CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET473	DIGITAL PROTECTION OF POWER SYSTEMS	PEC	2	1	0	3

Preamble: The basic objective of this course is to deliver fundamental concepts to design various electronic circuits to implement various relaying functions. The relays such as Static Relays, Microprocessor based protective relays, Digital relay Travelling wave based protection and adaptive relaying is comprehensively covered in this course. It should be also useful to practicing engineers and the research community.

Prerequisite : 1) EET 301 Power Systems I

2) EET 304 Power Systems II

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

CO 1	Identify the relay protection scheme suitable for over current, differential and distance protection.
CO 2	Develop the protection scheme for bus bars, transformers, generators, motors and distribution systems using appropriate protective relays.
CO 3	Illustrate the operation of a numerical relay in his/her own way.
CO 4	Explain signal processing methods and algorithms in digital protection.
CO 5	Infer emerging protection schemes in power systems.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2	-	-	-	-	-	-	-	-	-	-
CO 2	3	3	3	-	-	-	-	-	-	-	-	-
CO 3	3	2	3	-	-	-	-	-	-	-	-	-
CO 4	3	2	3	-	-	-	-	-	-	-	-	-
CO 5	3	3	-	2	-	-	-	-	-	-	-	-

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	30
Understand	20	20	40
Apply	20	20	30
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Discuss how saturation affects the accuracy of C.T.s. (K2)
2. Why I.D.M.T. relays are widely used for over current protection (K2))
3. Develop a criteria for the selection off distance relays.(K3)

Course Outcome 2 (CO2)

1. In what way distance protection is superior to over current protection for the protection of transmission lines.(K2)
2. Discuss the working principle of frame leakage protection.(K2)
3. Explain the differential scheme for bus zone protection.(K1)

Course Outcome 3(CO3):

1. Explain the principle of operation of numerical relays. (K1)
2. What is the function of the sample and hold circuit.(K2)
3. Explain the sliding window concept.(K2)

Course Outcome 4 (CO4):

1. Explain the concept of Finite Impulse Response filters,(K2)
2. Explain sinusoidal wave based algorithms. (K1)
3. Explain Least squares based algorithm. (K1)

Course Outcome 5 (CO5):

1. Compare the different decision making schemes in protective relays.(K2)
2. Explain the concept of synchronized sampling. (K2)
3. What are the basic components of a phasor measurement unit.(K1)

Model Question Paper

QP CODE: **PAGES:4**

Reg.No:_____

Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION,

MONTH & YEAR

Course Code: EET473

Course Name : DIGITAL PROTECTION OF POWER SYSTEMS

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Explain the basic principle and characteristics of impedance relays.
2. Explain current setting and time setting.
3. Explain the effect of power swings on the performance of distance relays.
4. What are the features of directional protection schemes for distribution system.
5. Give a comparison of numerical relays with static relays.
6. What are the basic components of numerical relays. Explain
7. Why digital filtering is required in a digital relay. Explain.
8. What are the useful properties of finite impulse filter.
9. What are the advantages of adaptive relaying
10. Give the definition of wide-area protection

PART B (14 x 5 = 70 Marks)

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11.a) Explain the time current characteristics of inverse, very inverse and extremely inverse over current relays. Discuss their area of applications 7

b) What are the requirements of C.T. s used for protection. 7

12.a) Explain the types of construction used for P.T.s. 7

b) Explain the basic principle and characteristics of reactance and mho relays. 7

Module 2

13.a) With the help of a schematic diagram explain the carrier current protection scheme. 7

b) With the help of a neat diagram explain the working of harmonic restraint relay. 7

14.a) Explain the Phase comparison line protection scheme. 7

b) Explain the loss of excitation protection for a generator. 7

Module 3

15.a) With the help of a block diagram explain the basic components of a digital relay. 8

b) Explain the communication in protective relays (IEC 61850) 6

16.a) Briefly explain the information handling with substation automation system. 7

b) Explain the signal conditioning subsystem in numerical relays. 7

Module 4

17.a) Explain the full cycle window algorithm. 8

b) Give a comparison between infinite impulse filter and finite impulse filter. 6

