Transformers: Transient phenomena in transformer, General characteristics of over voltage and current inrush, Transient over voltage characteristics.

Text Books:

1. B.Adkins and R.H. Harley, **The Generalized Theory of Electrical Machines**, Chapman and Hall, London, UK
2. P.C. Kraus, O. Wasynczuk, S.D. Sudhof, **Analysis of Electrical Machinery and Drives Systems**, IEEE Press, John Wiely and Sons, Piscataway, New Jersey, USA

Reference Books:

1. P S Bimbhra, **Generalized Theory of Electrical Machines,** Khanna Publishers

RENEWABLE ENERGY SOURCES

	L-P-T:Cr.	4-0-0: 4
Objectives:	The objectives of this subject are: 1. Adetailed exposure to different type of renewable energy sources, their principle of operation and real time applications 2. To impart knowledge about the techno-economic advantages of clean energy on environment. 3. To understand the benefits and utilization of renewable power for being utilized in various applications.	
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Renewable energy sources.**
	CO-2	Analyze the various concepts to understand them through case studies.
	CO-3	Apply knowledge in understanding practical problems.
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.

Module-1

INTRODUCTION TO RENEWABLE ENERGY SOURCES: Introduction to Nonconventional/Renewable Energy Sources & Technologies. Importance of Sustainable

Development and Environmental Protection. SOLAR RADIATIONS: Measurement and Prediction of Solar Radiations; Instruments for Solar Radiation; Characteristics of Solar Spectra including Wavelength Distribution; Radiation Properties and Spectral Characteristics of Materials; Selective Surfaces & Basics of Solar Collectors. SOLAR THERMAL SYSTEM: Solar Collection Devices; their analysis; Solar Collector Characteristics; Solar Pond; application of solar energy to space heating etc.

Module-II

Wind energy conversion, Efficiency limit: Betz's Law, Types of converters,aerodynamics of wind rotors, power ~ speed and torque ~ speed characteristics of windturbines, wind turbine control systems; conversion to electrical power: induction andsynchronous generators, grid connected and self-excited induction generator operation, constant voltage and constant frequency generation with power electronic control, single anddouble output systems, reactive power compensation; Characteristics of wind power plant.

Module-III

OTHER RENEWABLE SOURCES OF ENERGY: Tides: Origin & nature of Tides, Tidal Heads & Duration; Principles of Tidal Energy Conversion, Site Selection – Single and Multiple Bay System; Cycles & Load Factors; Regulation and Control of Tidal Waves: Nature and availability of Energy from waves Onshore & Off-shores: Principles of Wave Converters – Raft, Duck, Oscillating Water Columns, Tapered Channels & Buoys; Energy Conversion & Transmission; Secondary Applications of Waves such as Harbour Wall, Seawater Pumping.

Module-IV

GEOTHERMAL ENERGY

Name of Geothermal Resources, Location and Potential Assessment, Classification & Characteristics of Geothermal Resources – Hot Rock, Hot Water & Steam, Chemical & Physical Properties of Geothermal Brines: Control of Scale Deposition, Drilling, Logging & Cementing Operations for Geothermal Wells; Principles of Power Production System & Cycles: Refrigeration, Two-Phase Flow Turbines; Thermal Phase Flow Turbines; Thermal Utilization & Mineral Recovery.

Text books:

1. S.P. Sukhatme, "Solar Energy: Principles of thermal Collection and Storage", Tata McGraw Hill,
2. H.P. Garg and Jai Prakash, "Solar Energy: Fundamentals and Applications",Tata McGraw Hill

Reference books:

1. Ali Keyhani, Mohammad N Marwali, Min Dai, Integration of green and renewable energy in electric power systems, Wiley.
2. Duffic and Beckman, "Solar Engineering of Thermal Processes", John wiley.

ADVANCED COMMUNICATION THEORY

		L-P-T:Cr.	**4-0-0: 4**
Objectives:	1. Provide student with theoretical background and applied knowledge so that they can design an optimum Single and multi-carrier communication system under given power, spectral and error performance constraints. 2. Analyze the error performance of digital modulation techniques.		
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Advanced communication theory.**	
	CO-2	Analyze the various concepts to understand them through case studies.	
	CO-3	Apply knowledge in understanding practical problems.	
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.	

