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SEMESTER – VII
EXA-701 Power System Protection

EXA-701	**Power System Protection**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Course Preamble:

To provide an overview of the principles and schemes for protecting **power** lines, transformers, buses, generators and introduces the fundamentals of wide-area monitoring and control

Course Outcomes: At the end of this course, students will demonstrate the ability to

- Understand the different components of a protection system.
- Evaluate fault current due to different types of fault in a network.
- Understand the protection schemes for different power system components.
- Understand the basic principles of digital protection.
- Understand system protection schemes, and the use of wide-area measurements.

Unit 1: Introduction and Components of a Protection System (6 hours)
Principles of Power System Protection, Relays, Instrument transformers, Circuit Breakers

Unit 2: Faults and Over-Current Protection (6 hours)
Review of Fault Analysis, Sequence Networks. Introduction to Overcurrent Protection and overcurrent relay co-ordination.

Unit 3: Equipment Protection Schemes (10 hours)

Directional, Distance, Differential protection. Transformer and Generator protection. Busbar Protection, Bus Bar arrangement schemes,

Digital Protection Computer-aided protection, Fourier analysis and estimation of Phasors from DFT. Sampling, aliasing issues.

Unit 4: Modeling and Simulation of Protection Schemes (10 hours)
CT/PT modeling and standards, Simulation of transients using Electro-Magnetic Transients (EMT) programs. Relay Testing.

Unit 5: System Protection (10hours)
Effect of Power Swings on Distance Relaying. System Protection Schemes. Under-frequency, under- voltage and df/dt relays, Out-of-step protection, Synchro-phasors, Phasor Measurement Units and Wide-Area Measurement Systems (WAMS). Application of WAMS for improving protection systems.

Text/References

1. J. L. Blackburn, “Protective Relaying: Principles and Applications”, Marcel Dekker, New York, 1987.
2. Y. G.Paithankar and S. R. Bhide, “Fundamentals of power system protection”, Prentice Hall, India, 2010.
3. A. G. Phadke and J. S. Thorp, “Computer Relaying for Power Systems”, John Wiley & Sons, 1988.
4. A. G. Phadke and J. S. Thorp, “Synchronized Phasor Measurements and their Applications”, Springer, 2008.
5. D. Reimert, “Protective Relaying for Power Generation Systems”, Taylor and Francis, 2006.

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EXA-701 Power System Protection

6.

EXA-701	**Power System Protection**	**0L:0T:1P**	**1 credits**	**2Hrs/Week**

List of Experiments :(Extendable)

1.
2. 1. Determination of drop out factor of an instantaneous over current relay.
3. 2. Determination of operating characteristic of IDMT relay.
4. 3. Determination of operating characteristic of differential relay.
5. 4. Study and operation of gas actuated protective relay.
6. 5. Study and operation of static over current relay
7. 6. Analysis of power system faults (Symmetrical & Asymmetrical) using MATLAB.
8. 7. Study of SF6 circuit breaker

8. Protectional simulation study of generator, Transformer, Feeder & Motor protection

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EXA-702 Electrical Drives

EXA-702	**Electrical Drives**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Preamble:

To provide fundamental knowledge in dynamics and control of Electric Drives. To justify the selection of Drives for various applications. To familiarize the various semiconductor controlled drives employing various motors.

Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the characteristics of dc motors and induction motors.
- Understand the principles of speed-control of dc motors and induction motors.
- Understand the power electronic converters used for dc motor and induction motor speed control.

Unit 1: DC motor characteristics (6 hours)

Review of emf and torque equations of DC machine, review of torque-speed characteristics of separately excited dc motor, change in torque-speed curve with armature voltage, example load torque-speed characteristics, operating point, armature voltage control for varying motor speed, flux weakening for high speed operation.

Unit 2: Chopper fed DC drive (6 hours)

Review of dc chopper and duty ratio control, chopper fed dc motor for speed control, steady state operation of a chopper fed drive, armature current waveform and ripple, calculation of losses in dc motor and chopper, efficiency of dc drive, smooth starting.

Unit 3: Multi-quadrant DC drive (6 hours)

Review of motoring and generating modes operation of a separately excited dc machine, four quadrant operation of dc machine; single-quadrant, two-quadrant and four-quadrant choppers; steady-state operation of multi-quadrant chopper fed dc drive, regenerative braking.

