ACADEMIC REGULATIONS
COURSE STRUCTURE
AND
DETAILED SYLLABUS

ELECTRICAL AND ELECTRONICS ENGINEERING

for

M.Tech. - ADVANCED ELECTRICAL POWER SYSTEMS

(Applicable from 2016-2017 Batches)

UNIVERSITY COLLEGE OF ENGINEERING KAKINADA
(Autonomous)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA

KAKINADA - 533 003, ANDHRA PRADESH, INDIA

COURSE STRUCTURE

I Semester

S. No.	Subject	L	P	Credits
1	Microprocessors & Microcontrollers	4	--	3
2	HVDC Transmission	4	--	3
3	Power System Operation and Control	4	--	3
4	Reactive Power Compensation & Management	4	--	3
5	Elective – I i. Electrical Distribution Systems ii. EHVAC Transmission iii. Analysis of Power Electronics Converters iv. Renewable Energy Systems v. Artificial Intelligence Techniques	4	--	3
6	Elective – II i. Power System Security ii Advanced Digital Signal Processing iii. Generation & Measurement of High Voltages iv. Programmable Logic Controllers & Applications v. Modern Control Theory	4	--	3
7	Simulation Laboratory	--	4	2
Total Credits				**20**

II Semester

S. No.	Subject	L	P	Credits
1	Power System Dynamics and Stability	4	--	3
2	Flexible AC Transmission Systems	4	--	3
3	Real Time Control of Power Systems	4	--	3
4	Advanced Power System Protection	4	--	3
5	Elective – III i. Smart Grid Technologies ii. Power Quality iii. Power System Reliability iv. Voltage Stability	4	--	3
6	Elective – IV i. Power System Deregulation ii.High Voltage Testing Techniques iii.Power System Transients iv.Demand Side Energy Management	4	--	3
7	Power Systems Laboratory	--	4	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	--	--	2
2	Seminar – I	--	--	2
3	Project Work - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work - II	--	--	18
Total Credits				**20**

I-I MICROPROCESSORS &MICRO CONTROLLERS L / P / Credits
4 / -- / 3

Prerequisites: Basic Knowledge of digital electronics, analog electronics and computers.

Course Educational Objectives:

- To learn the basic architecture of 8086.
- To learn the assembly language programming using 8086.
- To teach various peripheral devices to interface processor with different components.
- Tolearn the 8051 micro controller and its various modes of operation and its instruction set.

Unit-1: Register Organization of 8086, Architecture, Signal description of 8086, memory segmentation, addressing modes of 8086. 8086/8088 instruction set and assembler directives, machine language instruction formats, Assembly language Programs.

Unit-2: General Bus Operation, minimum mode operation of 8086 and timing diagrams, Fundamental I/O considerations, Programmed I/O, Interrupt I/O, Block transfers and DMA.

Unit-3: Introduction to stack, stack structure of 8086/8088, Interrupts and Interrupt service routine, interrupt cycle of 8086/8088. Interfacing ROM/RAM, Interfacing of I/O ports to Micro Computer System, PPI (Programmable Peripheral Interface), 8255 modes of operation, Interfacing A to D converters, Interfacing D to A converters, Interfacing Principles and stepper motor interfacing.

Unit-4: Programmable Interval timer 8254, Programmable Interrupt Controller 8259A, Key Board or Display Controller 8279, Programmable Communication Interface 8251 USART.

Unit-5: Introduction to 8051/31 Micro Controller, PIN diagram, architecture, Different modes of Operation of timer/counters, addressing modes of 8051 and instruction set. Over view of 16 bit Microcontrollers.

Course Outcomes:

After completion of this coursethe students will be able to:

- Understand the basic architecture of 8086.
- Develop assembly language programming using 8086.
- Understand various peripheral devices to interface processor with different components.
- Understand the 8051 micro controller and its various modes of operation and its instruction set.

Reference Books:

1. Microprocessors and Interfacing: Programming and Hardware by DouglasV. Hall, 2nd edition, TMH, New Delhi, 1999.
2. Advanced Microprocessors and Peripherals, Architecture Programming and Interfacing by A.K. Ray & K.M. Bhurchandi, Forth reprint 2004, TMH
3. The 8051Microcontrollers: Architecture, Programming & Applications by Kenneth J Ayala, Second Edition, Penram International Publishing (India).
4. Micro Computer Systems: The 8086/8088 family by YU-CHENG LIU, GLENN A.GIBSON, 2nd edition, PHI India, 2000.
5. The 8051 Microcontroller and Embedded Systems – Mohammad Ali Mazdi, Janice GillispieMazidi, Pearson Education (Singapore) Pvt. Ltd., 2003.

I-I	HVDC TRANSMISSION	L / P / Credits

(Common to AEPS & HVE) **4 / -- / 3**

Prerequisites: Knowledge on Power Electronics, Power Systems and High Voltage Engineering

Course Educational Objectives:

- To learn various schemes of HVDC transmission.
- To learn about the basic HVDC transmission equipment.
- To learn the control of HVDC systems.
- To be exposed to the interaction between HVAC and HVDC system.
- To be exposed to the various protection schemes of HVDC engineering.

Unit -1: Limitation of EHV AC Transmission, Advantages of HVDC Technical economical reliability aspects. HVDC Transmission: General considerations, Power Handling Capabilities of HVDC Lines, Basic Conversion principles, static converter configuration. Types of HVDC links-Apparatus and its purpose.

Unit-2: Static Power Converters: 6-pulse bridge circuit and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Comparison of the performance of diametrical connection with 6-pulse bridge circuit

Unit-3 : Control of HVDC Converters and systems : constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control. Factors responsible for generation of Harmonics voltage and current harmonics effect of variation of α and μ. Filters Harmonic elimination.

Unit-4 : Interaction between HV AC and DC systems – Voltage interaction, Harmonic instability problems and DC power modulation. Development of DC circuit Breakers, Multi-terminal DC links and systems; series, parallel and series parallel systems, their operation and control.

Unit -5 : Transient over voltages in HV DC systems : Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults. Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC line protection, circuit breakers. Over voltage protection of converters, surge arresters.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the various schemes of HVDC transmission.
- Understand the basic HVDC transmission equipment.
- Understand the control of HVDC systems.
- Understand the interaction between HVAC and HVDC system.
- Understand the various protection schemes of HVDC engineering.

Reference Books:

1. S Kamakshaih and V Kamaraju:HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi – 1992.
3. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
4. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
5. Vijay K Sood: HVDC and FACTS controllers:Applications of static converters in power systems by, Kluwer Academic Press.

I-I **L / P / Credits**

POWER SYSTEM OPERATION AND CONTROL **4 / -- / 3**

(Common to AEPS & HVE)

Prerequisites: Knowledge on Power Generation Engineering, Power Transmission Engineering.

Course Educational Objectives:

- To study the unit commitment problem for economic load dispatch.
- To study the load frequency control of single area and two area systems with and without control.
- To study the effect of generation with limited energy supply.
- To study the effectiveness of interchange evaluation in interconnected power systems.

Unit-1: Unit commitment problem and optimal power flowsolution: Unitcommitment: Constraints in UCP,UC solutions. Methods-priority list method, introduction to Dynamic programming Approach.
Optimal power flow: OPF without inequality constraints, inequality constraints on control variables and dependent variables.

Unit-2: Single area Load Frequency Control: Necessity of keeping frequency constant. Definition of control area, single area control, Block diagram representation of an isolated Power System, Steady State analysis, Dynamic response-Uncontrolled case. Proportional plus Integral control of single area and its block diagram representation, steady state response, load frequency control and Economic dispatch control.

Unit-3: Two area Load Frequency Control : Load frequency control of 2-area system, uncontrolled case and controlled case, tie-line bias control. Optimal two-area LF control-steady state representation, performance Index and optimal parameter adjustment.

Unit-4: Generation with limited Energy supply : Take-or-pay fuel supply contract, composite generation production cost function. Solution by gradient search techniques, Hard limits and slack variables, Fuel scheduling by linear programming.

Unit-5 : Interchange Evaluation and Power Pools Economy Interchange, Economy interchange Evaluation, Interchange Evaluation with unit commitment, Multiple Interchange transactions, Other types of Interchange, power pools, transmission effects and issues.

Course Outcomes:
After completion of this course the students will be able to:

- Determine the unit commitment problem for economic load dispatch.
- Get the knowledge of load frequency control of single area and two area systems with and without control.
- Know the effect of generation with limited energy supply.
- Determine the interchange evaluation in interconnected power systems.