Module 1 (10 hours)

Random Variables and Processes Review of Random variable: Moment generating function, Chernoff bound, Markov's Inequality, Chebyshev,s inequality, Central limit Theorem, Chi square, Rayleigh and Rician distributions, Correlation, Covariance matrix- Stationary processes, wide sense Stationary processes, ergodic process, cross correlation and autocorrelation functions-Gaussian process- Communication over Additive Gaussian Noise Channels Characterization of Communication Signals and Systems- Signal space representation

Module 2 (10 hours)

Optimum waveform receiver in additive white Gaussian noise (AWGN) channels – Cross Correlation receiver, Matched filter receiver and error probabilities. Optimum Receiver for Signals with random phase in AWGN Channels- Optimum Receiver for Binary Signals-Optimum receiver for M-ary orthogonal signals- Probability Of error for envelope detection of M-ary orthogonal signals. Optimum waveform receiver Forcoloured Gaussian noise channels-KarhunenLoeve expansion approach, whitening.

Module 3 (10 hours)

Synchronization in Communication Systems, Carrier Recovery and Symbol Synchronization in Signal Demodulation- Carrier Phase Estimation- Effect of additive Noise on the phase estimate- Maximum Likelihood phase estimation- Symbol Timing Estimation- Maximum Likelihood timing estimation- Receiver structure with phase and Timing recovery.

Module 4 (10 hours)

Communication over Band limited Channels - Communication over band limited Channels- Optimum pulse shaping- Nyquist criterion for zero ISI, partial response Signalling- Equalization Techniques- Zero forcing linear Equalization- Decision Feedback equalization- Adaptive Equalization.

Text Book:

1. J.G. Proakis, **Digital Communication**, McGraw Hills Publication.

Reference Books:

1. Edward. A. Lee and David. G. Messerschmitt, **Digital Communication**, Allied Publishers (second edition).
2. J Marvin K Simon, Sami. M. Hinedi and William. C. Lindsey, **Digital Communication Techniques**, PHI.
3. William Feller, **An introduction to Probability Theory and its applications**, Wiley
4. Sheldon.M. Ross, **Introduction to Probability Models**, Academic Press

ADVANCED IMAGE PROCESSING

<table>
<tr><td colspan="2"></td><td>L-P-T:Cr.</td><td>4-0-0: 4</td></tr>
<tr><td>Objectives:</td><td colspan="3">1. To study the image fundamentals and mathematical transforms necessary for image processing.
2. To understand the image enhancement techniques
3. To analyze image restoration procedures.
4. To implement the image compression procedures.</td></tr>
<tr><td rowspan="4">Course Outcomes:</td><td>CO-1</td><td colspan="2">Remember and understand the basic concepts/principles of Advanced Image processing.</td></tr>
<tr><td>CO-2</td><td colspan="2">Analyze the various concepts to understand them through case studies.</td></tr>
<tr><td>CO-3</td><td colspan="2">Apply knowledge in understanding practical problems.</td></tr>
<tr><td>CO-4</td><td colspan="2">Execute/create the projects or field assignment as per knowledge gained in the course.</td></tr>
</table>

Module I

Digital Image Fundamentals: Components of image processing system, digital image fundamentals, image sampling and quantization, basic relationships between pixels, color image fundamentals, RGB, YCbCr, HSI models,

Image Acquisition: Camera Geometry, Transformation in 2D (Translation, Rotation, Scaling, Shearing, Affine and rigid transformation), Transformation in 3D (Translation, Rotation about X, Y and Z axis, rotation about arbitrary axis, 3D affine, number of degrees of freedom) **Camera Calibration:**Basic aim of camera calibration, implications for 3D reconstruction using two calibrated camera

Module II

Image Enhancement: Enhancement in spatial domain: basic gray level transformations, histogram processing, smoothing and sharpening of spatial filters. Enhancement in frequency domain: Introduction to filtering in frequency domain, smoothing and sharpening of frequency domain filters.

Image Restoration: Degradation model, restoration in presence of noise only – spatial filtering, linear, position invariant degradations, estimating degradation functions, inverse filtering, Wiener filtering.

Module III

Color image processing: Introductory concepts of color image processing, different color models (RGB, HIS, YCbCr), Standard color matching functions, CIELAB and CIELUV color space, Chromatic adaptation Transforms and Colour Appearance,

Module IV

Image compression and segmentation: Redundancy and compression models, Lossless coding – Run length coding, Huffman coding, vector quantization, JPEG, concepts of fractals, fractal image compression. Edge detection, Boundary description, Morphological image processing, Region based segmentation – region growing, region merging and splitting.

