Department of Electrical Engineering						
Curriculum of M Tech Programme (Specialization: Power Systems)						
Sl. No.	**Subject Code**	**Name of the Subject**	**L**	**T**	**P**	**CP**
Semester I						
1	EE1001	EHV TRANSMISSION	3	1	0	4
2	EE1002	POWER SYSTEM OPERATION	3	1	0	4
3	EE1003	HIGH VOLTAGE ENGINEERING	3	1	0	4
4		ELECTIVE I	3	1	0	4
5		ELECTIVE II	3	1	0	4
6	EE1051	HIGH VOLTAGE LABORATORY	0	0	4	2
7	EE1052	COMPUTATION LABORATORY	0	0	4	2
Total Credit						**24**
Semester II						
1	EE2001	POWER SYSTEM PROTECTION AND TRANSIENTS	3	1	0	4
1	EE2002	POWER SYSTEM CONTROL & INSTRUMENTATION	3	1	0	4
3	EE2003	FLEXIBLE AC TRANSMISSION SYSTEMS	3	1	0	4
4		ELECTIVE III	3	1	0	4
5		ELECTIVE IV	3	0	0	3
6	EE2051	POWER SYSTEM PROTECTION & INSTRUMENTATION LABORATORY	0	0	4	2
7	EE2052	POWER SYSTEM SIMULATION LABORATORY	0	0	4	2
8	EE2053	PROJECT-I	0	0	2	1
Total Credit						24
Semester III						
1	EE3051	PROJECT–II				11
2	EE3052	PROJECT SEMINAR - I				2
Total Credit						**13**
Semester IV						
1	EE4051	PROJECT–III				11
2	EE4052	PROJECT SEMINAR - II & VIVA-VOCE				3
Total Credit						**14**
TOTAL						**75**

Part time

Sl. No.	Subject Code	Name of the Subject	L	T	P	CP
Semester I						
1	EE1001	EHV TRANSMISSION	**3**	**1**	**0**	**4**
2	EE1002	POWER SYSTEM OPERATION	**3**	**1**	**0**	**4**
3		ELECTIVE I	**3**	**1**	**0**	**4**
4	EE1052	COMPUTATION LABORATORY	**0**	**0**	**4**	**2**
Total Credit						**14**
Semester II						
1	EE2001	POWER SYSTEM PROTECTION AND TRANSIENTS	**3**	**1**	**0**	**4**
2	EE2002	POWER SYSTEM CONTROL & INSTRUMENTATION	**3**	**1**	**0**	**4**
3		ELECTIVE III	**3**	**1**	**0**	**4**
4	EE2051	POWER SYSTEM PROTECTION & INSTRUMENTATION LABORATORY	**0**	**0**	**4**	**2**
Total Credit						**14**
Semester III						
1	EE3001	HIGH VOLTAGE ENGINEERING	**3**	**1**	**0**	**4**
2		ELECTIVE II	**3**	**1**	**0**	**4**
3	EE3051	HIGH VOLTAGE LABORATORY	**0**	**0**	**4**	**2**
Total Credit						**10**
Semester IV						
1	EE2003	FLEXIBLE AC TRANSMISSION SYSTEMS	**3**	**1**	**0**	**4**
2		ELECTIVE IV	**3**	**0**	**0**	**3**
3	EE2052	POWER SYSTEM SIMULATION LABORATORY	**0**	**0**	**4**	**2**
4	EE2053	PROJECT-I	**0**	**0**	**2**	**1**
Total Credit						**10**
Semester V						
1	EE3051	PROJECT–II				**11**

2	EE3052	PROJECT SEMINAR - I				**2**
Total Credit						**13**
Semester VI						
1	EE4051	PROJECT–III				**11**
2	EE4052	PROJECT SEMINAR - II & VIVA-VOCE				**3**
Total Credit						**14**
TOTAL						**75**

LIST OF ELECTIVES

Sl. No.	Subject Code	Name of the Subject
1	EE9011	POWER SYSTEM STABILITY
2	EE9012	POWER SYSTEM RELIABILITY
3	EE9013	DISTRIBUTED ENERGY SYSTEMS
4	EE9014	POWER SYSTEM OPTIMIZATION
5	EE9015	POWER SYSTEM MODELING
6	EE9016	SPECIAL ELECTRICAL MACHINES
7	EE9017	LINEAR CONTROL THEORY
8	EE9018	REAL TIME SYSTEMS DESIGN
9	EE9019	PROCESS INSTRUMENTATION & CONTROL
10	EE9020	ELECTRICAL VEHICLES
11	EE9021	MICROPROCESSOR BASED INDUSTRIAL CONTROL
12	EE9022	ROBOTICS & AUTOMATION
13	EE9023	INTELLIGENT CONTROL
14	EE9024	DIGITAL SIGNAL PROCESSING
15	EE9025	SOFT COMPUTING TECHNIQUES
16	EE9026	EMBEDDED SYSTEMS
17	EE9027	VLSI SYSTEMS
18	EE9028	BIOMEDICAL INSTRUMENTATION

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1001	**EHV Transmission**	**4 (3-1-0)**	**Prof. S. Ghosh**

AC Transmission: Role of EHV transmission, standard transmission voltages, power handling capacity and line loss, calculation of line and ground parameters, sequence inductances and capacitances. [4]

Voltage gradients on conductors: field of line charges, surface voltage gradient on conductors, charge potential relations for multi-conductor lines, maximum gradient on actual lines. [4]

Electrostatic field of EHV lines: Electric shock currents, capacitance of long object, calculation of electrostatic field of AC lines, electrostatic induction in un-energized circuit, induced voltages in insulated ground wires. [4]

Overvoltages in EHV lines caused by switching operations: origin of overvoltages, overvoltages caused by interruption of low inductive currents, interruption of capacitive currents, ferroresonance overvoltages, calculation of switching surges.[5]

Power frequency voltage control and overvoltages: Generalized constant, no-load voltage conditions and charging current, power circle diagram, voltage control using synchronous condensers, shunt and series compensation, static reactor compensating systems. [6]

DC Transmission: Advantages and disadvantages in comparison with high voltage AC systems. Types of DC links, Schematic diagram of typical HVDC converter station 12-pulse converter unit. Recent trends of HVDC valves. [4]

Analysis of Bridge Converters: 6-pulse Bridge; Analysis with grid control with or without overlap. Inversion; Equations for average direct current and voltage, commutation failure; Control of Converters: Control characteristics, starting and stopping of DC link. DC Circuit Breakers. [12]

Smoothing Reactor: Prevention of simple, consequent and double commutation failures. [2]

Harmonics Analysis: Characteristic and Uncharacteristic harmonics in twelve pulse converters, Causes and suppression of uncharacteristic harmonics. [3]

HVDC Circuit Breakers [1]

Text Books:

1. R. D. Begamudre, Extra High Voltage AC Transmission Engineering
2. E. W. Kimbark, *Direct Current Transmission: Vol.1*, Wiley-Interscience.