Reference Books:

1. Modern Power System Analysis - by I.J.Nagrath&D.P.Kothari, Tata McGraw-Hill Publishing Company ltd, 2nd edition.
2. Power system operation and control PSR Murthy B.S publication.
3. Power Generation, Operation and Control - by A.J.Wood and B.F.Wollenberg,Johnwiley& sons Inc. 1984.
4. Electrical Energy Systems Theory - by O.I.Elgerd, Tata McGraw-Hill Publishing Company Ltd, 2nd edition.
5. Reactive Power Control in Electric Systems - by TJE Miller, John Wiley & sons.

I-I **L / P / Credits**

REACTIVE POWER COMPENSATION & MANAGEMENT

4 / -- / 3

Prerequisites: Brief idea of power system analysis, electric traction systems and Arc furnaces

Course Educational Objectives:

- To know the basic objectives of reactive power compensation.
- To know the types of compensation and their behavior.
- To know the mathematical modeling of reactive power compensating devices.
- To know the reactive power compensation has to be done at distribution side.
- To know the role of reactive power compensation at electric traction systems and Arc furnaces.

Unit-1:Load Compensation

Objectives and specifications – reactive power characteristics – inductive and capacitive approximate biasing – Load compensator as a voltage regulator – phase balancing and power factor correction of unsymmetrical loads- examples.

Unit-2: Reactive power compensation in transmission system:

Steady state -Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples

Transient state - Characteristic time periods – passive shunt compensation – static compensations- series capacitor compensation –compensation using synchronous condensers – examples

Unit -3:Reactive power coordination:

Objective – Mathematical modeling – Operation planning – transmission benefits – Basic concepts of quality of power supply – disturbances- steady –state variations – effects of under voltages – frequency – Harmonics, radio frequency and electromagnetic interferences

Unit -4:Distribution side Reactive power Management:

System losses –loss reduction methods – examples – Reactive power planning – objectives – Economics Planning capacitor placement – retrofitting of capacitor banks

User side reactive power management:

KVAR requirements for domestic appliances – Purpose of using capacitors – selection of capacitors – deciding factors – types of available capacitor, characteristics and Limitations

Unit-5: Reactive power management in electric traction systems and are furnaces:

Typical layout of traction systems – reactive power control requirements – distribution transformers- Electric arc furnaces – basic operations- furnaces transformer –filter requirements – remedial measures –power factor of an arc furnace

Course Outcomes:

After completion of this course the students will be able to:

- Learn various load compensations.
- Obtain the mathematical model of reactive power compensating devices.
- Get application of reactive power compensation in electrical traction & arc furnaces.

Reference Books:

1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982
2. Reactive power Management by D.M.Tagare,Tata McGraw Hill,2004

I-I

ELECTRICAL DISTRIBUTION SYSTEMS (ELECTIVE-I)

L / P / Credits
4 / -- / 3

Prerequisites: Knowledge on basics of distribution systems, Compensation in electrical distribution systems, Circuit Analysis, concept of load modelling.

Course Educational Objectives:

- To learn the importance of economic distribution of electrical energy.
- To analyse the distribution networks for V-drops, P_{Loss} calculations and reactive power.
- To understand the co-ordination of protection devices.
- To impart knowledge of capacitive compensation/voltage control.
- To understand the principles of voltage control.

Unit -1: General : Introduction to Distribution systems, an overview of the role of computers in distribution system planning-Load modelling and characteristics: definition of basic terms like demand factor, utilization factor, load factor, plant factor, diversity factor, coincidence factor, contribution factor and loss factor-Relationship between the load factor and loss factor - Classification of loads (Residential, Commercial, Agricultural and Industrial) and their characteristics.

Unit -2: Distribution Feeders and Substations: Design consideration of Distribution feeders: Radial and loop types of primary feeders, voltage levels, feeder-loading. Design practice of the secondary distribution system. Location of Substations: Rating of a Distribution Substation, service area with 'n' primary feeders. Benefits derived through optimal location of substations.

Unit -3 : System analysis : Voltage drop and power loss calculations : Derivation for volt-drop and power loss in lines, manual methods of solution for radial networks, three-phase balanced primary lines, non-three-phase primary lines. Methods to analyse distribution feeder costs.

Unit -4: Protective devices and coordination: Objectives of distribution system protection, types of common faults and procedure for fault calculation. Protective Devices: Principle of operation of fuses, circuit reclosers, line sectionalizer and circuit breakers. Coordination of protective devices: General coordination procedure; types of coordination.

Unit -5 : Capacitive compensation for power factor control: Different types of power capacitors, shunt and series capacitors, effect of shunt capacitors (Fixed and switched) power factor correction, capacitor location. Economic justification. Procedure to determine the best capacitor location. Voltage control: Equipment for voltage control, effect of series capacitors, effect of AVB/AVR, line drop compensation.

Course Outcomes:

After completion of this course the students will be able to:

- Analyse a distribution system.
- Design equipment for compensation of losses in the distribution system.
- Design protective systems and co-ordinate the devices.
- Understand of capacitive compensation.
- Understand of voltage control.

Reference Books:

1. "Electric Power Distribution System Engineering " byTuran Gonen, Mc.Graw-Hill Book Company,1986.
2. Electric Power Distribution-by A.S.Pabla, Tata McGraw-Hill Publishing Company, 4th edition, 1997.
3. Electrical Distribution V.Kamaraju-McGraw Hill
4. .Handbook of Electrical Power Distribution – Gorti Ramamurthy-Universities press

I-I	EHVAC TRANSMISSION (ELECTIVE-I)	L / P / Credits 4 / -- / 3

Prerequisites: Transmission line parameters and properties, Corona etc.

Course Educational Objectives:

- To calculate the transmission line parameters.
- To calculate the field effects on EHV and UHV AC lines.
- To have knowledge of corona, RI and audible noise in EHV and UHV lines.
- To have knowledge of voltage control and compensation problems in EHV and UHV transmission systems.

Unit-1:E.H.V. A.C. Transmission , line trends and preliminary aspects ,standard transmission voltages – power handling capacities and line losses – mechanical aspects. Calculation of line resistance and inductance: resistance of conductors, temperature rise of conductor and current carrying capacity. Properties of bundled conductors and geometric mean radius of bundle, inductance of two conductor lines and multi conductor lines, Maxwell's coefficient matrix. Line capacitance calculation.capacitance of two conductor line, and capacitance of multi conductor lines, potential coefficients for bundled conductor lines, sequence inductances and capacitances and diagonalization.

Unit-2 : Calculation of electro static field of AC lines - Effect of high electrostatic field on biological organisms and human beings. Surface voltage Gradient on conductors, surface gradient on two conductor bundle and cosine law, maximum surface voltage gradient of bundle with more than 3 sub conductors, Mangolt formula.

Unit-3 : Corona : Corona in EHV lines – corona loss formulae – attenuation of traveling waves due to corona – Audio noise due to corona, its generation, characteristics and limits, measurement of audio noise.

Unit-4 : Power Frequency voltage control : Problems at power frequency, generalized constants, No load voltage conditions and charging currents, voltage control using synchronous condenser, cascade connection of components : Shunt and series compensation, sub synchronous resonance in series – capacitor compensated lines

Unit -5 : Static reactive compensating systems : Introduction, SVC schemes, Harmonics injected into network by TCR, design of filters for suppressing harmonics injected into the system.

Course Outcomes:

After completion of this course the students will be able to:

- Calculate the transmission line parameters.
- Calculate the field effects on EHV and UHV AC lines.
- Determine the corona, RI and audible noise in EHV and UHV lines.
- Analyze voltage control and compensation problems in EHV and UHV transmission systems.

Reference Books :

1. Extra High Voltage AC Transmission Engineering – Rakesh Das Begamudre, Wiley Eastern ltd., New Delhi – 1987.
2. EHV Transmission line reference book – Edison Electric Institute (GEC) 1986.

I-I ANALYSIS OF POWER ELECTRONIC CONVERTERS (ELECTIVE-I) **L / P / Credits 4 / -- / 3**

Prerequisites: Knowledge on electrical circuit analysis, electronic devices and power electronics.

Course Educational Objectives:

- To understand the control principle of ac to ac conversion with suitable power semi - conductor devices.
- To have the knowledge of ac to dc conversion and different ac to dc converter topologies.
- To understand the effect of operation of controlled rectifiers on p.f. and improvement of p.f. with PFC converters
- To acquire the knowledge on dc-ac converters and to know the different control techniques of dc-ac converters.
- To know multilevel inverter configuration to improve the quality of the inverter output voltage.