18.a) Give the basic formulation of sample and first derivative method in sinusoidal wave based algorithm. 8

b) Explain how the impedance to the fault is found by using Least square method. 6

Module 5

19.a) Explain the methods of deterministic decision making and decision making with multiple criteria in protective relays. 8

b) Explain the architectures of wide-area protection 6

20.a) Explain the concept of Adaptive relaying and its applications. 8

b) Explain the Adaptive Differential protective scheme. 6

Syllabus

Module 1 (8 hours)

Introduction: Need for protective systems, Zones of protection, Current transformers and voltage transformers (Electromagnetic and Capacitive voltage transformers), Principle of operation of magneto optic CT/ PT, effect on relaying philosophy.

Relays: Over current relays - time-current characteristics of over current relays: definite time over current relays, inverse Definite Minimum time - directional over current relays, current setting and time setting - Numerical Problems - Differential relays: Operating and restraining characteristics, types of differential relays, Distance relays: impedance relays, reactance relays, mho relays, quadrilateral relays, elliptical relays (basic principles and characteristics only).

Module 2 (8 hours)

Protection of Transmission Line Systems: Schemes of distance protection, Differential line protection, Phase comparison line protection, Use of line carrier and communication links, Effect of power swings on the performance of distance relays.

Protection of Bus-bar, Transformer and Generator & Motor Systems*:* Types of faults, differential protection: High impedance and low impedance differential protection schemes, harmonic restraint relay, Restricted Earth Fault Protection, frame leakage protection, stator and rotor protection against various types of faults.

Pilot relaying schemes: Pilot wire protection, carrier current protection (Basic Principles and schematic).

Protection Scheme for Distribution Systems: Protection criteria for distribution system, Features of directional and non-directional protection schemes for distribution system,

Fundamentals of travelling wave protection scheme.

Module 3 (8 hours)

Introduction to Digital (Numerical) Relays- Basic Components of numerical Relays with block diagram, Processing Unit, Human machine Interface, Principle of operation- Comparison of numerical relays with electromechanical and static relays, Advantages of numerical relays - communication in protective relays (IEC 61850), Information handling with substation automation system (SAS)

Signal Conditioning Subsystems: Surge Protection Circuits, Anti-aliasing filter, Conversion Subsystem, The Sampling Theorem, aliasing, Sample and Hold Circuit, Concept of analog to digital and digital to analog conversion, Idea of sliding window concept, Fourier, Discrete and fast Fourier transforms

Module 4 (6 hours)

Signal processing techniques: Sinusoidal wave based algorithms, Fourier Analysis based algorithms (half cycle and full cycle), Least squares based algorithm.

Digital filters – Fundamentals of Infinite Impulse Response Filters, Finite Impulse Response filters, Filters with sine and cosine windows

Module 5 (6 hours)

Decision making in Protective Relays – Deterministic decision making, Statistical Hypothesis testing, Decision making with multiple criteria, Adaptive decision schemes.

Wide Area Protection and Measurement: Phasor Measurement Units, concept of synchronized sampling, Definition of wide-area protection, Architectures of wide-area protection, concept of Adaptive relaying, advantages of adaptive relaying and its application, Adaptive Differential protective scheme.