Reference Books:

1. K. R. Padiyar, *HVDC Power Transmission Systems,* New Age International (P) Limited

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1002	**Power System Operation**	**4 (3-1-0)**	**Prof. S. P. Ghoshal & Prof. S. S. Thakur**

Load Flow Studies: Network model formulation, formulation of the problem, Classification of buses, Gauss-Seidel and Network-Raphson methods of solution, considerations for voltage controlled buses. Fast decoupled method of solution. Calculation of line flows and slack bus power, optimal load flow study, DC load flow study. [7]

Introduction to power system state Estimation: Formulation of the problem and solution technique. Introduction to detection and identification of bad data. [5]

Economic Load Dispatch: Formulation of problem without and with network losses, various methods of solution. [7]

Unit Commitment: Introduction, Constraints in Unit Commitment, Unit Commitment Solution Methods [3]

Hydrothermal Scheduling: Long-Range Hydro-Scheduling, Short-Range Hydro-Scheduling The Short-Term Hydrothermal Scheduling Problem, Short-Term Hyrdo-Scheduling: A Gradient Approach Dynamic-Programming Solution to the Hydrothermal Scheduling Problem, Hydro-Scheduling Using Linear Programming [4]

Power Systems Stability Studies: Swing equation, equal area criterion, solution methods of swing equation. [4]

Short-circuit Studies: Studies on asymmetrical shunt and series faults. [4]

Automatic Generation Control: Models of governor, turbine, power system and tie-line; multi-area load frequency control and state representation, Q-V loop by AVR. [6]

Introduction to Power Systems Security: Introduction, Factors Affecting Power System Security, Contingency Analysis: [2]

Optimal Power Flow: Definition of optimal power flow and application of evolutionary techniques for optimal power flow [3]

Text Books:

1. Power Generation, Operation and Control By: A. J. Wood and B. F. Woolenberg, John Wiley & Sons, Inc.
2. Modern-Power-Systems-Analysis-By: D. P. Kothari and I. J. Nagrath. Tata McGraw Hill Education private Limited, New Delhi.

Reference Books:

1. Electric Energy Systems Theory An Introduction By: O. I. Elgerd McGraw Hill Education.
2. Computer Methods in Power Systems Analysis By: G. W. Stagg and A. H. El-Abiad McGraw-Hill Kogakusha, Ltd.
3. Power System Engineering By: D. P. Kothari and I. J. Nagrath. Tata McGraw-Hill Education.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1003	**High Voltage Engineering**	**4 (3-1-0)**	**Prof. N. K. Roy**

Overview of High Voltage Engineering, Air as an Insulation, Concept of Dielectric Strength, Electric field and electrode configuration, Parameters for dependence of Dielectric strength, Introduction to Breakdown of Insulation. [5]

Breakdown of Gases, Solids, Liquids and Vacuum [7]

Generation of AC high voltages and DC High Voltages [5]

Generation of impulse voltages and currents:- Analysis of different circuits, Marx multi-stage impulse generator [5]

Methods of measuring high voltage and high currents of power frequency and D.C and Impulse [5]

Introduction to Lightning phenomenon, Insulation Co-ordination. Brief reviews of high voltage testing-Methods for different power system equipment [8]
Introduction to H.V. testing transformer design. Capacitive voltage transformer Introduction to partial discharge. and partial discharge testing [5]
Planning & design of a high voltage laboratory, Introduction of virtual Laboratory and ICT enabled concept for high voltage testing [5]

Text Books:

1. C.L.Wadhwa, High Voltage Engineering
2. M S Naidu & Kamraju, High Voltage Engineering

Reference Books:

1. Kueffel & Zangel, Introduction in High Voltage Engineering
2. J Lucas, High Voltage Engineering

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1051	High Voltage Laboratory	2 (0-0-4)	Prof. N. K. Roy

1. Calibration of power frequency high voltage by sphere-sphere gap arrangement
2. Study the BDV strength of air for various pressure and vacuum with different geometrical configuration of electrode
3. To study the characteristics of impulse voltage and the wave shape of lightning impulse voltage
4. (a) Measurement of capacitance and tanδ of insulating material with the help of Schering bridge
   (b) To study the BDV strength of insulating oils
5. (a) To study the (i) variation of resistivity of transformer oil with temperature and (ii) variation of insulation resistance of paper with applied voltage
   (b) To study the ratio and phase angle error measurement of transformer
6. (a) To study the four terminal sensing method for measuring very low resistances using micro-ohm meter
   (b) To study the partial discharges in an 300 kV AC systems
7. Survey of lightning in the class room and spatial magnetic field in the vicinity of overhead power lines
8. To study the insulation resistance for paper, impregnated oil paper and paper with moisture

Reference Books:

1. Laboratory manuals

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1052	Computation Laboratory	2 (0-0-4)	Dr. P. Acharjee

1. To Solve Economic Load Dispatch without losses and with losses by Evolutionary Techniques
2. Determination of Optimal Power Flow solutions for the IEEE systems based on cost optimization, transmission loss optimization and total voltage deviation optimization and the combined optimization. Apply Genetic algorithm

3. Determination of Optimal Reactive Power Dispatch applied to the solution of various IEEE systems, transmission loss optimization and total voltage deviation optimization and the combined optimization, using PSO technique
4. To determine Optimal Hydrothermal Scheduling for short-range fixed head and variable head hydrothermal systems based on Differential Evolutionary Technique
5. To determine Small Signal stability analysis based on various types of power system stabilizers, evolutional technique based optimization and Application of Fuzzy Logic
6. To determine Optimal Automatic Generation Control and Optimal AVR control based on evolutionary techniques and Fuzzy logic
7. Optimization of distributed systems based on some evolutionary techniques
8. Using artificial neural network, analysis L-G fault for IEEE 14-bus test system.