Unit-1 :AC voltage Controllers

Single Phase AC Voltage Controllers with R & RL load-ac voltage controller's with PWM control-Effects of source and load inductance–synchronous tap changers –Application- numerical problems

Three Phase AC Voltage controllers-Analysis of star and delta connected controllers with resistive load –Application- numerical problems.

Unit –2: AC-DC converters

Single phase Half controlled and Fully controlled Converters with RL load– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-Power factor improvements-Extinction angle control-symmetrical angle control-PWM single phase sinusoidal PWM-Single phase series converters- numerical problems.

Three Phase ac-dc Converters- Half controlled and fully controlled Converters with RL load– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-three phase dual converters-Power factor improvements-three phase PWM-twelve pulse converters- numerical problems

Unit-3: Power Factor Correction Converters

Single-phase single stage boost power factor corrected rectifier, power circuit principle of operation, and steady state- analysis, three phase boost PFC converter.

Unit –4: PWM Inverters

Principle of operation-Voltage control of single phase inverters - sinusoidal PWM – modified PWM – phase displacement Control – Trapezoidal, staircase, stepped, harmonic injection and delta modulation – numerical problems. Voltage Control of Three-Phase Inverters- Sinusoidal PWM- 60^0 PWM- Third Harmonic PWM- Space Vector Modulation- Comparison of PWM Techniques-current source inverters-Variable dc link inverter - numerical problems

Unit 5: Multi level inverters

Introduction, Multilevel Concept, Types of Multilevel Inverters- Diode-Clamped Multilevel Inverter, Principle of Operation, Features of Diode-Clamped Inverter, Improved Diode-Clamped Inverter- Flying Capacitors Multilevel Inverter- Principle of Operation, Features of Flying-Capacitors Inverter- Cascaded Multilevel Inverter- Principle of Operation- Features of Cascaded Inverter- Switching Device Currents-DC-Link Capacitor Voltage Balancing- Features of Multilevel Inverters- Comparisons of Multilevel Converters

Course Outcomes:

After completion of this course the students will be able to:

- Have the knowledge on principle of ac voltage controller and their control techniques.
- Convert ac voltage to dc voltage and different control strategies of the converter.
- Control the power factor of single phase and three phase ac to dc converters.
- Understand the conversion of dc to ac and their control strategies.
- Analyze different multilevel inverters to improve the quality of the output voltage of the inverter.

Reference books

1. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First Indian Reprint- 2008
2. Power Electronics- Ned Mohan, Tore M.Undelan and William P.Robbins –John Wiley & Sons -2nd Edition.
3. Power Electronics – Lander –Ed.2009
4. Modern power Electronics and AC Drives – B.K.Bose
5. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee Publishing Pvt Ltd.

I-I

RENEWABLE ENERGY SYSTEMS
(Elective-I)

L / P / Credits
4 / -- / 3

Prerequisites: Basic idea of non-conventional energy sources.

Course Educational Objectives:

- To learn basic principle of renewable energy sources.
- To adoption of alternative energy sources for power generation.
- To learn alternative energy sources not based on sun.
- To the adoption and inter connection of renewable and alternative energy sources to grid.

Unit-1

Solar Energy - Availability - Solar radiation data and measurement - Estimation of average solar radiation - Solar water heater types - Heat balance – Flat plate collector efficiency – Efficiency of heat removal - Thermo siphon flow calculation - Forced circulation calculation - Evacuated collectors - Basics of solar concentrators Solar Energy Applications - Solar air heaters – Solar Chimney - Crop driers - Passive solar system - Active solar systems - Water desalination - Output from solar still – Principle of solar ponds.

Unit-2

Wind Energy – Nature of wind – Characteristics – Variation with height and time – Power in wind –Aerodynamics of Wind turbine – Momentum theory – Basics of aerodynamics – Aero foils and their characteristics – HAWT – Blade element theory – Prandtl's lifting line theory (prescribed wake analysis) VAWT aerodynamics – Wind turbine loads – Aerodynamic loads in steady operation – Yawed operation and tower shadow. Wind Energy Conversion System – Siting – Rotor selection – Annual energy output – Horizontal axis wind turbine (HAWT) – Vertical axis wind turbine (VAWT) – Rotor design considerations – Number of blades – Solidity - Blade profile – Upwind/Downwind – Yaw system – Tower – Braking system - Synchronous and asynchronous generators and loads – Integration of wind energy converters to electrical networks – Inverters – Control system – Requirement and strategies – Noise Applications of wind energy

Unit-3

Biomass energy - Bio fuel classification – Examples of thermo chemical, Pyrolysis, biochemical and agrochemical systems – Energy farming – Direct combustion for heat – Process heat and electricity – Ethanol production and use – Anaerobic digestion for biogas – Different digesters – Digester sizing – Applications of Biogas - Operation with I.C.Engine

Unit-4

Ocean Energy - OTEC Principle - Lambert's law of absorption - Open cycle and closed cycle - heat exchanger calculations – Major problems and operational experience. Tidal Power - Principles of power generation - components of power plant – Single and two basin systems – Turbines for tidal power - Estimation of energy – Maximum and minimum power ranges - tidal powerhouse.Wave Energy – Concept of energy and power from waves – Wave characteristics – period and wave velocities - Different wave energy conservation devices (Saltor duck, oscillating water column and dolphin types) – operational experience.

Unit-5

Geothermal Energy - Classification- Fundamentals of geophysics - Dry rock and hot aquifer energy analysis - Estimation of thermal power - Extraction techniques - Prime movers.

Course Outcomes:

After completion of this course the students will be able to:

- Identify alternate energy sources.
- Classify and analyze different renewable energy systems.
- Adopt different alternate energy sources for power generation.
- Adopt optimally usage of different sources and interconnection with grid.

Reference Books :

1. Renewable Energy Resources / John Twidell and Tony Weir / E &F.N.Spon
2. Renewable Energy Resources Basic Principles and Applications / G.N.Tiwari and M.K.Ghosal / Narosa
3. Solar Energy - Principles of thermal collection and storage/ S.P. Sukhatme / TMH
4. Solar Energy Thermal Processes,/Duffie& Beckman
5. Solar Heating and Cooling / Kreith&Kreider, CRC press.
6. Wind Energy Handbook / Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyi / WileyWind Electrical Systems / S.N.Bhadra, D.Kastha and S.Banerjee / Oxford
7. Biogas Technology - A Practical Hand Book / K.Khendelwal& S.S. Mahdi / McGraw-Hill.

I-I ARTIFICIAL INTELLIGENCE TECHNIQUES L / P / Credits
(Common to AEPS & HVE) 4 / -- / 3
(Elective-I)

Prerequisites: Basic knowledge on human biological systems, concept of optimization and electrical engineering.

Course Educational Objectives:

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm and its application in optimization.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in electrical engineering.

Unit – 1: Introduction to Neural Networks

Introduction, Humans and Computers, Biological Neural Networks, Historical development of neural network, Terminology and Topology, Biological and artificial neuron models, Learning laws-supervised, unsupervised and reinforced learning laws.

Unit- 2:Feed Forward Neural Networks

Introduction, Perceptron models: Discrete, continuous and multi-category, Training algorithms: Discrete and Continuous Perceptron Networks, Limitations and applications of the Perceptron model, Generalized delta learning rule, Feed forward recall and error back propagation training-Radial basis function algorithms, kohonen's self-organising maps -Hope field networks

Unit -3: Fuzzy Logic

Introduction to classical sets - properties, operations and relations; Fuzzy sets - properties, operations and relations, Uncertainty, cardinalities, membership and types of membership functions.Fuzzy Logic System Components-Fuzzification, Membership value assignment, development of rule base and decision making system, defuzzification to crisp sets, defuzzification methods.

Unit – 4: Genetic algorithms &Modelling-introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm

UNIT 5: Application of AI Techniques-load forecasting-load flow studies-economic load dispatch-load frequency control-reactive power control-speed control of dc and ac motors

Course Outcomes:

After completion of this course the students will be able to:

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and design fuzzy logic systems.
- Apply AI Techniques in electrical engineering.

Reference Books :

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by RajasekharanandPai – PHI Publication.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.

I-I

POWER SYSTEM SECURITY
(ELECTIVE II)

L / P / Credits
4 / -- / 3

Prerequisites: Basic knowledge of measurements in power systems.