Unit 4: Closed-loop control of DC Drive (12 hours)

Control structure of DC drive, inner current loop and outer speed loop, dynamic model of dc motor – dynamic equations and transfer functions, modeling of chopper as gain with switching delay, plant transfer function, for controller design, current controller specification and design, speed controller specification and design.

Induction motor characteristics

Review of induction motor equivalent circuit and torque-speed characteristic, variation of torque- speed curve with (i) applied voltage, (ii) applied frequency and (iii) applied voltage and frequency, typical torque-speed curves of fan and pump loads, operating point, constant flux operation, flux weakening operation.

Unit 5: Scalar control or constant V/f control of induction motor (12 hours)

Review of three-phase voltage source inverter, generation of three-phase PWM signals, sinusoidal modulation, space vector theory, conventional space vector modulation; constant V/f control of induction motor, steady-state performance analysis based on equivalent circuit, speed drop with loading, slip regulation.

Control of slip ring induction motor

Impact of rotor resistance of the induction motor torque-speed curve, operation of slip-ring induction motor with external rotor resistance, starting torque, power electronic based rotor side control of slip ring motor, slip power recovery.

References:

1. G. K. Dubey, “Power Semiconductor Controlled Drives”, Prentice Hall, 1989.
2. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control”, Prentice Hall, 2001.
3. G. K. Dubey, “Fundamentals of Electrical Drives”, CRC Press, 2002.
4. W. Leonhard, “Control of Electric Drives”, Springer Science & Business Media, 2001.

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EXA-702	**Electrical Drives**	**0L:0T:1P**	**1 credits**	**2Hrs/Week**

List of experiments:

1.To study the starting and running characteristics of converter fed DC traction motor.
2. To study the energy recovery systems and braking of a DC drive.
3. To study the braking methods of a three-phase induction motor.
4. To study the performance of VSI fed three-phase induction motor using PWM technique.
5. To control the speed of a three phase slip ring Induction motor using rotor impedance control.
6. To study the performance of Vector Controlled three phase Induction motor drive.
7. To Study frequency Controlled Synchronous motor drive.

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Open Core Elective-III

EXA-703 (A) Wind and Solar Energy Systems

EXA-703 (A)	**Wind and Solar Energy Systems**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Course Preamble:

To study clean and *renewable energy* sources, i.e. *wind energy turbines* and *systems*, *solar* photovoltaic devices and *systems* and to practice *system*-level designs, analytical design and analysis and modeling and simulation.

Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the energy scenario and the consequent growth of the power generation from renewable energy sources.
- Understand the basic physics of wind and solar power generation.
- Understand the power electronic interfaces for wind and solar generation.
- Understand the issues related to the grid-integration of solar and wind energy systems.

Unit 1: Physics of Wind Power: (6 Hours)

History of wind power, Indian and Global statistics, Wind physics, Betz limit, Tip speed ratio, stall and pitch control, Wind speed statistics-probability distributions, Wind speed and power-cumulative distribution functions.

Unit 2: Wind generator topologies: (10 Hours)

Review of modern wind turbine technologies, Fixed and Variable speed wind turbines, Induction Generators, Doubly-Fed Induction Generators and their characteristics, Permanent-Magnet Synchronous Generators, Power electronics converters. Generator-Converter configurations, Converter Control.

Unit 3: The Solar Resource: (6 Hours)

Introduction, solar radiation spectra, solar geometry, Earth Sun angles, observer Sun angles, solar day length, Estimation of solar energy availability.

Unit 4: Solar photovoltaic: (10 Hours)

Technologies-Amorphous, monocrystalline, polycrystalline; V-I characteristics of a PV cell, PV Unit , array, Power Electronic Converters for Solar Systems, Maximum Power Point Tracking (MPPT) algorithms.Converter Control.

Unit 5: Network Integration Issues: (10 Hours)

Overview of grid code technical requirements. Fault ride-through for wind farms - real and reactive power regulation, voltage and frequency operating limits, solar PV and wind farm behavior during grid disturbances. Power quality issues. Power system interconnection experiences in the world. Hybrid and isolated operations of solar PV and wind systems.

Solar thermal power generation:

Technologies, Parabolic trough, central receivers, parabolic dish, Fresnel, solar pond, elementary analysis.