Assignment - Simulation of protection schemes using SIMULINK

Text/References Books

1. A. T. Johns and S. K. Salman, "Digital Protection for Power Systems," Peter Peregrinus Ltd, UK, 1995.
2. Waldemar Rebizant, Digital Signal Processing in Power System Protection and Control –Springer Publication
3. J. L. Blackburn, "Applied Protective Relaying," Westinghouse Electric Corporation, New York, 1982.
4. A. G. Phadke and J. S. Thorp, "Computer Relaying for Power Systems," Research study press Ltd, John Wiley & Sons, Taunton, UK, 1988.
5. S.P Patra, S.K Bl,lsu and S. Choudhary, "Power System Protection", Oxford IBH Pub.
6. S. Ravindernath and M. Chander, "Power System Protection and Switchgear", Wiley Eastern Ltd.
7. Badri Ram and Vishwakarma, Power System Protection and Switchgear, A McGraw Hill.
8. Digital Signal Processing in Power System Protection and Control by Waldemar Rebizant, Janusz Szafran ,Andrzej Wiszniewski - Springer publication

Course Contents and Lecture Schedule:

No	Topic	No. of Lectures
1	**Introduction to protective relays (8 hours)**	
1.1	Introduction: Need for protective systems, Zones of protection, Current transformers and voltage transformers (Electromagnetic and Capacitive voltage transformers), Principle of operation of magneto optic CT/ PT, effect on relaying philosophy.	2
1.2	Relays: Over current relays-time-current characteristics of over current	2

	relays: definite time over current relays, inverse Definite Minimum time -directional over current relays, current setting and time setting- Numerical Problems	
1.3	Differential relays: Operating and restraining characteristics, types of differential relays,	1
1.4	Distance relays: impedance relays, reactance relays, mho relays, quadrilateral relays, elliptical relays (basic principles and characteristics only).	3
2	**Protection of Transmission, Distribution, Bus-bar, Transformer, Generator & Motor Systems (8 hours)**	
2.1	**Protection of Transmission Line Systems:** Schemes of distance protection, Differential line protection, Phase comparison line protection, Use of line carrier and communication links, Effect of power swings on the performance of distance relays.	2
2.2	**Protection of Bus-bar, Transformer and Generator & Motor Systems*:*** Types of faults, differential protection: High impedance and low impedance differential protection schemes, harmonic restraint relay, Restricted Earth Fault Protection, frame leakage protection, stator and rotor protection against various types of faults.	3
2.3	**Pilot relaying schemes:** Pilot wire protection, carrier current protection (Basic Principles and schematic) .	1
2.4	**Protection Scheme for Distribution Systems:** Protection criteria for distribution system, Features of directional and non-directional protection schemes for distribution system, Fundamentals of travelling wave protection scheme.	2
3	**Introduction to Digital (Numerical) Relays (8 hours)**	
3.1	Basic Components of numerical Relays with block diagram, Processing Unit, Human machine Interface, Principle of operation- Comparison of numerical relays with electromechanical and static relays, Advantages of numerical relays	3
3.2	Communication in protective relays (IEC 61850), Information handling with substation automation system (SAS)	1
3.3	Signal Conditioning Subsystems: Surge Protection Circuits, Anti-aliasing filter, Conversion Subsystem, The Sampling Theorem, aliasing, Sample and Hold Circuit, Concept of analog to digital and digital to analog conversion	3
3.4	Idea of sliding window concept, Fourier, Discrete and fast Fourier transforms	1

4	**Signal processing techniques (6 hours)**	
4.1	Signal processing techniques: Sinusoidal wave based algorithms, Fourier Analysis based algorithms (half cycle and full cycle), Least squares based algorithm	3
4.2	Digital filters – Fundamentals of Infinite Impulse Response Filters, Finite Impulse Response filters, Filters with sine and cosine windows	3
5	**Decision making in Protective Relays (6 hours)**	
5.1	Decision making in Protective Relays – Deterministic decision making, Statistical Hypothesis testing, Decision making with multiple criteria, Adaptive decision schemes.	2
5.2	Wide Area Protection and Measurement: Phasor Measurement Units, concept of synchronized sampling, Definition of wide-area protection, Architectures of wide-area protection	2
5.3	concept of Adaptive relaying, advantages of adaptive relaying and its application, Adaptive Differential protective scheme.	2