Course Educational Objectives:

- To study the short circuit analysis of balanced and unbalanced power systems.
- To study the power system security analysis.
- To study the real time control of power system.
- To study the principles and applications of SCADA.

Unit-1: Short circuit analysis techniques in AC power Systems- Simulation of short circuit and open circuit faults using network theorems- fixed impedance short circuit analysis techniques-time domain short circuit analysis in large scale power systems- analysis of time variation of AC and DC short circuit components

Unit-2: Fixed impedance Short circuit analysis of large scale power systems-general analysis of balanced, unbalanced and open circuit faults- 3-phase short circuit analysis in large scale power systems, Network equivalents and practical short circuit current assessments in large scale Ac power systems-general studies- uncertainties in short circuit current calculations-probabilistic Short circuit analysis

Unit-3: Risk assessment and safety considerations-control and limitation of high short circuit currents-limitation of short circuit currents in power system operation, design and planning, Types of short circuit fault current limiters- earthing resistor or reactor connected to transformer neutral-pyrotechnic fault current limiters- series resonant current limiters- saturable reactor limiters-other types of fault current limiters and their applications.

Unit-4: Power System Securityanalysis- concept of security- security analysis and monitoring-factors affecting power system security- detection of network problems –overview, contingency analysis for generator and line outages by ILPF method – fast decoupled inverse Lemma-based approach, network sensitivity factors –contingency selection –concentric relaxation and bounding.

Unit-5: Computer control power systems – need for real time and computer control of power systems- operating states of power system – SCADA- implementation considerations – software requirements for implementing above functions.

Course Outcomes:

After completion of this course the students will be able to:

- Analyze the balanced and unbalanced power system under short circuit conditions.
- Understand how to minimize the short circuit effect on the power System.
- Design the power system with more security with real time control.
- Implant SCADA for power system security.

Reference Books:

1.Allen J. Wood and Bruce Woolenberg: Power System Generation, Operation and Control ,John Willey and sons,1996

2.John J.Grainger and William D Stevenson Jr.: Power System analysis,McGraw Hill,ISE,1994.

3.Nasser D.Tleis : Power System Modelling and fault analysis, Elsevier, 2008.

4. Hand book of Power Systems, GrigsBee.,CRC Press ,Newyork.

I-I	ADVANCED DIGITAL SIGNAL PROCESSING (Common to AEPS & HVE) (Elective II)	L / P / Credits 4 / -- / 3

Prerequisites: Knowledge on signal processing and Z-transform.

Course Educational Objectives:

- To have knowledge on structures of different digital filters.
- To design digital filters with different techniques.
- To understand the implementation aspects of digital filters.
- To analyze the effect of finite word length in signal processing.
- To understand power spectrum estimation techniques in signal processing.

UNIT-1: Digital Filter Structure

Block diagram representation-Equivalent Structures-FIR and IIR digital filter Structures All pass Filters-tunable IIR Digital Filters-IIR tapped cascaded Lattice Structures-FIR cascaded Lattice structures-Parallel-Digital Sine-cosine generator-Computational complexity of digital filter structures.

UNIT-2: 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

UNIT-3: DSP algorithm implementation

Computation of the discrete Fourier transform- Number representation-Arithmetic operations-handling of overflow-Tunable digital filters-function approximation.

UNIT-4 : Analysis of finite Word length effects

The Quantization process and errors- Quantization of fixed -point and floating -point Numbers-Analysis of coefficient Quantization effects - Analysis of Arithmetic Round-off errors, Dynamic range scaling-signal- to- noise ratio in Low -order IIR filters-Low-Sensitivity Digital filters-Reduction of Product round-off errors using error feedback-Limit cycles in IIR digital filters-Round-off errors in FFT Algorithms.

UNIT 5: Power Spectrum Estimation

Estimation of spectra from Finite Duration Observations signals – Non-parametric methods for power spectrum Estimation – parametric method for power spectrum Estimation, Estimation of spectral form-Finite duration observation of signals-Non-parametric methods for power spectrum estimation-Walsh methods-Blackman & torchy method.

Course Outcomes:

After completion of this course the students will be able to:

- Describe structure of digital filters.
- Design digital filters with different techniques.
- Understand the implementation aspects of signal processing algorithms.
- Know the effect of finite word length in signal processing.
- Analyze different power spectrum estimation techniques.

Reference Books:

1. Digital signal processing-sanjit K. Mitra-TMH second edition
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1st edition-9th reprint
3 Digital Signal Processing principles, algorithms and Applications – John G.Proakis -PHI – 3rd edition-2002
4. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2nd reprint-2001
5. Theory and Applications of Digital Signal Proceesing-LourensR. Rebinar&Bernold
6. Digital Filter Analysis and Design-Auntonian-TMH

I-I GENERATION & MEASUREMENTS OF HIGHVOLTAGES **L / P / Credits**
(Common to AEPS & HVE) **4 / -- / 3**
(Elective II)

Prerequisites: Basics of Electrical circuits, Electronics and measurements for testing purpose

Course Educational Objectives:

- To study the numerical methods for analyzing electrostatic field problems.
- To study the fundamental principles of generation of high voltage for testing.
- To study the methods for measurement of high AC ,DC and transient voltages.
- To Study the measurement techniques for high AC ,DC and impulse currents.

Unit 1- Electrostatic fields and field stress control : Electric fields in homogeneous Isotropic materials and in multi dielectric media-Simple configurations-field stress control. Methods of computing electrostatic fields-conductive analogues-Impedance networks Numerical techniques-finite difference method-finite element method and charge simulation method.

Unit 2-Generation of High AC & DC Voltages:

Direct Voltages : AC to DC conversion methods electrostatic generators-Cascaded Voltage Multipliers.

Alternating Voltages : Testing transformers-Resonant circuits and their applications, Tesla coil.

Unit 3-Generation of Impulse Voltages :

Impulse voltage specifications-Impulse generations circuits-Operation, construction and design of Impulse generators-Generation of switching and long duration impulses.

Impulse Currents : Generation of High impulse currents and high current pulses.

Unit 4- Measurement of High AC & DC Voltages :

Measurement of High D.C. Voltages : Series resistance meters, voltage dividers and generating voltmeters.

Measurement of High A.C. Voltages : Series impedance meters electrostatic voltmeters potential transformers and CVTS-voltage dividers and their applications.

Unit 5-Measurement of Peak Voltages :

Sphere gaps, uniform field gaps, rod gaps.Chubb-Fortesque methods. Passive and active rectifier circuits for voltage dividers.

Measurement of Impulse Voltages : Voltage dividers and impulse measuring systems-generalized voltage measuring circuits-transfer characteristics of measuring circuits-L.V. Arms for voltage dividers-compensated dividers.

Measurement of Impulse Currents : Resistive shunts-current transformers-Hall Generators and Faraday generators and their applications-Impulse Oscilloscopes.

Course Outcomes:

After completion of this course the students will be able to:

- Understand numerical computation of electrostatic problems.
- Understand the techniques of generation of high AC, DC and transient voltages.
- Measure high AC, DC and transient voltages.
- Measure high AC, DC and transient currents.

Reference Books :

1. High Voltage Engineering – by E.Kuffel and W.S.Zaengl. Pergaman press Oxford, 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Mc.Graw-Hill Books Co., New Delhi, 2^{nd} edition, 1995.
3. High Voltage Technology – LL Alston, Oxford University Press 1968.
4. High Voltage Measuring Techniques – A. Schwab MIT Press, Cambridge,USA, 1972.
5. Relevant I.S. and IEC Specifications.

I-I PROGAMMABLE LOGIC CONTROLLERS & APPLICATIONS (Elective II)

L / P / Credits
4 / -- / 3

Prerequisites: Knowledge on relay logic and digital electronics.

Course Educational Objectives:

- To have knowledge on PLC.
- To acquire the knowledge on programming of PLC.
- To understand different PLC registers and their description.
- To have knowledge on data handling functions of PLC.
- To know how to handle analog signal and converting of A/D in PLC.**Unit 1:**

PLC Basics: PLC system, I/O modules and interfacing, CPU processor, programming equipment, programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

Unit 2:

PLC Programming: Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation. Digital logic gates, programming in the Boolean algebra system, conversion examples. Ladder diagrams for process control: Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

Unit 3:

PLC Registers: Characteristics of Registers, module addressing, holding registers, input registers, output registers. PLC Functions: Timer functions and Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions.