Text / References:

1. T. Ackermann, “Wind Power in Power Systems”, John Wiley and Sons Ltd., 2005.
2. G. M. Masters, “Renewable and Efficient Electric Power Systems**”,** John Wiley and Sons, 2004.
3. S. P. Sukhatme, “Solar Energy: Principles of Thermal Collection and Storage”, McGraw Hill, 1984.
4. H. Siegfried and R. Waddington, “Grid integration of wind energy conversion systems” John Wiley and Sons Ltd., 2006.
5. G. N. Tiwari and M. K. Ghosal, “Renewable Energy Applications”, Narosa Publications, 2004.
6. J. A. Duffie and W. A. Beckman, “Solar Engineering of Thermal Processes”, John Wiley & Sons, 1991.

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EXA-703 (B) Strength of Materials

EXA-703 (B)	**Strength of Materials**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Preambles:

- To understand the nature of stresses developed in simple geometries such as bars, cantilevers, beams, shafts, cylinders and spheres for various types of simple loads
- To calculate the elastic deformation occurring in various simple geometries for different types of loading

Course Outcomes:

- After completing this course, the students should be able to recognise various types loads applied on machine components of simple geometry and understand the nature of internal stresses that will develop within the components
- The students will be able to evaluate the strains and deformation that will result due to the elastic stresses developed within the materials for simple types of loading

Unit 1 Deformation in solids-:: (10 Hours)

Hooke's law, stress and strain- tension, compression and shear stresses- elastic constants and their relations- volumetric, linear and shear strains- principal stresses and principal planes- Mohr's circle.

Unit 2 Beams and types transverse loading on beams-: (10 Hours)

shear force and bend moment diagrams- Types of beam supports, simply supported and over-hanging beams, cantilevers. Theory of bending of beams, bending stress distribution and neutral axis, shear stress distribution, point and distributed loads.

Unit 3 Moment of inertia: (10 Hours)

Moment of inertia about an axis and polar moment of inertia, deflection of a beam using double integration method, computation of slopes and deflection in beams, Maxwell's reciprocal theorems.

Unit 4 Torsion: (6 Hours)

Torsion, stresses and deformation in circular and hollow shafts, stepped shafts, deflection of shafts fixed at both ends, stresses and deflection of helical springs.

Unit 5 Axial and hoop stresses (6 Hours)

Axial and hoop stresses in cylinders subjected to internal pressure, deformation of thick and thin cylinders, deformation in spherical shells subjected to internal pressure

Course Outcomes:

- After completing this course, the students should be able to recognise various types loads applied on machine components of simple geometry and understand the nature of internal stresses that will develop within the components
- The students will be able to evaluate the strains and deformation that will result due to the elastic stresses developed within the materials for simple types of loading

Text Books:

1. Egor P. Popov, Engineering Mechanics of Solids, Prentice Hall of India, New Delhi, 2001.
2. R. Subramanian, Strength of Materials, Oxford University Press, 2007.
3. Ferdinand P. Been, Russel Johnson Jr and John J. Dewole, Mechanics of Materials, Tata McGrawHill Publishing Co. Ltd., New Delhi 2005.

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EXA-703(C) Intelligent System

EXA-703 (C)	Intelligent System	3L:0T:0P	3 credits	3Hrs/Week

Course Preambles:

The primary Preamble of this course is to introduce the basic principles, techniques, and applications of Artificial Intelligence. ... Investigate applications of AI techniques in intelligent agents, expert systems, artificial neural networks and other machine learning models.

Course Outcomes:
Students will gain deep understanding of the basic artificial *intelligence* techniques. o Strategies and Actions used to produce the *outcome*: ▪ Learn about artificial *intelligence* techniques and *intelligent systems*

UNIT I Fundamental Issues in IS: (6 Hrs)

Definition of AI , History ,Domains AI ,AI problems & State space ,Some examples problems representations like Travelling Salespersons, Syntax analysis Problem. Basic issues to solve AI problems, Underlying assumptions, AI techniques, Level of model, Criteria for success, Control strategies, DFS, BFS

UNIT II Heuristic Search Techniques (4 Hrs)
Generate & Test, Hill Climbing (simple &stipest), Best first search, A*, AO*, Constraint Satisfaction.