Reference Books:

1. Laboratory manuals

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE2001	**Power System Protection and Transients**	**4 (3-1-0)**	**Dr. S. S. Thakur & Dr. P. S. Bhowmik**

Normal Switching Transients: Circuit breaker making and breaking transients, Resistance switching, Load Switching, Capacitance Switching, Reactor Switching, [5]

Abnormal Switching Transients: Current chopping, Arc furnace switching, Transformer Magnetizing Inrush Current, Arcing Ground Phenomenon, Current Limiting Static Circuit Breaker [5]

Lightning Protection: Mechanism of Lightning, over voltage due to lightning, protection of electrical apparatus against lightning strokes, behaviour of machine windings under transient conditions, Kilometric Fault. [5]

Lighting protection schemes: Arrestors, Surge absorbers, Neutral Grounding. LightingOver voltagesand Protection of Substation Equipment, Switching Over voltages in EHVSubstations, Switching Overvoltage in Medium Voltage Substations, Rating of Surge Arrester, Installation as Surge Arresters, Overhead Shielding Screen, Protective Angle [5]

Introduction to Insulation coordination, Over voltages and their Significance, Standard Voltage Levels, Insulation Levelof anEquipment, Insulation Co-ordination of a Substation. [4]

Protective Relays:

Basic requirement; classification on applications; principles of operation. Over current relays; directional relays, characteristics and connections; distance relays - impedance, reactance and mho types. Differential relays and percentage differential relays- voltage and current balance types. Biased beam relay; Negative sequence relay. [8]

Protection of transmission lines:

Unit and non-unit types; time and current graded systems; setting of relays for coordination; distance protection- impedance, reactance and mho types; three zone distance protection; pilot wire protection using current and voltage balance; Translay system; carrier current protection. [4]

Protection of transformer:

Types of faults- faults in auxiliary equipments, winding faults, overloads and external short circuits. Gas actuated devices- pressure relief and pressure relay, rate of rise pressure relay, gas accumulator relay. Biased differential protection for different transformer connections; earth fault protection. Over current protection. [4]

Protection of generator:

Types of faults- stator faults, rotor faults, abnormal running conditions. Biased differential protection for different stator connections. Protection against earth fault, turn to turn fault, rotor earth fault, loss of field excitation. Negative sequence protection. [4]

Text books:

1. C. R. Mason, The Art and Science of Protective Relaying, Wiley Eastern Limited.
2. 2. A. Greenwood, Electrical transients in Power Systems*, Wiley Interscience*

Reference Books:

1. D. P. Kothari and I. J. Nagrath, *Power System Engineering,*Tata McGraw Hill.
2. C. S. Indulkar and D. P. Kothari, Power system transients: A Statistical approach, *PHI*
3. 3. Warrington, A.R.v.C. (1962) Protective Relays, The Theory and Practice, Vol. 1, Chapman and Hall, London/John Wiley & Sons, Inc., New York.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE2002	**Power System Control and Instrumentation**	**4 (3-1-0)**	**Dr. P. Acharjee and Dr. C. Koley**

Overview of Power System, Optimal Power Flow, Power System Stability, Conventional Control Scheme for Power System; [1+1+1]

Automatic Generation Control: Automatic Voltage Regulator (AVR), Load Frequency Control (LFC) with tuning of Controller parameters; [1+1+2]

Power Flow Control: Compensators for power flow control, Unified Power Flow Controller, Interline Power Flow Controller; [1+1+2+1]

Phasor Measurement Unit (PMU): Overview of Synchro phasor, PMU architecture, PMU placement, PMU Applications; [1+2+2+1]

Smart Grid (SG): SG concept, Impact of SG for power system control & Measurement, Systems & Functions of SG [1+1+2+2]

Power systems instrumentation:

Measurement, Errors, Statistical Analysis of Errors, [4]

Signal Conditioning Circuit, Converters, Optical Insulator, Sensor and Transducer; Instrument transformers: C.T. and P. T., principle, characteristics, construction, errors, and transient behaviour etc.; [5]

Power System Measurement: Voltage, Current, Phase, Power, Energy, Frequency, Power factor etc.; [3]

Supervisory control and data acquisition system: Functional blocks, Software and Hardware features, operation, PLCs and DCS; [6]

Measurement of transients and harmonic distortion: THD, Power Quality meter; Phasor Monitoring Unit (PMU): block diagram representation, functions, characteristics. [4]

Text Books:

1. S. Sivanagaraju & G. Sreenivasan, “Power System operation and Control”, Pearson 2010.
2. Ernest O. Doebelin, Measurement system, Tata McGraw-Hill Education.

Reference Books:

1. Stuart A., Supervisory Control and Data Acquisition, Boyer International Society of Automation
2. Surya Santoso, Mark F. McGranaghan, Roger C. Dugan, H. Wayne Beaty, Electrical Power Systems Quality, Access Engineering.
3. Andres Carvallo, John Cooper, “The Advanced Smart Grid: Edge Power Driving Sustainability”, Artech House, Boston London, 2011.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE2003	**Flexible Ac Transmission Systems**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

FACTS concept and General System of Considerations: [1]

Checklist of possible benefits from FACTS technology. [1]

Lumped/Distributed model analysis for Series and Shunt compensation. [4]

Methods of Controllable Var Generation:

Variable Impedance Type Static Var Generators, lumped/distributed model analysis, TCR, TSR, TSC, FC-TCR. [6]

Switching Converter Type Var Generators, STATCOM, basic concepts, lumped/distributed model analysis, basic converter configurations. [6]

Static Series Compensators:

Basic principles of operation of TSSC, TCSC, SSSC, lumped/distributed model analysis Applications. [6]

Static Voltage and Phase angle regulators:

TCVR and TCPAR, lumped/distributed model analysis, Applications. [7]

Combined Compensators:

Unified Power Flow Controller (UPFC), basic operating principles, conventional transmission control capabilities. Functional control of shunt converter and series converter, basic control systems for P and Q control, lumped/distributed model analysis. [10]

Introduction to steady state analysis and control, oscillation stability analysis and control by UPFC. Transient stability control by CSC, SSSC, SVC, STATCOM and UPFC. [4]

Text Books:

1. Y.H. Song and A.T. Johns,” Flexible AC Transmission Systems (FACTS), IET Power and Energy Series, Shankar’s Book Agency Publisher (Indian Edition).
2. K.R. Padyyar,” FACTS Controller in Power Transmission and Distribution”,

Reference Books:

1. Mey Ling Sen, Kalyan K. Sen,” Introduction To FACTS Controllers – Theory, Modeling And Applications, Wiley (IEEE) Publisher.
2. N.G. Hingorani & L. Gyugyi, “Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems”.