Text Books:

1. Rafel C Gonzaelz, Richard E Woods, **Digital Image Processing**, Pearson
2. Anil K Jain, **Fundamentals of Digital Image Processing,** Pearson
3. William K. Pratt,**Digital Image Processing,** John Wiley
4. Richard Szeliski, **Computer Vision: Algorithms and Applications,** Springer

Reference Books

1. Stephan Westland, Caterina Ripamonti, **Computational Colour Science using MATLAB**, John Wiley and Sons
2. Al Bovik, **The essential guide to image processing,** AP
3. K S Thyagarajan, **Still Image and Video Compression with MATLAB,** Wiley
4. Frank Y. Shih, **Image Processing and Pattern Recognition: Fundamentals and Techniques**, Wiley

ADVANCED SIGNAL PROCESSING

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Objective:	The objective of this subject are: 1. To Comprehend characteristics of discrete time signals and systems 2. To analyze and process signals using various transform techniques 3. To identify various factors involved in design of digital filters 4. To illustrate the effects of finite word length implementation.			
Course Outcomes:	CO-1	Remember and understand the basic concepts/principles of **Advanced signal Processing**		
	CO-2	Analyze the various concepts to understand them through case studies.		
	CO-3	Apply knowledge in understanding practical problems.		
	CO-4	Execute/create the projects or field assignment as per knowledge gained in the course.		

Module I

Digital Filter Structures:Block diagram representation – Equivalent Structures – FIR and IIR digital filter Structures AII pass Filters-tunable IIR Digital Sine-cosine generator- Computational complexity of digital filter structures.

Digital Filter Design: Preliminary considerations- Bilinear transformation method of IIR filter design – design of Low pass high-pass – Band-pass, and Band stop- IIR digital filters – Spectral transformations of IIR filters – FIR filter design –based on Windowed Fourier series – design of FIR digital filters with least – mean square-error – constrained Least –square design of FIR digital filters.

Module II

DSP Algorithm Implementation: Computation of the discrete Fourier transform- Number representation – Arithmetic operations – handling of overflow – Tunable digital filters – function approximation.Introduction to Digital Signal Processor, Architecture and features of TMS320C67xx. DSP processor packaging (Embodiments), Fixed point vs floating point DSP processor, data paths , Memory architecture of a DSP processor (Von Neumann, Harvard, Modified Havard), Addressing modes, pipelining, TMS320 family of DSPs(architecture of C5x).

Module III

Bias and Consistency of estimators, Non-Parametric methods, Correlation method, Co-variance estimator, Performance analysis of estimators, Unbiased consistent estimators, Periodogram estimator, Barlett spectrum estimation, Welch estimation. **Model based approach:** AR, MA, ARMA Signal modeling, Parameter estimation using Yule-Walker method, Maximum likelihood criterion, Efficiency of estimator, Least mean squared error criterion, Wiener filter, Discrete Wiener Hoff equations, Mean square error

Module IV

Recursive estimators: Kalman filter, Linear prediction, Forward prediction and Backward prediction, Prediction error, Whitening filter, **Inverse filter:**Levinson recursion, Lattice realization, Levinson recursion algorithm for solving Toeplitz system of equations.**FIR Adaptive filters:** Newton's steepest descent method, **Adaptive filters based on steepest descent method:** Widrow Hoff LMS Adaptive algorithm, Adaptive channel equalization, Adaptive echo canceller, Adaptive noise cancellation, RLS Adaptive filters, Exponentially weighted RLS, Sliding window RLS, Simplified IIR LMS Adaptive filter.

Text Books

1. John G Proakis, **Dimitris G Manolakis, Digital Signal Processing,** PHI
2. Monson H Hayes, **Statistical Signal Processing and Modeling,** John Wiley and Sons
3. P P Vaidyanthan, **Multirate systems and filter banks,** Prentice Hall
4. S Kay, **Modern Spectrum Estimation Theory and Application,**Prentice Hall

References Books:

1. Simon Haykin, **Adaptive Filter Theory**, Prentice Hall
2. B Venkataramani and M Bhaskar, **Digital Signal Processors: Architecture, Programming and Applications**, TMH
3. Avatar Singh and S Srinivasan, **Digital Signal Processing: Implementation using DSP Microprocessors with examples from TMS320C54XX**, Cenage