UNIT III Knowledge Representation Issues: (12 Hrs)
Syntax & Semantic for Propositional logic, Syntax & Semantic for FOPL, Properties for WFF_s, Resolution Basics : conversion to clausal form ,Resolution of proposition logic, Resolution algorithms for predicates, Problems with FOPL ,Semantic nets ,Frames ,Scripts

UNIT IV Reasoning under Uncertainty: (10 Hrs)
An introduction, Default reasoning & Closed world assumptions, Model & Temporal logic ,Fuzzy logic, Basian Probabilistic inference Dempster Shafer theory ,Heuristic reasoning methods

UNIT V Planning & Learning: (10 Hrs)
Planning, Planning in Situational calculus ,Representation for planning ,Partial order palnning, Partial order palnning algorithm, Learning by Examples, Learning by Analogy, Explanation based learning, Neurals nets, Genetics algorithms
Minimax: Game playing strategy, Natural language processing ,Overview of linguistics , Grammer& Language, Transformation Grammer, Basic Parsing Techniques, Expert System, Architecture of Rule based Expert system ,Non Rule based Expert system.

References:
1. Artificial Intelligence by Elain Rich & Kevin Knight, Tata McGraw Hills Pub.
2. Principals of AI by Nills .J.Nilsson, Pearson Education Pub. 177
3. Artificial Intelligence by DAN. W.Petterson. Printice Hall of India
4. Artificial Intelligence by Petrick Henry Winston,
5. Artificial Intelligence by Russel and Norvig, Pearson Education Pub.

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Open Core Elective IV

EXA-704 (A) Prime Movers

EXA-704 (A)	**Prime Movers**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Unit-I Fluid Mechanics: (10 Hrs):
Newtonian and non-newtonian fluids, viscosity, types of fluid flows, continuity, momentum & energy equations, Bernoulli's equation and its applications, laminar and turbulent flows, flow through pipes, friction losses in pipes, Darcy equation, Reynolds number and its significance.

Unit-II Hydraulic Turbines: (10 Hrs):
Classification and working principles of turbines, Pelton, Francis, and Kaplan turbine, velocity diagrams for impulse and reaction turbine, calculation of blade angles, work-done, power output and efficiencies, specific speed of turbines, function of draft tube and type of draft tubes, unit quantities, performance and characteristic curves.

Unit-III Generation of steam: (10 Hrs):
Dryness fraction and properties of steam function of boilers, working principle of Lancashire boiler, Cornish boiler, Cochran boiler, Locomotive boiler, Babcock and Wilcox boiler, boiler mounting and accessories, Rankine and Modified Rankine cycle for steam engines, evaluation of mean effective pressure, power and cylinder dimension for single acting and double acting steam engines.

Unit-IV Steam turbines: **(4 Hrs):**
Classification of steam turbines, velocity diagrams for simple impulse and reaction turbines, compounding of steam turbines, pressure compounding, velocity compounding, and pressure-velocity compounding, problems on work done, blade angles, power and thermal efficiency of the turbine. Gas turbine, classification of gas turbine-constant pressure combustion cycle, closed cycle and constant volume combustion gas turbine plants, calculation of various efficiencies and parameters.

Unit-V Pumps: (8 Hrs):
Reciprocating pumps, working of single and double acting types, effect of acceleration head and friction, use of air vessels, work done and power required without and with air vessels centrifugal pumps: classification and working of centrifugal pumps, need for priming, work done and efficiencies, specific speed of pumps, cavitation and its effect on performance.

References:

1. R.K.Rajput, Thermal Engineering, Laxmi Publications, 2004
2. R.Yadav, Steam and Gas turbines, Central Publishing House Ltd 2004 .
3. S.Ramamrutham, Hydraulic Machines, Dhanpat Raiand Sons.2004.

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EXA-704 (B) Total Quality Management

EXA-704 (B)	**Total Quality Management**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Preambles: To facilitate the understanding of total quality management principles and processes

Course Outcomes: Upon completion of this course, the students will be able to use the tools and techniques of TQM in manufacturing and service sectors.

Unit 1 Introduction (6 Hrs)

need for quality, evolution of quality; Definitions of quality, product quality and service quality; Basic concepts of TQM, TQM framework, contributions of Deming, Juran and Crosby. Barriers to TQM; Quality statements, customer focus, customer orientation & satisfaction, customer complaints, customer retention; costs to quality.

Unit 2 TQM principles (6 Hrs)

leadership, strategic quality planning; Quality councils- employee involvement, motivation; Empowerment; Team and Teamwork; Quality circles, recognition and reward, performance appraisal; Continuous process improvement; PDCE cycle, 5S, Kaizen; Supplier partnership, Partnering, Supplier rating & selection.

Unit 3 The seven traditional tools of quality (10Hrs)

New management tools; Six sigma- concepts, methodology, applications to manufacturing, service sector including IT, Bench marking process; FMEA- stages, types.