Unit 4:

Data Handling functions: SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axis and three axis Robots with PLC, Matrix functions.

Unit 5:

Analog PLC operation: Analog modules and systems, Analog signal processing, multi bit data processing, analog output application examples, PID principles, position indicator with PID control, PID modules, PID tuning, PID functions.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the PLCs and their I/O modules.
- Develop control algorithms to PLC using ladder logic etc.
- Manage PLC registers for effective utilization in different applications.
- Handle data functions and control of two axis and their axis robots with PLC.
- Design PID controller with PLC.

Reference Books:

1. Programmable Logic Controllers – Principle and Applications by John W. Webb and Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR. Hackworth and F.D Hackworth Jr. – Pearson, 2004.
3. Introduction to Programmable Logic Controllers- Gary Dunning-Cengage Learning.
4. Programmable Logic Controllers –W.Bolton-Elsevier publisher

I-I

MODERN CONTROL THEORY
(ELECTIVE-II)

L / P / Credits
4 / -- / 3

Prerequisites: Control Systems, differential equations.

Course Educational Objectives:

- To facilitate the evolution of state variable approach for the analysis of control systems.
- To examine the importance of controllability and observability in modern control engineering.
- To enable students to analyze various types of nonlinearities & construction of trajectories using describing functions and phase plane analysis.
- To study the analysis of stability and instability of continuous time invariant system

Unit –1: State Variable Analysis

The concept of state – State Equations for Dynamic systems – State diagram - Linear Continuous time model for physical systems – Existence and Uniqueness of Solutions to Continuous – Time State Equations – Solutions – Linear Time Invariant Continuous – Time State Equations – State transition matrix and it's properties

Unit – 2: State Variable Techniques

General concept of Controllability - General concept of Observability Controllability tests for Continuous &Time Invariant systems - Observability tests for Continuous &Time Invariant systems - Controllability and Observability of state model in Jordan Canonical form - Controllability and Observability Canonical forms of State model – State feedback controller design through pole assignment.

Unit – 3: Non Linear Systems – I

Introduction – Non Linear Systems – Types of Non – Linearities – Saturation – Dead – Zone – Backlash – Jump Phenomenon etc; - Singular Points – Introduction to Linearization of nonlinear systems, properties of Non Linear Systems – Describing function – describing function analysis of nonlinear systems- Stability analysis of Non – Linear systems through describing functions.

Unit – 4: Non Linear Systems – II

Introduction to phase – plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase – plane analysis of nonlinear control systems.

Unit – 5: Stability Analysis

Stability in the sense of Lyapunov, Lyapunov's stability and Lyapunov's instability theorems – Stability Analysis of the Linear Continuous time invariant systems by Lyapunov second method – Generation of Lyapunov functions – Variable gradient method – Krasooviski's method.

Course Outcomes:

After completion of this course the students will be able to:

- Understanding the state variable approach is suitable for higher order.
- To analyze the concepts of controllability and observability.
- To analyze the various non-linearities through describing functions and phase plane analysis.
- Typical issues of stability and instability of continuous time invariant systems.

Reference Books :

1. Modern Control System Theory by M. Gopal – New Age International – 1984
2. Modern Control Engineering by Ogata. K – Prentice Hall – 1997
3. Nonlinear systems, Hassan K. Klalil, Prentice Hall, 1996
4. Modern control systems, Richard C. Dorf and Robert H. Bishop, 11th Edition, Pearson Edu, India, 2009

I-I **SIMULATION LABORATORY** **L / P / Credits**
--/ 4 / 2

Course Educational Objectives:

To understand the modeling of various aspects of Power System analysis and develop the MATLAB programming.

List of Experiments:

1. Formation of Y- Bus by Direct-Inspection Method.
2. Load Flow Solution Using Gauss Siedel Method
3. Load Flow Solution Using Newton Raphson Method
4. Load Flow Solution UsingFast Decoupled Method
5. Formation of Z-Bus by Z-bus building algorithm
6. Symmetrical Fault analysis using Z-bus
7. Unsymmetrical Fault analysis using Z-bus
8. Economic Load Dispatch with & without transmission losses
9. Transient Stability Analysis Using Point By Point Method
10. Load Frequency Control of Single Area Control & Two Area Control system with and without controllers.

Course Outcomes:

After the completion of the lab they will verify the theoretical concepts of various aspects of Power System analysis.

I-II

POWER SYSTEM DYNAMICS AND STABILITY

L / P / Credits
4/ -- / 3

Prerequisites: Knowledge of synchronous machine, Power System Analysis

Course Educational Objectives:

- To study the model of synchronous machines.
- To study the stability studies of synchronous machines.
- To study the solution method of transient stability.
- To study the effect of different excitation systems.

Unit 1 : System Dynamics : Synchronous machine model in state space from computer representation for excitation and governor system –modeling of loads and induction machines.

Unit 2: Steady state stability – steady state stability limit – Dynamics Stability limit – Dynamic stability analysis – State space representation of synchronous machine connected to infinite bus-time response – Stability by eighvalue approach.

Unit 3: Digital Simulation of Transient Stability : Swing equation machine equations – Representation of loads – Alternate cycle solution method – Direct method of solution – Solution Techniques : Modified Euler method – RungeKutta method – Concept of multi machine stability.

Unit 4: Effect of governor action and excite on power system stability effect of saturation, saliency & automatic voltage regulators on stability.

Unit 5: Excitation Systems : Rotating Self-excited Exciter with direct acting Rheostatic type voltage regulator – Rotating main and Pilot Exciters with Indirect Acting Rheostatic Type Voltage Regulator – Rotating Main Exciter, Rotating Amplifier and Static Voltage Regulator – Static excitation scheme – Brushless excitation system.

Course Outcomes:

After completion of this course the students will be able to:

- Able to determine the model of synchronous machines.
- Able to know the stability studies of synchronous machines.
- Able to get the knowledge of solution methods of transient stability.
- Able to know the effect of different excitation systems in power systems.

Reference Books :

1. Power System Stability by Kimbark Vol. I&II, III, Willey.
2. Power System control and stability by Anderson and Fund, IEEE Press.
3. Power systems stability and control by PRABHA KUNDUR, TMH.
4. Computer Applications to Power Systems–Glenn.W.Stagg& Ahmed. H.El.Abiad, TMH.
5. Computer Applications to Power Systems – M.A.Pai, TMH.
6. Power Systems Analysis & Stability – S.S.VadheraKhanna Publishers
7.

I-II | **L / P / Credits**
4/ -- / 3

FLEXIBLE AC TRANSMISSION SYSTEMS
(Common to AEPS & HVE)

Prerequisites: Concepts on Power Electronics and Power Systems

Course Educational Objectives:

- To study the performance improvements of transmission system with FACTS.
- To study the effect of static shunt compensation.
- To study the effect of static series compensation.
- To study the effect of UPFC.

Unit 1 : FACTS concepts, Transmission interconnections, power flow in an AC System, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

Unit 2 : Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters.

Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable VAr generation, variable impedance type static VAr generation, switching converter type VAr generation, hybrid VAr generation.

Unit 3: SVC and STATCOM: The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

Unit 4 : Static series compensators : Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

Unit 5 : Unified Power Flow Controller: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control, comparison of the UPFC to series compensators and phase angle regulators. Introduction to Inter line Power Flow Controller (IPFC)

Course Outcomes:
After completion of the course, the student will be able to:

- Know the performance improvement of transmission system with FACTS.
- Get the knowledge of effect of static shunt and series compensation.
- Know the effect of UPFC.
- Determine an appropriate FACTS device for different types of applications.

Reference Books:

1. "Understanding FACTS Devices" N.G.Hingorani and L.Guygi, IEEE Press.
   Indian Edition is available:--Standard Publications
2. Sang.Y.H and John.A.T, "Flexible AC Transmission systems" IEEE Press (2006).
3. HVDC & FACTS Controllers: applications of static converters in power systems-
   Vijay K.Sood- Springer publishers

I-II

REAL TIME CONTROL OF POWER SYSTEMS

L / P / Credits
4/ -- / 3

Prerequisites: Power system operation and control.

Course Educational Objectives:

- To understand the importance of state estimation in power systems.
- To know the importance of security and contingency analysis.
- To understand SCADA, its objectives and its importance in power systems.
- To know the significance of voltage stability analysis.
- To know the applications of AI to power systems problems.

Unit 1 : State Estimation : Different types of State Estimations, Theory of WLS state estimation, sequential and non-sequential methods to process measurements. Bad data Observability, Bad data detection, identification and elimination.