<table>
<tr><th>SUBJECT CODE</th><th>SUBJECT NAME</th><th>CREDIT</th><th>DEVELOPER</th></tr>
<tr><td>EE2051</td><td>Power System Protection & Instrumentation Laboratory</td><td>2 (0-0-4)</td><td>Prof. S. S. Thakur</td></tr>
<tr><td colspan="4">1. Determination of Characteristics of IDMT Non-directional and Directional overcurrent Relays
2. Parallel Feeder Protection
3. Protection against short-circuit faults and ground faults in power lines
4. Determination of Characteristic of Differential Relay
5. Transformer protection by Differential Relay
6. Restricted Earth Fault Protection for Transformer
7. (a) To study Numerical Distance Relay (Areva make) for different types of power system faults
(b) To study Numerical Distance Relay (ABB make) for different types of power system faults
8. (a) To study different types of power system faults using Eurostag Software
(b) To study different types of power system faults using MiPower Software</td></tr>
<tr><td colspan="4">Reference Books:
1. Laboratory manuals</td></tr>
</table>

<table>
<tr><th>SUBJECT CODE</th><th>SUBJECT NAME</th><th>CREDIT</th><th>DEVELOPER</th></tr>
<tr><td>EE2052</td><td>Power System Simulation Laboratory</td><td>2 (0-0-4)</td><td>Dr. P. Acharjee</td></tr>
<tr><td colspan="4">1. Load Flow Studies using Gauss-Seidel, Newton-Raphson and Fast Decoupled Methods
2. Study of Economic Load Dispatch Problems, considering various non-linearities and constraints
3. Study of Automatic Voltage Regulator using MATLAB
4. Study of Power System Stabilizer Using MATLAB
5. Study of Automatic Generation Control of multi-area power systems
6. Study of Static State Estimation by EUROSTAG software
7. Study of power systems by EUROSTAG software
8. Protection against simulated power system faults by Numerical Relay
9. Power System Analysis using MiPower Software
10. Power Flow Control using TCSC</td></tr>
<tr><td colspan="4">Reference Books:
1. Laboratory manuals</td></tr>
</table>

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9011	**Power System Stability**	**4 (3-1-0)**	**Prof. S. P. Ghoshal and Prof. S. Ghosh**

Small Signal Stability: Small Signal stability of a single machine infinite bus system, Effects of excitation system, Power system stabilizer, Small-signal stability of multi machine systems and very large systems, Small-signal stability enhancement. [6]

Steady State Stability: Analysis of steady state stability of unregulated and regulated systems. [6]

Transient Stability: An elementary view of transient stability, Numerical integration methods, Simulation of power system dynamic response, Analysis of unbalanced faults, Performance of protective relaying, Case study of transient stability of a large system, Direct method of transient stability analysis, Transient stability enhancement. [10]

Voltage Stability: Basic concepts related to voltage stability, Voltage stability analysis, Voltage collapse, Examples of Voltage collapse, Prevention of voltage collapse. [12]

Subsynchronous Oscillations: Turbine-generator torsional characteristics, Torsional interaction with power system controls, Subsynchronous resonance, Impact of network-switching disturbances, Torsional interaction between closely coupled units, Hydro generator torsional characteristics. [5]

Mid-term and Long-term Stability: Nature of system response to severe upsets, Distinction between mid-term and long-term stability, Power plant response during severe upsets, Simulation of long-term dynamic response, Case studies of severe system upsets. [6]

Text Books:

1. PrabhaKundur, Power System Stability and Control, TMH
2. P. M. Anderson & A. A. Fouad, Power System Control and Stability, IEEE Series on Power Engineering.

Reference Books:

1. Power Systems Stability, Vol. -1 – E. W. Kimbark, Dover Publications, New York.
2. Power Systems Stability, Vol. -2 – E. W. Kimbark, Dover Publications, New York.
3. Power Systems Stability, Vol. - 3 – E. W. Kimbark, Dover Publications, New York.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9012	**Power System Reliability**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Fundamentals of probability and statistics [3]

Binomial, Poisson and normal distribution; [3]

Sampling theory [3]

General reliability function [1]

Exponential distribution	[1]
Mean time to failure	[3]
Markov processes	[4]
Recursive techniques	[6]
Loss of load probability method	[2]
Load forecast uncertainty	[3]
Loss of energy probability method	[2]
Spinning capacity evaluation	[4]
Derated capacity levels	[3]
Transmission system reliability	[4]
Interconnected system generating capacity reliability evaluation	[3]

Text Books:

1. R. Billinton, Power System Reliability, Gordon & Breach

Reference Books:

1. M. Cepin, Assessment of Power System Reliability: Methods and Applications, Springer
2. A. A. Chowdhury and D. O. Koval, Power Distribution System Reliability, IEEE Press

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9013	**Distributed Energy Systems**	**4 (3-1-0)**	**Prof. N. K. Roy**

Evolution of world energy consumption, Nonrenewable and Renewable resources, Transformation of energy; [4]

Solar thermal, Solar radiation at the Earth's surface, Flat plate and concentrating type collectors, Solar energy storage, Solar pond, Solar heating and cooling techniques, Solar thermal power plant, Solar photo voltaic conversion, Solar cells, PV applications; [8]

Basic principles of wind energy conversion, Basic components of a Wind Energy Conversion System (WECS), classification of WECS, Details of wind turbine generator, Performance, Safety and Environmental aspects, applications; [5]

Classification of Small Hydro Power Plants, Components, Turbines and generators for small scale hydroelectric power plant Protection and control [4]

Geothermal Energy, Ocean Thermal Electric Conversion (OTEC), Tidal Power Generation, Fuel Cells, Magneto Hydro Dynamic (MHD) Power Generation, Thermo-electric power, Thermionic generation; [8]

Integration of renewable energy sources with the grid using Modern Power Electronics Technologies; Introduction to Distributed Generation & Intentional Islanding, Transient Analysis of Distributed Generators connected with grid, Micro-grid. [6]

Text Books:

1. G.D. Rai, Non-conventional energy resources, Khanna Publishers, New Delhi, 2003.
2. N. G. Clavert, Wind Power Principle, their application on small scale, Calvert Technical Press.