Unit 4 TQM tools and techniques, (10 Hrs)

control charts, process capability, concepts of six sigma, Quality Function Development (QFD), Taguchi quality loss function; TPM- concepts, improvement needs, performance measures. Quality systems, need for ISO 9000, ISO 9001-9008;

Unit 5 Quality system-(10Hrs)

Elements, documentation,; Quality auditing, QS 9000, ISO 14000- concepts, requirements and benefits; TQM implementation in manufacturing and service sectors.

Text Books:

1. Bester field D.H. et al., Total quality Management, 3rd ed., Pearson Education Asia, 2006.

2. Evans J.R. and Lindsay W.M., The management and Control of Quality, 8th ed., first Indian edition, Cengage Learning, 2012.

3. Janakiraman B. and Gopal R.K., Total Quality Management, Prentice Hall India, 2006. Suganthi L. and Samuel A., Total Quality Management, Prentice Hall India, 2006.

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EXA-704 (C) Evolutionary Techniques

EXA-704 (C)	**Evolutionary Techniques**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Unit –I: Introduction: (8 Hrs)
Approaches to intelligent control, architecture for intelligent control, symbolic reasoning system, rule-based systems, the AI approach, knowledge representation - expert systems.

Unit –II: Artificial Neural Networks: (6 Hrs)
Basic concept mathematical model, mcculloch-pitts neuron model, simple perceptron, Adaline and Madaline, feed-forward multilayer perceptron, learning and training the neural network, data processing, scaling, fourier transformation, principal-component analysis, wavelet transformations, hopfield network, self-organizing network and recurrent network, neural network based controller.

Unit –III: Fuzzy Logic System: (12 Hrs)
Crisp sets, fuzzy sets, basic fuzzy set operation and approximate reasoning, fuzzy logic modeling and control, fuzzification, inferencing and defuzzification, fuzzy knowledge and rule bases, fuzzy modeling and control schemes for nonlinear systems, self organizing fuzzy logic control.

Unit –IV: Genetic Algorithm: (10 Hrs)
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.

Unit –V: Applications: (10 Hrs)
GA application to power system optimisation problem, Case studies: Identification and control of linear and nonlinear dynamic systems using MATLAB-neural network toolbox, stability analysis of neural-network interconnection systems, implementation of fuzzy logic controller using MATLAB fuzzy-logic toolbox, stability analysis of fuzzy control systems.

References:

1. Introduction to Artificial Neural Systems - Jacek.M.Zurada, Jaico Publishing House, 1999.
2. Neural Networks and Fuzzy Systems - Kosko, B., Prentice-Hall of India Pvt. Ltd., 1994.
3. Fuzzy Sets, Uncertainty and Information - Klir G.J. & Folger T.A., Prentice-Hall of India Pvt. Ltd., 1993.
4. Fuzzy Set Theory and Its Applications - Zimmerman H.J. Kluwer Academic Publishers, 1994.. Introduction to Fuzzy Control - Driankov, Hellendroon, Narosa Publishers.
5. Artificial Neural Networks - Dr. B. Yagananarayana, 1999, PHI, New Delhi.
6. Elements of Artificial Neural Networks - Kishan Mehrotra, Chelkuri K. Mohan, Sanjay Ranka, Penram International.
7. Artificial Neural Network –Simon Haykin, 2nd Ed., Pearson Education.
8. Introduction Neural Networks Using MATLAB 6.0 - S.N. Shivanandam, S. Sumati, S. N. Deepa,1/e, TMH, New Delhi.

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EXA 705 Projects-I (Major)

EXA 705	**Project-I (Minor)**	**0L:0T:4P**	**4 credits**	**8Hrs/Week**

Course Outcomes:

At the end of this course students will demonstrate the ability to

1. Design and validate electrical algorithms for optimum solution
2. Analyze the dynamic response and the calibration of few instruments
3. Build projects as per industry and society demands.

Guidelines:

1. The Major-project is a team activity having 3-4 students in a team. This is electronic product design work with a focus on electronic circuit design.
2. The Major project may be a complete hardware or a combination of hardware and software.The software part in Minor project should be less than 50% of the total work.
3. Minor Project should cater to a small system required in laboratory or real life.
4. It should encompass components, devices, analog or digital ICs, micro controller with which functional familiarity is introduced.
5. After interactions with course coordinator and based on comprehensive literature survey/need analysis, the student shall identify the title and define the aim and Preambles of Minor project.
6. Student is expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within first week of the semester.
7. The student is expected to exert on design, development and testing of the proposed work as per the schedule.
8. Art work and Layout should be made using CAD based PCB simulation software. Due considerations should be given for power requirement of the system, mechanical aspects for enclosure and control panel design.