Unit 2 : Security and Contingency Evaluation : Security concept, Security Analysis and monitoring, Contingency Analysis for Generator and line outages by iterative linear power flow method, Fast Decoupled model, and network sensitivity methods.

Unit 3 : Computer Control of Power Systems : Need for real time and computer control of power systems, operating states of a power system, SCADA - Supervisory control and Data Acquisition systems implementation considerations, energy control centres, software requirements for implementing the above functions.

Unit 4 : Voltage Stability, voltage collapse, and voltage security, relation of voltage stability to rotor angle stability. Voltage stability analysis Introduction to voltage stability analysis `P-V' curves and `Q-V' curves, voltage stability in mature power systems, long-term voltage stability, power flow analysis for voltage stability, voltage stability static indices and Research Areas.

Unit 5: Need and conditions for deregulation. Introduction of Market structure, Market Architecture, Spot market, forward markets and settlements. Review of Concepts marginal cost of generation, least-cost operation, incremental cost of generation. Power System Operation.

Course Outcomes:

After completion of this course the students will be able to:

- Understand state estimation, security and contingency evaluation.
- Understand about Supervisory control and data acquisition.
- Real time software application to state estimation.
- Understand application of AI in power system.

Reference Books :

1. John J.Grainger and William D.Stevenson, Jr. : Power System Analysis, McGraw-Hill, 1994, International Edition
2. Allen J.Wood and Bruce F.Wollenberg : Power Generation operation and control, John Wiley & Sons, 1984
3. R.N.Dhar : Computer Aided Power Systems Operation and Analysis, Tata McGraw Hill, 1982
4. L.P.Singh : Advanced Power System Analysis and Dynamics, Wiley Eastern Ltd. 1986
5. PrabhaKundur : Power System Stability and Control -, McGraw Hill, 1994
6. P.D.Wasserman : `Neural Computing : Theory and Practice' Van Nostrand - Feinhold, New York.

I-II	**ADVANCED POWER SYSTEM PROTECTION** **(Common to AEPS & HVE)**	**L / P / Credits** **4/ -- / 3**

Prerequisites: Concepts of Power Electronics, Electronic circuits, STLD and basics of Relays and protection.

Course Educational Objectives:

- To learn about classification and operation of static relays.
- To understand the basic principles and application of comparators.
- To learn about static version of different types of relays.
- To understand about numerical protection techniques.

Unit 1 : Static Relays classification and Tools : Comparison of Static with Electromagnetic Relays, Basic classification, Level detectors and Amplitude and phase Comparators – Duality – Basic Tools – Schmitt Trigger Circuit, Multivibrators, Square wave Generation – Polarity detector – Zero crossing detector – Thyristor and UJT Triggering Circuits. Phase sequence Filters – Speed and reliability of static relays.

Unit 2 : Amplitude and Phase Comparators (2 Input) : Generalized equations for Amplitude and Phase comparison – Derivation of different characteristics of relays – Rectifier Bridge circulating and opposed voltage type amplitude comparators – Averaging & phase splitting type amplitude comparators – Principle of sampling comparators.

Phase Comparison : Block Spike and phase Splitting Techniques – Transistor Integrating type, phase comparison, Rectifier Bridge Type Comparison – Vector product devices.

Unit 3 : Static over current (OC) relays – Instantaneous, Definite time, Inverse time OC Relays, static distance relays, static directional relays, static differential relays, measurement of sequence impedances in distance relays, multi input comparators, elliptic & hyperbolic characteristics, switched distance schemes, Impedance characteristics during Faults and Power Swings,

Unit 4 : PILOT Relaying schemes: Wire pilot protection: circulating current scheme – balanced voltage scheme – translay scheme – half wave comparison scheme - carrier current protection: phase comparison type – carrier aided distance protection – operational comparison of transfer trip and blocking schemes – optical fibre channels.

Unit 5 : Microprocessor based relays andNumerical Protection: Introduction – over current relays – impedance relay – directional relay – reactance relay.

Numerical Protection: Introduction - numerical relay - numerical relaying algorithms - mann-morrison technique - Differential equation technique and discrete fourier transform technique - numerical over current protection - numerical distance protection.

Course Outcomes:

After completion of this course the students will be able to:

- Know the classifications and applications of static relays.
- Understand the application of comparators.
- Understand the static version of different types of relays.
- Understand the numerical protection techniques.

Reference Books :

1. Power System Protection with Static Relays – by TSM Rao, TMH.
2. Protective Relaying Vol-II Warrington, Springer.
3. Art & Science of Protective Relaying - C R Mason, Willey.
4. Power System Stability KimbarkVol-II, Willey.
5. Power system protection & switchgear by Badri Ram & D N viswakarma, TMH.
6. Electrical Power System Protection –C.Christopoulos and A.Wright- Springer
7. Protection & Switchgear –Bhavesh Bhalaja, R.PMaheshwari, NileshG.Chothani-Oxford publisher

I-II

SMART GRID TECHNOLOGIES
(Elective – III)

L / P / Credits
4/ -- / 3

Prerequisites: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

Course Educational Objectives:

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

Unit 1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient &Self Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.

Unit 2

Smart Grid Technologies: Part 1: Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

Unit 3

Smart Grid Technologies: Part 2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

Unit 4

Microgrids and Distributed Energy Resources: Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuelcells, microturbines, Captive power plants, Integration of renewable energy sources.

Unit 5

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Information and Communication Technology for Smart Grid: Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).

Course Outcomes:

Aftercompletion of this course the students will be able to:

- Understand smart grids and analyse the smart grid policies and developments in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyse micro grids and distributed generation systems.
- Analyse the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley
2. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,“Smart Grid: Technology and Applications”, Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, “Smart Grids”, Wiley Blackwell 19
5. Peter S. Fox Penner, “Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities”, Island Press; 1 edition 8 Jun 2010
6. S. Chowdhury, S. P. Chowdhury, P. Crossley, “Microgrids and Active Distribution Networks.” Institution of Engineering and Technology, 30 Jun 2009
7. Stuart Borlase, “Smart Grids (Power Engineering)”, CRC Press

Reference Books:

1. Andres Carvallo, John Cooper, “The Advanced Smart Grid: Edge Power Driving Sustainability: 1”, Artech House Publishers July 2011
2. James Northcote, Green, Robert G. Wilson “Control and Automation of Electric Power Distribution Systems (Power Engineering)”, CRC Press
3. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert “Substation Automation (Power Electronics and Power Systems)”, Springer
4. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, “Electrical Power System Quality”, 2nd Edition, McGraw Hill Publication
5. Yang Xiao, “Communication and Networking in Smart Grids”, CRC Press

I-II **POWER QUALITY (Elective III)** **L / P / Credits**
4/ -- / 3

Prerequisites: Knowledge on electric circuit analysis, power systems and power electronics.

Course Educational Objectives:

- To understand significance of power quality and power quality parameters.
- To know types of transient over voltages and protection of transient voltages.
- To understand harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To understand long duration voltage variation and flicker
- To know power quality aspects in distributed generation.

Unit-1 Introduction
Overview of Power Quality - Concern about the Power Quality - General Classes of Power Quality Problems – Transients -Long-Duration Voltage Variations - Short-Duration Voltage Variations - Voltage Unbalance - Waveform Distortion - Voltage fluctuation - Power Frequency Variations - Power Quality Terms - Voltage Sags and Interruptions - Sources of Sags and Interruptions – Nonlinear loads.

Unit-2 Transient Over Voltages
Source of Transient Over Voltages - Principles of Over Voltage Protection - Devices for Over Voltage Protection - Utility Capacitor Switching Transients - Utility Lightning Protection - Load Switching Transient Problems - Computer Tools for Transient Analysis

Unit-3 Harmonic Distortion and solutions
Voltage vs. Current Distortion - Harmonics vs. Transients - Power System Quantities under Nonsinusoidal Conditions - Harmonic Indices – Sources of harmonics - Locating Sources of Harmonics – System Response Characteristics - Effects of Harmonic Distortion – Interharmonics - Harmonic Solutions Harmonic Distortion Evaluation - Devices for Controlling Harmonic Distortion - Harmonic Filter Design - Standards on Harmonics

Unit- 4 Long Duration Voltage Variations
Principles of Regulating the Voltage - Device for Voltage Regulation - Utility Voltage Regulator Application - Capacitor for Voltage Regulation - End-user Capacitor Application - Regulating Utility Voltage with Distributed Resources – Flicker

Unit-5 Distributed Generation and Power Quality
Resurgence of Distributed Generation - DG Technologies - Interface to the Utility System - Power Quality Issues - Operating Conflicts - DG on Low Voltage Distribution Networks - Interconnection standards - Wiring and Grounding - Typical Wiring and Grounding Problems - Solution to Wiring and grounding Problems

Course Outcomes:

After completion of this course the students will be able to:

- Have the knowledge on causes of power quality, power quality parameters.
- Understand sources of transient over voltages and providing protection to transient over voltages.
- Understand effects of harmonics, sources of harmonics and harmonic minimization.
- Analyze long duration voltage variations and regulation of voltage variations.
- Describe power quality aspects in distributed generation and develop solutions to wiring and grounding problems.