Reference Books:

1. Fuel Cell Handbook, Parsons Inc.
2. I. Earnest and T. Wizelius, Wind Power Plants and Projects development, PHI.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9014	**Power System Optimization**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Economic Load Dispatch without losses and with losses; [4]
Optimal Power Flow applied to the solution of various IEEE systems, cost optimization, transmission loss optimization and total voltage deviation optimization, multi-objective optimization; [6]
Optimal Reactive Power Dispatch applied to the solution of various IEEE systems, [6]
Transmission loss optimization and total voltage deviation optimization and the combined optimization; [4]
Optimal load shedding; [4]
Optimal Hydrothermal Scheduling for short-range fixed head and variable head hydrothermal systems; multi-objective generation scheduling; [4]
Small Signal stability analysis based on various types of power system stabilizers; [4]
Optimal Automatic Generation Control, [8]
Optimal AVR control; [2]
Optimization of distributed systems; Evolutionary Programming. [3]

Text Books:

1. D.P. Kothari and J.S. Dhillon, *Power System Optimzation*, , Prentice Hall of India
2. J. A. Momoh, *Electric Power system Applications of Optimization*, CRC Press

Reference Books:

1. J. Zhu, *Optimization of power system operation*, John Wiley & Sons

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9015	**Power System Modeling**	**4 (3-1-0)**	**Dr. P. Acharjee**

Static Analysis and Model: background, motivation for modelling of physical systems, hybrid dynamic model, power system architecture. [4]
Network Model: lines and cables, transformers (single and three phase), series and shunt elements, load, generator. [6]
Formulation: network equations, equality and inequality constraints, active and reactive power flow with in-phase transformers and phase shifting transformers, decoupling properties, ac and DC power flow model. [5]
Fault analysis: transients on a transmission line, short circuit of a synchronous machine, generator model and Takahashi method for short circuit studies, examples. [5]
Power System Dynamics and Stability: power system stability, dynamics of power system and their modelling, examples. [5]

Synchronous Machine Models: Design and operating principle of rotor, stator and magnetic torque, stationary and dynamic operation of single phase equivalent circuit, phasor diagram, operational limits. [6] Power Swings in a Simple Power System: swing equation and its solutions, qualitative analysis, stable and unstable solutions, equal area criterion, lyapunov stability, small signal analysis, oscillations in multi-machine systems. [6] Control of Electric Power Systems: Control of Active Power and Frequency, Spinning reserve, Supplementary reserves, Back-Up Reserves; Control of Reactive Power and Voltage, Reactive Power Control Voltage; Control Supervisory Control of Electric Power Systems. [6] Protections in Electric Power Systems: Design of Protections, Distance Protections, Out of Step Protections, System Protections. [4]
Text Books: 1. S. **Krishna**, "An Introduction to Modelling of Power System Components", springer, 2014. 2. Nasser D. Tleis, "Power Systems Modelling and Fault Analysis", Elsivier, 2008
Reference Books: 1. G¨oran Andersson, "Modelling and Analysis of Electric Power Systems", ETH Z¨urich, 2008. 2. Mircea Eremia, Mohammad Shahidehpour, "Handbook of Electrical Power System Dynamics: Modeling, Stability, and Control", Wiley-IEEE Press, 2013 3. Milano, Federico, "Power System Modelling and Scripting", Springer, 2010.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9016	**Special Electrical Machines**	**4 (3-1-0)**	**Dr. S. N. Mahato**

STEPPER MOTORS: Constructional features, Principle of operation, Permanent magnet stepper motor, Variable reluctance motor, Hybrid motor, Single and multi-stack configurations, Torque equations, Modes of excitations, Characteristics, Drive circuits, Control of stepping motors. [10]

HIGH-SPEED OPERATION OF STEPPER-MOTORS: Pull-out torque/speed, characteristics of Hybrid stepper motors, calculation of pull-out torque, pull-out torque/speed characteristics for the VR stepper-motors, calculation of the pull out torque. [5]

SWITCHED RELUCTANCE MOTORS: Constructional features – Principle of operation – Torque production, Steady state performance prediction, Power Converters, Methods of Rotor position sensing, Closed loop control of SRM. [8]

BRUSHLESS D.C. MOTORS: Construction, Types, Principle of operation, Magnetic circuit analysis, Motor characteristics and control. [7]

PERMANENT MAGNET SYNCHRONOUS MOTORS: Principle of operation, EMF and Torque equations, Synchronous Reactance, Phasor diagram, Torque/speed characteristics, Power controllers, Converters, Control of motors. [7]

LINEAR INDUCTION AND SYNCHRONOUS MOTORS: Development of a Double-sided LIM from Rotary type IM, Schematic of LIM drive for electric traction, Development of one-sided LIM, Equivalent circuit of LIM, Linear Synchronous motor. [5]

SINGLE-PHASE SYNCHRONOUS MOTORS: Single Phase Reluctance and hysteresis motors. [3]
Text Books: 1. K. Venkataratnam, Special Electric Machines, Universities Press. 1. T. Kenjo and A. Sugawara, Stepping Motors and Their Microprocessor Controls, Claredon Press.
Reference Books: 1. T. Kenjo and S. Nagamori, Permanent Magnet and Brushless DC Motors, Claredon Press. 2. T.J.E. Miller, Brushless Permanent Magnet and Reluctance Motor Drives, Clarendon Press, Oxford, 1989.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9017	**Linear Control Theory**	**4 (3-1-0)**	**Prof. S. Banerjee & Dr. J. Dey**

Introduction [2]
Historical Perspective, Open loop Control, Development of Feedback/ Servomechanism/ Closed-loop Control

Dynamic System Representation [2]
Mathematical Modelling, Transfer Function/ matrix

Performance Objectives/ Goals [4]
Response and Loop Goals, Stabilization, Pole-placement, Tracking, Robustness, Disturbance Rejection, Noise Attenuation

Performance Analysis and Tests [4]
Time Domain Analysis, Internal Model Principle (IMP), Frequency Response analysis by bode diagram and Nyquist criterion, Loop Shaping Techniques, Sensitivity analysis, Utilities of Gain and Phase Margin determination

Compensation [4]
Feedforward Control, Feedback Control, Classical Controller P, PI, PID, Lead and Lag, One degree-of-freedom (1 DOF) control, Two DOF configuration, Linear State Variable Feedback (LSVF) control

State Space Representation of Continuous-time Systems [14]
State model state models for linear discrete time systems, conversion of state variables models to transfer functions in z-domain, solutions of state equations, state transition matrix, state transition flow graphs, eigenvalues, eigenvectors and stability similarity transformation, decompositions of transfer functions, canonical state variable models, controllability and observability, state feedback and pole placement, MATLAB tools and case studies

Robust and Optimal Control [15]
Linear Quadratic Regulator (LQR), Linear Quadratic Guassian (LQG), LQR with state estimator, Kalman filter/state estimator, Loop Transfer Recovery (LTR), H_2 and H_∞ control, Linear Matrix Inequality (LMI) technique

Text Books:

1. *Modern Control Engineering*, K. Ogata
2. *Feedback Control Theory*, John Doyle, Bruce Francis, Allen Tannenbaum
3. *Kalman Filtering Theory and Practice*, Mahinder S. Grewal and Angus P Andrews

Reference Books:

1. *Linear Control System Analysis And Design With MATLAB*, John J. D'Azzo

and Constantine H. Houpis and Stuart N. Sheldon 2. *Linear Robust Control*, Michael Green and David J.N. Limebeer