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EXA-706 Self Study/GD/Seminar

EXA-706	**Self-Study/GD/Seminar**	**0L:0T:1P**	**1 credits**	**1Hrs/Week**

Course Preamble:

The main Preamble is to improve the mass communication and convincing/understanding skills of students .And to give the students an opportunity to exercise their rights to express themselves. The evaluation will be done based on their presentation work and group discussion.

Couse Outcomes:

In terms of **content**, students will be able to

Presentation Skills

They will be able to make use of visual, audio and audio-visual material to support their presentation, and will be able to speak cogently with or without notes. Students will present either in groups or as individuals.

Discussion Skills

Students will be able to judge when to speak and how much to say, speak clearly and audibly in a manner appropriate to the subject, ask appropriate questions, use evidence to support claims, respond to a range of questions, take part in meaningful discussion

Listening Skills

Students will demonstrate that they have paid close attention to what others say and can respond constructively. Through listening attentively, they will be able to build on discussion fruitfully, supporting and connecting with other discussants. They will be able to follow academic discussions, infer meanings that are not overt, and take notes from a discussion or presentation.

Argumentative Skills and Critical Thinking

Students will develop persuasive speech, present information in a compelling, well-structured, and logical sequence, respond respectfully to opposing ideas, show depth of knowledge of complex subjects, and develop their ability to synthesize, evaluate and reflect on information.

Questioning

Through asking appropriate questions, students will demonstrate their understanding of discussions and spark further discussion.

Interdisciplinary Inquiry

Students will be able to reach across diverse disciplines to apply theories, methods and knowledge bases from multiple fields to a single question or problem.

Engaging with Big Questions

Students will engage with important questions that stimulate discussion and debate.

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Studying Major Works

Students will engage with works that are widely held to be significant in the field of study, while recognizing cultural diversity and the ever-changing nature of what is regarded as important.

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Program Elective – IV

EXA-701 (A) Power System Protection

EXA-701 (A)	**Power System Protection**	**3L:0T:0P**	**3 credits**	**3Hrs/Week**

Course Preamble:

To provide an overview of the principles and schemes for protecting **power** lines, transformers, buses, generators and introduces the fundamentals of wide-area monitoring and control

Course Outcomes: At the end of this course, students will demonstrate the ability to

- Understand the different components of a protection system.
- Evaluate fault current due to different types of fault in a network.
- Understand the protection schemes for different power system components.
- Understand the basic principles of digital protection.
- Understand system protection schemes, and the use of wide-area measurements.

Unit 1: Introduction and Components of a Protection System (6 hours)
Principles of Power System Protection, Relays, Instrument transformers, Circuit Breakers

Unit 2: Faults and Over-Current Protection (6 hours)
Review of Fault Analysis, Sequence Networks. Introduction to Overcurrent Protection and overcurrent relay co-ordination.

Unit 3: Equipment Protection Schemes(10 hours)

Directional, Distance, Differential protection. Transformer and Generator protection. Busbar Protection, Bus Bar arrangement schemes,

Digital Protection Computer-aided protection, Fourier analysis and estimation of Phasors from DFT. Sampling, aliasing issues.

Unit 4: Modeling and Simulation of Protection Schemes (10 hours)
CT/PT modeling and standards, Simulation of transients using Electro-Magnetic Transients (EMT) programs. Relay Testing.

Unit 5: System Protection (10hours)
Effect of Power Swings on Distance Relaying. System Protection Schemes. Under-frequency, under-voltage and df/dt relays, Out-of-step protection, Synchro-phasors, Phasor Measurement Units and Wide-Area Measurement Systems (WAMS). Application of WAMS for improving protection systems.

Text/References

1. J. L. Blackburn, “Protective Relaying: Principles and Applications”, Marcel Dekker, New York, 1987.
2. Y. G.Paithankar and S. R. Bhide, “Fundamentals of power system protection”, Prentice Hall, India, 2010.
3. A. G. Phadke and J. S. Thorp, “Computer Relaying for Power Systems”, John Wiley & Sons, 1988.
4. A. G. Phadke and J. S. Thorp, “Synchronized Phasor Measurements and their Applications”, Springer, 2008.
5. D. Reimert, “Protective Relaying for Power Generation Systems”, Taylor and Francis, 2006.