Reference Books :

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
3. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
4. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
5. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
6. Power Quality c.shankaran, CRC Press, 2001
7. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis)
8. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier

I-II	POWER SYSTEM RELIABILITY (Elective – III)	L / P / Credits 4/ -- / 3

Prerequisites: Probability theory, power systems.

Course Educational Objectives:

- Will be able to get the basic understanding of network modelling and reliability.
- Markov chains.
- Reliability analysis of generation systems.
- Decomposition techniques.

Unit 1 : Basic probability theory – rules for combining probabilities of events – Bernoulli`s trials – probability density and distribution functions – binomial- distributions – expected value and standard deviation of binomial distribution.

Unit 2 : Network Modelling and Reliability Analysis of Series, Parallel, Series-Parallel networks – complex networks – decomposition method
Reliability functions F(t), F(t), R(t), h(t) and their relationship – exponential distributions – Expected value and standard deviation of exponentional distribution – Bath tub curve – reliability analysis of series parallel networks using exponential distribution – reliability measures MTTF, MTTR, MTBF

Unit 3 : Markov chains – concept of stochastic transitional probability Matrix, Evaluation of limiting state Probabilities – Markov processes one component repairable system – time dependent probability evaluation using Laplace transform approach – evaluation of limiting state probabililties using STPM – two component repairable models – Frequency and duration concept – Evaluation of frequency of encountering state, mean cycletime, for one, two component repairable models – evaluation of cumulative probability and cumulative frequency of encountering merged states

Unit 4 : Generation system reliability analysis – reliability model of a generation system – recursive relation for unit addition and removal – load modelling – merging of generation load model – evaluation of transition rates for merged state model – cumulative Probability, cumulative frequency of failure evaluation – LOLP, LOLE.

Unit 5 : Composite system reliability analysis decomposition method – distribution system reliability analysis – radial networks – weather effects on transmission lines – Evaluation of load and energy indices.

Course Outcomes:

After completion of this course the students will be able to:

- Understand reliability analysis applied to power systems.
- Understand Markov Chains and application to power systems.
- Perform stability analysis of generation systems.
- Understand decomposition techniques applied to power system.

Reference Books :

1. Reliability Evaluation of Engg. System – R.Billinton, R.N.Allan, Plenum Press, New York.
2. Reliability Evaluation of Power System – R.Billinton, R.N.Allam, Plenum Press, New York
3. An Introduction to Realiability and Maintainability Engineering. Sharies E Ebeling, TATA McGraw Hill – Edition

I-II **VOLTAGE STABILITY (Elective III)** **L / P / Credits 4/ -- / 3**

Prerequisites: Basic concepts of power system analysis and power factor correction.

Course Educational Objectives:

- To study the importance of voltage stability.
- To study the various load modelling in power system.
- To study the effect of reactive power compensation and voltage control.
- To study the modelling of voltage stability static indices.
- To study the voltage stability margin and its improvement.

Unit 1: Reactive Power flow and voltage stability in power systems: Physical relationship indicating dependency of voltage on reactive power flow - reactive power transient stability; Q-V curve; definition of voltage stability, voltage collapse and voltage security. Voltage collapse phenomenon, Factors of voltage collapse, effects of voltage collapse.

Unit 2: Power system loads: Load characteristics that influence voltage stability such as – Discharge lighting, lighting and heating loads, Induction motor, Air conditioning and heat pumps, Electronic power supplies, Overhead lines and cables.

Unit 3 : Reactive Power compensation : Generation and absorption of reactive power – Reactive power compensators & voltage controllers : - shunt capacitors, synchronous phase modifier – static VAR system – on load tap changing transformer, booster transformers.

Unit 4 : Voltage stability static indices : Development of voltage collapse index – power flow studies – singular value decomposition – minimum singular value of voltage collapse.

Unit 5: voltage stability margins & Improvement of voltage stability: Stability margins, voltage stability margin of un compensated and compensated power system. Dynamic voltage stability – voltage security , Methods of improving voltage stability and its practical aspects.

Course Outcomes:

After completion of this course the students will be able to:

- Know the importance of voltage stability.
- Determine the load modelling of power systems.
- Get the knowledge of reactive power compensation and voltage control.
- Determine the modelling of static voltage stability indices.
- Know the voltage stability margin and its improvement.

Reference Books :

1. Performance operation and control of EHV power transmission Systems A. chakrabarti, D.P.Kothari, A.K. Mukhopadhyay, A.H. Wheeler publishing, 1995.
2. Power system Voltage stability - C.W. Taylor , Mc. Graw Hill, 1994

I-II **POWER SYSTEM DEREGULATION** **L / P / Credits**
(Common to AEPS & HVE) **4/ -- / 3**
(Elective IV)

Prerequisites: Knowledge on power systems

Course Educational Objectives:

- To provide in-depth understanding of operation of deregulated electricity market systems.
- To examine typical issues in electricity markets and how these are handled world –wide in various markets.
- To enable students to analyze various types of electricity market operational and control issues using new mathematical models.

Unit 1

Need and conditions for deregulation. Introduction of Market structure, Market Architecture, Spot market, forward markets and settlements. Review of Concepts marginal cost of generation, least-cost operation, incremental cost of generation. Power System Operation.

Unit 2

Electricity sector structures and Ownership /management, the forms of Ownership and management. Different structure model like Monopoly model, Purchasing agency model, wholesale competition model, Retail competition model.

Unit 3

Framework and methods for the analysis of Bilateral and pool markets, LMP based markets, auction models and price formation, price based unit commitment, country practices

Unit 4

Transmission network and market power. Power wheeling transactions and marginal costing, transmission costing. Congestion management methods- market splitting, counter-trading; Effect of congestion on LMPs- country practices

Unit 5

Ancillary Services and System Security in Deregulation. Classifications and definitions, AS management in various markets- country practices. Technical, economic, & regulatory issues involved in the deregulation of the power industry.

Course Outcomes:

After completion of this course the students will be able to:

- Understand of operation of deregulated electricity market systems
- Typical issues in electricity markets
- To analyze various types of electricity market operational and control issues using new mathematical models.

Reference Books:

1. Power System Economics: Designing markets for electricity - S. Stoft, wiley.
2. Power generation, operation and control, -J. Wood and B. F. Wollenberg, Wiley.
3. Operation of restructured power systems - K. Bhattacharya, M.H.J. Bollen and J.E. Daalder, Springer.
4. Market operations in electric power systems - M. Shahidehpour, H. Yaminand Z. Li,Wiley.
5. Fundamentals of power system economics - S. Kirschen and G. Strbac, Wiley.
6. Optimization principles: Practical Applications to the Operation and Markets of the Electric Power Industry - N. S. Rau, IEEE Press series on Power Engineeirng.
7. Competition and Choice in Electricity - Sally Hunt and Graham Shuttleworth, Wiley.

I-II	HIGH VOLTAGE TESTING TECHNIQUES (Common to AEPS & HVE) (Elective IV)	L / P / Credits 4/ -- / 3

Prerequisites: Basics of high voltage engineering.

Course Educational Objectives:

- To understand non-destructive testing methods.
- To understand commercial and technical testing of different HV power applications.

Unit 1 : Non Destructive Testing Techniques : Measurement of DC Resistivity – Dielectric loss and dielectric constant of insulating materials – Schering bridge method – Transformer ratio arm bridge for high voltage and high current applications – null detectors.

Unit 2 : High Voltage Testing of Power Apparatus : Need for testing standards – Standards for porcelain/Glass insulators-Classification of porcelain/glass insulator tests – Tests for cap and pin porcelain/Glass insulators.