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9018	**Real Time Systems Design**	**4 (3-1-0)**	**Dr. C. Koley**

Fundamentals of Real-Time Systems: History, Concepts, Definitions for Real-Time Systems, Diverse field of Applications, Modern Real-Time Systems [7]
Hardware for Real-Time Systems: Different microprocessor, classification, architecture, general feature, multi-core processors, Interfacing, memory, digital input and output, analog input and output. [7]
Memory Access and Layout Issues, Hierarchical Memory Organization, Pipelined Instruction Processing. [6]
Real-Time Operating Systems, Software Architecture, Round Robin- Round Robin with interrupts -Function Queue, Scheduling, Tasks and Task States -Tasks and Data -Semaphores and Shared Data Message Queues -Mail Boxes and pipes -Timer Functions -Events -Memory Management, Interrupt Routines. [8]
Handling Resource sharing among real-time tasks, Priority, handling priority [5]
Scheduling Real-Time Tasks in Multiprocessor and Distributed systems, Introduction, system architecture design option. [5]
Real-Time Communication [4]
Real-Time Databases [4]

Text Books:

1. Real-Time Systems Design and Analysis: Tools for the Practitioner, 4th Edition, Phillip A. Laplante, Seppo J. Ovaska, Wiley-IEEE Press
2. Real-Time Systems: Design Principles for Distributed Embedded Applications, Authors: Kopetz, Hermann, Publisher: Springer, 2011

Reference Books:

1. Raj Kamal, *Embedded Systems Architecture*, Programming and Design, TMH
2. D. E. Simon, *An Embedded Software Primer*, Pearson Education

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9019	**Process Instrumentation and Control**	**4 (3-1-0)**	**Dr. C. Koley**

Measurement of Process Variables: Pressure, Flow, Temperature, Liquid Level, Strain, Force, Torque, Linear and angular displacement/speed etc.; [8]
Programmable Logic Controller (PLC): Introduction, Application, Physical and functional components, Timers, Counters, Shift Registers, Memory, Ladder Diagram, PLC Programming, Interfacing with sensors and actuators. Advance PLCs, analog input output, HMI, SCADA, Communication protocols, PID control through PLC; Data Acquisition Systems: Objective of a DAS, single channel DAS, Multi-channel DAS, Components used in DAS– Converter Characteristics-Resolution-Non-linearity, settling time, Monotonicity; [8]

Optical Fiber Based Instrumentation: General principles of optical fiber, brag grating fiber, amplitude modulating FO sensors, measurement of high current and voltage, temperature etc.; Power System Instrumentation: Measurement of Voltage, Current Frequency Phase and Transmission line Transients; [4]
Ultrasonic Instrumentation: Ultrasonic transmitter and receiver properties, propagation through medium and interfaces, application in Non-destructive Testing (NDT), measurement of process variables such as flow, level, thickness etc.; [5]
Digital Measurement Techniques and instrumentations: Different Digital Instrumentation, Digital Measurement of Power Factor, Frequency and Time Period, Counters; [3]
Recorders and Data Loggers: General Description, Measuring Parts and Recording Means; [3]
Microprocessor Based Instruments: Embedded systems, Microprocessor/Microcontrollers, classification, different field of application, design of microcontroller based measuring instrument. [4]
Industrial Process Control, ON-OFF Control, P, PI and PID control of interacting and non-interacting process. [10]

Text Books:

1. A. D. Helfrick and William David Cooper, *Modern electronic instrumentation and measurement techniques*, Prentice Hall
2. John-G. Webster (ed.), *The Measurement, Instrumentation, and Sensors: Handbook*, Springer

Reference Books:

1. Curtis D. Johnson, *Process control instrumentation technology*, Prentice Hall
2. Robert N. Thurston and Allan D. Pierce, *Ultrasonic measurement methods*, Academic Press
3. William Bolton, *Programmable Logic Controllers*, Newness
4. Stuart A. Boyer, *Supervisory Control And Data Acquisition*, International Society of Automation
5. T. V. Kenneth and B. T. Meggitt, *Optical Fiber Sensor Technology*, Springer.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9020	**Electrical Vehicles**	**4 (3-1-0)**	**Mr. J. C. Barman**

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. [6]
Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, and mathematical models to describe vehicle performance. [6]
Hybrid-Electric vehicles: Concept and architecture of hybrid electric drive trains, series and parallel of hybrid electric drive trains, torque and speed coupling of hybrid electric drive trains. [6]
Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control

of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency [12] Energy Storage: 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, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices. [8] Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems. [7]
Text Books: 1. Iqbal Husain, "*Electric and Hybrid Vehicles Design Fundamentals*" Published by: *CRC Press*, Boca Raton, Florida, USA, 2003.
Reference Books: 1. Chan, "*Modern Electric Vehicle Technology*", Oxford 2002

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9021	**Microprocessor Based Industrial Control**	**4 (3-1-0)**	**Dr. C. Koley**

INTRODUCTION: Block Diagram of a typical microprocessor based system pointing out the role of microprocessor and other peripheral blocks, functions; [4] Microprocessor and Microcontroller: 68000, 8051, PIC16XXX, ARM controllers [8] Interfacing I/O Devices I/O Controllers, Programmable Peripheral Devices, Interfacing, memory management; [4] INTERFACING: Interfacing of Digital I/O Devices: Handshaking Logic, Programmed I/O, Interrupt driven I/O, Direct memory access, [3] High Power Device Interfacing – Wave shaping, Driving and level shifting, Isolation; Interfacing of analog devices: [3] D/A Converter (MC1408 8-bit D/A, DAC 1208 12-bit D/A), [2] A/D Converter (ADC0808 8-bit ADC, ICL7109 12-bit ADC), Signal Conditioning; [2] COMMUNICATION: Asynchronous serial data communication, Serial Data transmission methods and standards, USART, RS-232C Serial Data Standard, IEEE 488; [2] MICROPROCESSOR BASED INDUSTRIAL SYSTEMS: Sensors: measurement of phase, frequency, power factor, temperature, flow, liquid level, pressure; [4] Actuators: Mechanical and solid state Relays, AC Regulator, and Variable Frequency Drive; Controller: Digital ON-OFF and PID controller, [3] PLC, DCS; Data Acquisition System: Functional block diagram, characteristics, and functions; Data Logger: Configuration, characteristics; Recorders: Functional block diagram, characteristics, and functions; [6] APPLICATION OF MICROPROCESSOR BASED SYSTEM: PID control of electrical heater using solid state Relays, Speed Control of DC and Induction Motor, and Phasor Measurement Unit. [6]
Text Books: 1. Douglas V. Hall, *Microprocessors & Interfacing*, Tata McGraw-Hill

2. M. Predko, *Programming & Customising 8051 Microcontroller*, TMH

Reference Books:

1. John Uffenbeck, *Microcomputers and Microprocessors*, Pearson Education
2. Michel Slater, *Microprocessor Based Design*, PHI

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9022	**Robotics and Automation**	**4 (3-1-0)**	**Prof. S. Banerjee & Dr. J. Dey**

BASIC CONCEPTS: Definition and origin of robotics – different types of robotics – various generations of, robots – degrees of freedom – Asimov's laws of robotics – dynamic stabilization of, robots. [6]

POWER SOURCES AND SENSORS: Hydraulic, pneumatic and electric drives – determination of HP of motor and gearing ratio – variable speed arrangements – path determination – micro machines in robotics –machine vision – ranging – laser – acoustic – magnetic, fiber optic and tactile sensors. [8]

MANIPULATORS, ACTUATORS AND GRIPPERS: Construction of manipulators – manipulator dynamics and force control – electronic and pneumatic manipulator control circuits – end effectors – U various types of grippers –design considerations. [8]

KINEMATICS AND PATH PLANNING: Solution of inverse kinematics problem – multiple solution jacobian work envelop – hill climbing techniques – robot programming languages [8]

CONTROL SYSTEMS: The manipulator Control problem, Linear control schemes, Linear model of a manipulator joint, Joint actuators, PID control scheme, Computed torque control, Force control strategies, Hybrid position/force control architecture, Impedance force/torque control, Adaptive Control. [10]

CASE STUDIES: Mutiple robots – machine interface – robots in manufacturing and non- manufacturing applications – robot cell design – selection of robot. [5]

Text Books:

1. L. Sciavicco and B. Siciliano, *Modeling and Control of Robot Manipulators*, Springer
2. K. S. Fu, R. C. Gonzalez and C. S. G Lee, *Robotics: Control, Sensing, Vision, and Intelligence*, McGraw-Hill Inc.
3. Mikell P. Weiss G.M., Nagel R.N., Odraj N.G., Industrial Robotics, McGraw-Hill, Singapore, 1996.

Reference Books:

1. J. J. Craig, *Introduction to Robotics, Mechanics and Control*, Addison Wesley
2. R. J. Schilling, *Fundamentals of Robotics Analysis and Control*, Prentice Hall.
3. Deb.S.R., Robotics technology and flexible Automation, John Wiley, USA 1992.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9023	**Intelligent Control**	**4 (3-1-0)**	**Prof. S. Banerjee & Dr. J. Dey**

A challenge to automatic control, Definition of intelligent control, Advance in intelligent control, Structural theories of intelligent control, Research and applications of intelligent control, Methodology of Knowledge representation, General interference principles, Hierarchical control systems. [6]

Expert control systems; Mathematical foundation for fuzzy control, fuzzy logic, crisp sets and fuzzy sets, fuzzy set operations and approximate reasoning, Fuzzification, inferencing and defuzzification. Fuzzy knowledge and rule bases, Architecture of fuzzy controllers, Design of fuzzy controllers, properties of fuzzy controllers, Fuzzy modeling and control schemes for nonlinear systems, Self-organizing fuzzy logic control, Fuzzy logic control for nonlinear time-delay system, Implementation of fuzzy logic controller using Matlab Stability analysis of fuzzy control systems, applications. [15]

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch-Pitts neuron model, simple perceptron, Adaline and Madaline, Feed-forward Multilayer Perceptron, Learning and Training the neural network, Data Processing, Fourier transformation, principal-component analysis and wavelet transformations ANN Networks: Hopfield network, Self-organizing network and Recurrent network. Structural Schemes of neurocontrol systems, Neural Network based controller. [12]

Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab, Stability analysis of Neural-Network interconnection systems, Integration of Fuzzy logic, NN and expert systems for control, Paradigms of NN-based control system; Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters, Solution of typical control problems using genetic algorithm. Concept on some other search techniques like tabu search and ant-colony search techniques for solving optimization problems. [12]

Text Books:

1. Large-Scale Systems: Modeling, Control and Fuzzy Logic, Author:Mo Jamshidi (on line)
2. L. A. Zadeh, *Fuzzy Sets and Applications*, John Wiley & Sons
3. Simon Haykin, *Neural Networks: A Comprehensive Foundation*, Prentice Hall

Reference Books:

1. Jyh-Shing Roger Jang, Chuen-Tsai Sun & Eiji Mizutani, *Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence*, Prentice Hall
2. S. Rajasekaran and G. A. Vijayalakshmi Pai, Neural Networks, Fuzzy Logic and genetic Algorithm Synthesis and Applications, PHI
3. Intelligent Control Systems, Using Soft Computing Methodologies, Editors: Ali Zilouchian, Mo Jamshidi (on line).

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9024	**Digital Signal Processing**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Discrete time signals and systems, properties, convolution, analysis of discrete time systems in time-domain; [4]

Frequency domain representation of discrete time systems and signals, Gibbs phenomenon, band limited signals, sampling theorem aliasing sampling of

continuous time signals; [4]
Z- transforms, region of convergence, Z- transform theorems and properties, methods of Inverse Z-transforms, analysis of discrete time signals and systems in Z-domain, pole-zero plots, stability; [4]
Realization of FIR Systems and IIR systems; [6]
Discrete time Fourier transform of discrete time signals and systems, Inverse discrete time Fourier transform, Eigen function, [4]
Discrete Fourier transform (DFT), properties of DFT, Linear convolution using DFT, Computation of DFT by FFT algorithms like decimation in frequency and decimation in time; [6]
Various Filter design techniques for FIR and IIR filters; [8]
Sampling rate conversion, up rate and down rate sampling, interpolation and decimation; [3]
Introduction to discrete Hilbert Transform, Complex Capstrum, Application of Capstral analysis; [4]
Practical applications of DSP, DSP processors. [2]

Text Books:

1. J. G. Proakis & D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, Prentice Hall of India.
2. E. Ifeachor & B.W. Jervis, *Digital Signal Processing, A practical Approach*, Pearson Education Ltd.