Unit 3 : High voltage AC testing methods-Power frequency tests-Over voltage tests on insulators, Isolators, Circuit Breakers and power cables. Artificial Contamination Tests : Contamination flashover phenomena-Contamination Severity-Artificial contamination tests-Laboratory Testing versus in-Service Performance-Case study.

Unit 4 : Impulse Testing : Impulse testing of transformers, insulators, Surge diverters, Bushings, cables, circuit breakers.

Unit 5 : Partial Discharge Measurement : PD equivalent model-PD currents-PD measuring circuits-Straight and balanced detectors-Location and estimation of PD in power apparatus-PD measurement by non electrical methods-Calibration of PD detectors. RIV Measurements : Radio Interference – RIV – Measurement of RI and RIV in laboratories and in field. Different test arrangements and their limitations.

Course Outcomes:

After completion of this course the students will be able to:

- Understand different testing procedures on electrical a) Insulating materials
  b) Insulation Systems. c) Power apparatus.
- Learn the different testing techniques adopted on electrical power apparatus.

Reference Books :

1. High Voltage Engineering – by E.KUFFEL and W.S.ZAENGL, Pergamon press, Oxford 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Tata McGraw Hill Publishing Company Limited, New Delhi – 2001.
3. Discharge Detection in H.V. Equipment – by KREUGER, F.H. Haywood London – 1964.
4. Hyltencavallius. N. High voltage laboratory planning EnileHaefely&Co. Ltd. Based Switzerland 1988

5. Ryan H.M. and Whiskand: design and operation perspective of British UHV Lab IEE pre 133 H.V. Testing Techniques Halfly

I-II **POWER SYSTEM TRANSIENTS** **L / P / Credits**
(Elective IV) **4/ -- / 3**

Prerequisites: This course required knowledge of circuit transients, symmetrical components, fault analysis and lightning.

Course Educational Objectives:

- To study the effect of over voltages on power system.
- To study the techniques of travelling wave on transmission lines.
- To study the effect of lightning and switching transients on power systems.

Unit 1 : Basic Concepts and Simple Switching Transients;- Switching an LR,LC,RLC circuits Transients Analysis of Three-Phase power Systems: – Symmetrical components inthree-phase Systems, Sequence Components for Unbalanced Network Impedances, the Sequence Networks, analysis of Unsymmetrical Three-Phase Faults-single line-to-Ground Fault, Three phase-to-ground fault.

Unit 2 : Travelling Waves:- Velocity of Travelling waves and Characteristic Impedance, Energy Contents of Travelling Waves, Attenuation and Distortion of Electromagnetic Waves, telegraph equations-lossless line, distortion less line, Reflection and Refraction of Travelling Waves, Reflection of Travelling Waves against Transformer-and-Generator-windings, the Origin Transient Recovery voltages, bewley-lattice diagram. travelling waves and multi conductor system.

Unit 3 :Switching Transients:- arc interruption in circuit breaker , transient recovery voltage, arc-circuit interaction, interruption of capacitive currents, interruption of inverse currents, interruption of fault current in transmission line and transformers.

Unit 4 : Power System Transient Recovery Voltages:-Characteristics of the Transient Voltage- Short-circuit test duties based on IEC 60056 (1987),ANSI/IEEE Standards, the Harmonization between IEC and ANSI/IEEE Standards with respect to Short-circuit Test duties, transient recovery voltage for Different types of faults.

Unit 5 : Lightning –Induced Transients:-Mechanism of Lightning, wave shape of the lightning current, Direct lighting Stroke to transmission line towers, direct lightening stroke to a line, lightning protection scheme. Numerical simulation of electrical transients, The Electromagnetic Transient Program, principles of numerical techniques used in transient simulation.

Course Outcomes:
After completion of this course the students will be able to:

- Understand the severity of over voltages due to faults on a given power system.
- To limit the effects of lightning over voltages in power systems.
- Understand the various transient over voltages and their effects on power system.

Reference Books :

1. Electrical Transients in Power System by Allen Greenwood, McGraw Hill 1990
2. Power system grounding & transients by A.P.SakisMeliopolous.
3. "Transients in power systems" by Lou Van Sluis
4. Bewley LV "travelling waves on transmission system" Dover publications Inc.,
5. Walter Diesendorf, Insulation co-ordination in high-voltage electric power systems, Butterworths, London, (1974),
6. J. G. Anderson: EHV Transmission Line Reference Book (Edison Electric Institute, New York, 1968) p. 126.

I-II

DEMAND SIDE ENERGY MANAGEMENT (Elective IV)

L / P / Credits
4/ -- / 3

Prerequisites: Students require concepts on utilization of electrical energy.

Course Educational Objectives:

- To know the energy audit principles in power system.
- To know the energy economics associated with consumption of energy.
- To know the energy conservation in electric utility and industry.
- To know the lighting schemes and methods to conserve the energy.
- To understand the energy conservation aspect in space heating, ventilation, air Condition etc.

Unit-1 : Energy Audit and Energy management information systems: Energy audit: Definitions-Need-concepts-Types of energy audit; Energy management information systems: Introduction-Need-components-designing-using the system-identifying plant outages

Unit-2 : Energy Economics: Introduction-Cost benefit risk analysis-Payback period-Straight line depreciation-Sinking fund depreciation—Reducing balance depreciation-Net present value method-Internal rate of return method-Profitability index for benefit cost ratio.

Unit-3 : Energy Conservation in Electric utilities and Industry: Electrical load management: Energy and load management devices-Conservation strategies; conservation in electric utilities and industry: Introduction-Energy conservation in utilities by improving load factor-Utility voltage regulation-Energy conservation in Industries-Power factor improvement.

Energy –efficient electric motors: Energy efficient motors-construction and technical features-case studies of EEMs with respect to cost effectiveness-performance characteristics; Economics of EEMs and system: life cycle-direct savings and payback analysis-efficiency factor or efficiency evaluation factor

Unit-4 : Electric Lighting: Introduction-Need for an energy management program-Building analysis-Modification of existing systems-Replacement of existing systems-priorities:
Illumination requirement : Task lighting requirements-lighting levels-system modifications-non illumination modifications-lighting for non task areas-reflectances-space geometry ;System elements: light sources - characteristics of families of lamps-lamp substitution in an existing systems-selection of Higher efficiency lamps for a new system-Luminaries-ballasts-energy conservation in lighting.

Unit-5 : Space Heating ,Ventilation, Air-Conditioning(HVAC) and Water Heating: Introduction-Heating of buildings-Transfer of Heat-Space heating methods-Ventilation and air-conditioning-Insulation-Cooling load-Electric water heating systems-Energy conservation methods.

Co-generation and storage: Combined cycle cogeneration-energy storage: pumped hydro schemes-compressed air energy storage(CAES)-storage batteries-superconducting magnetic energy storage (SMES).

Course Outcomes:

After completion of this course the students will be able to:

- Understand the principles and application of energy audit.
- Understand energy economics in utility systems.
- Understand the principle of energy conservation in lightning schemes.
- Apply energy audit principles in heating, ventilation and airconditioning etc.

Reference Books :

1.Energy management Hand book by Wayne C.Turner,Johnwiley and sons publications
2.Electric Energy Utilization and Conservation by S C Tripath, TMH publishing company ltd.New Delhi
3.Energy efficient electric motors selection and application by John C.Andreas
4.Hand book on Energy Audit and Management by AmitkumarTyagi,published by TERI(Tata energy research Institute)
5.Energy management by Paul W.O' Callaghan McGraw hill book company
6.Energy conversion systems by Rakosh Das Begamudre New age international publishers.

I-II **POWER SYSTEMS LABORATORY** **L / P / Credits**
--/ 4 / 2

Course Educational Objectives:
To understand the experimental determination of various parameters used in power system area and to analyse the performance of transmission line with and without compensation.

List of Experiments:

1. Determination of Sequence Impendence of an Alternator by direct method.
2. Determination of Sequence impedance of an Alternator by fault Analysis.
3. Measurement of sequence impedance of a three phase transformer
   (a). by application of sequence voltage.
   (b). using fault analysis.
4. Power angle characteristics of a salient pole Synchronous Machine.
5. Poly-phase connection on three single phase transformers and measurement of phase displacement.
6. Determination of equivalent circuit of 3-winding Transformer.
7. Measurement of ABCD parameters on transmission line model.
8. Performance of long transmission line without compensation.
9. Study of Ferranti effect in long transmission line.
10. Performance of long transmission line with shunt compensation.

Course Outcomes:
After the Completion of lab they will understand procedure for determination of various parameters used in power system as well as performance of transmission line.