Reference Books:

1. S. K. Mitra, *Digital Signal Processing*, McGraw Hill Co. Inc.
2. S, Poornachandra & B. Sasikala, *Digital Signal Processing*, Tata McGraw-Hill Education Pvt. Ltd.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9025	**Soft Computing Techniques**	**4 (3-1-0)**	**Dr. P. Acharjee**

Introduction to soft-computing techniques and its necessity [1]
Fundamentals of genetic algorithm, Genetic algorithm, Encoding, Fitness function, Reproduction, Genetic modelling, Cross Over, Inversion and Deletion, Mutation operator, Bit-wise operators, examples. [1+3+2+1+1]
Basic Steps in Particle Swarm Optimization algorithm, Bird flocking & fish schooling, velocity, inertia weight factor, pbest solution, gbest solution, local optima, global optima, examples, new modifications of PSO, Parameter Selection in PSO. [1+2+2+2+1]
Fundamentals of Differential Evolution algorithm, difference vector and its significance, Mutation and crossover, comparisons among DE, PSO and GA, Examples, new modifications of DE, Improved DE schemes for noisy optimization problems. [1+1+2+1+2+1]
Fuzzy set theory, Fuzzy systems, crisp sets and fuzzy sets, fuzzy set operations and approximate reasoning, Fuzzification, inferencing and defuzzification, Fuzzy knowledge and rule bases, examples. [1+2+2+2+1]
Biological neural networks, Model of an artificial neuron, neural network

architecture, Characteristics of neural network, learning methods, Taxonomy of neural network architecture, Back propagation networks, architecture of a back propagation network, back propagation learning, Examples, RBF network, Associative memory, Adaptive resonance theory. [1+1+2+2+2+1]

Applications of Soft Computing to various fields of engineering. [2]

Text Books:

1. Devendra K. Chaturvedi, "Soft Computing- techniques and its application in electrical engineering", Springer, 2008.
2. Carlos A. Coello,Garry B. Lamont, David A. van Veldhuizen, "Evolutionary Algorithms for solving Multi-objective Problems", Second Edition, Springer, 2007.

Reference Books:

1. Jyh-Shing Roger Jang, Chuen-Tsai Sun &EijiMizutani, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, Prentice Hall
2. S. Rajasekaran and G. A. VijayalakshmiPai, Neural Networks, Fuzzy Logic and genetic Algorithm Synthesis and Applications, PHI
3. Simon Haykin, Neural Networks: A Comprehensive Foundation, Prentice Hall
4. L. A. Zadeh, Fuzzy Sets and Applications, John Wiley & Sons

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9026	**Embedded Systems**	**4 (3-1-0)**	**Dr. C. Koley**

Introduction to Embedded systems:

Introduction – Features – Microprocessors – ALU - Von Neumann and Harvard Architecture, Classification, SPP, ASIC, ASIP [4]

CISC and RISC - Instruction pipelining. Fixed point and Floating point processor[3]

General characteristics of embedded system, introduction to different components etc. [6]

Microcontroller 89CX51/52 Series: Characteristics and Features, Overview of architectures, and Peripherals, Timers, Counters, Serial communication, Digital I/O Ports. [4]

Microcontroller PIC Series: Characteristics and Features, Overview of architectures, and Peripherals, Interrupts, Timers, watch-dog timer, I/O port Expansion, analog-to-digital converter, UART, I2C and SPI Bus for Peripheral Chips, Accessories and special features. [5]

ARM Architecture: Evolution, Characteristics and Features, Overview of architectures, Modes, Registers etc [8]

Digital Signal Processor [4]

Software architecture and RTOS:

Software Architecture: Round Robin- Round Robin with interrupts -Function Queue. Scheduling

Architecture RTOS: Architecture -Tasks and Task States -Tasks and Data - Semaphores and Shared Data Message Queues -Mail Boxes and pipes -Timer

Functions -Events -Memory Management, Interrupt Routines. [6]
Basic design using a real time operating system:
Overview. General principles. Design of an embedded system.
Development Tool: Cross-Compiler, Cross-Assemblers, Linker/locator. PROM Programmers, ROM, Emulator, In-Circuit Emulators. Debugging Techniques. Instruction set simulators. The assert macro. [6]

Text Books:

1. Raj Kamal, *Embedded Systems Architecture*, Programming and Design, TMH
2. D. E. Simon, *An Embedded Software Primer*, Pearson Education

Reference Books:

1. J. B. Peatman, *Design with PIC Microcontrollers*, Pearson Education

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9027	**VLSI Systems**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Physics and Modelling of MOSFETS [4]
Fabrication and Layout of CMOS Integrated Circuits; [4]
The CMOS Inverter: Analysis and Design [6]
Switching Properties of MOSFETS [6]
Static Logic Gates; [6]
Dynamic Logic Circuit Concepts [6]
CMOS Dynamic Logic Families [6]
CMOS Differential Logic Families [6]
Issues in Chip Design [4]

Text Books:

1. John P. Uyemura, *CMOS Logic Circuit Design*, Kluwer Academic Publishers

Reference Books:

1. Sung-Mo (Steve) Kang & Yusuf Leblebici, CMOS Digital Integrated Circuits Analysis and Design, McGraw-Hill Education
2. Christian Piguet, Low-Power CMOS Circuits, Technology, Logic Design and CAD Tools, Taylor & Francis.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9028	**Biomedical Instrumentation**	**3 (3-0-0)**	**Dr. Suman Halder**

Organization of Cell, Cellular Constituents, Cellular Organelles, Cell Membrane Structure, Cellular Transport Processes [5]
Generation of Nernst Potential, Establishment of diffusion potential, Goldmann Equation, Measurement of membrane potential, resting potential, action potential, role of voltage gated channels for controlling action potentials. [5]
Role of sinus node for generation of ECG, ECG Transmission Process, Ectopic pacemakers, Analysis of ECG. [4]
Use of electrodes for measurement of biopotentials, polarization in electrodes, principle of operation of Ag/Agcl electrode, Equivalent circuit of electrode, motion artifact, various types of electrodes for biopotential measurement. [4]
Measurement of ECG, Einthoven triangle method, unipolar and bipolar limb leads,

ECG amplifiers, Problems encountered in ECG recording [5]
Pacemakers, Different types of pacing modes, Physiological effects of electric currents. Defibrillators. [4]
Measurement of blood pressure, measurement of blood pH, measurement of blood flow, measurement of heart sounds, chemical tests on blood cells. [5]
X ray instrumentation. Ultrasonography, Magnetic Resonance Imaging, Application of telemetry in patient care. [4]
Text Books: 1. John Enderle. Joseph Brinzino, *Introduction to Biomedical Engineering*, Elsevier, 2012. 2. John G Webster, *Medical Instrumentation, Application & Design*, John Wiley & Sons, 2009.
Reference Books: 1. L. Cromwell, Fred J. Weibell, Erich A. Pfeiffer, , Biomedical Instrumentation & Measurements, PHI, 2014 2. Arthur C Guyton, John E Hall, Textbook of Medical Physiology, Elsevier, 2006.