

SWITCHGEAR AND PROTECTION

EENE 305

Year/Part: III/I

Teaching Schedule				Examination Scheme					
L	T	P	Total	Theory			Practical		
				Assessment Marks	Final		Assessment Marks	Final	
					Duration (Hrs)	Marks		Duration (Hrs)	Marks
4	1	1.5	6.5	40	3	60	25	0	0

Depth Codes:

E-Explanation	C-Circuit	D-Definition	DM-Demonstration
DV-Derivation	DW-Drawing	P-Proof	I-Illustration
NUM-Numerical	PRG-Programming	S-State	ACT-Activity-based Learning
MP-Mini Project	EXP-Experiment	REV-Review / Recap	PS-Problem Solving
QA-Question Answer	Q-Quiz	ST-Surprise Test	MT-Mid Term Test

Unit	Topic/Sub topic	Depth Code	Description	Actual Plan			Week
				L	T	P	
1	Fundamental of power system protection						
	1.1 Need for protective schemes	E, D, I	Meaning, necessity, objectives of protection; role in system stability	1	1		
	1.2 Types, causes and effects of Faults	E, D, I	Basic Symmetrical / asymmetrical faults, causes (environmental, mechanical, insulation failure), system impacts.	0.75			
	1.3 Functions of basic elements of a protective system	E, I	Role of CT, PT, relays, CB, Isolators / Disconnect Switches, fuses; coordination among elements	0.75			
	1.4 Zones of Protection, Primary and Backup Protection	E, DW, I	Typical Protection Zones, Why Overlap Is Important, Primary Protection, Backup Protection,	1			
	1.5 Essential Qualities of Protection	E, I	Speed, sensitivity, reliability, selectivity, stability	0.5			
	Evaluation	QA					

Unit	Topic/Sub topic	Depth Code	Description	Actual Plan			Week
				L	T	P	
2	Fuses, Isolators, and Contactors						
	2.1 Fuses: Characteristics, Fusing Factor, Types and classification, Selection, Applications, Discrimination	E, C, I, NUM	Characteristics of a Fuse - T-I Characteristic, Breaking Capacity, Rated Current, Rated Voltage, Fusing Factor. Types and Classification of Fuses - Low Voltage (LV) Fuses (Rewirable Fuse, Cartridge Fuse, D-O Fuse, Thermal Fuse) High Voltage (HV), Selection of Fuses Applications of Fuses, discrimination & grading	3.5	2		
	2.2 Isolators: construction, operating Principle, Classification, Types and applications	E, DW, I	Construction, Classification of Isolators (Voltage Level , Installation Location, Operating Mechanism), Types of Isolators (Single Break, Double Break, Pantograph, Bus	2.5			

			Transfer) Function of isolators, operation sequence, 1-phase/3-phase isolators, Applications of Isolators.				
	2.3 Contactors: Constructional features, NO/NC contacts, classifications, Operating principles, Applications and control circuits.	E, DW, I	Construction (Coil, core, contacts, arc chute, springs, enclosure), NO/NC Contacts, Classification Based on voltage, poles, duty, Operating Principle, Control Circuits (DOL, forward–reverse, star–delta, interlocking), Applications.	2			
	Evaluation	QA					

Unit	Topic/Sub topic	Depth Code	Description	Actual Plan			Week
				L	T	P	
3	Circuit Breakers						
	3.1 Need, importance in power system protection	E, C, I	Why CBs are required; protection against faults; system isolation	1	4		
	3.2 Arc Extinction Methods – High resistance interruption, low resistance interruption.	E, DV, I	Introduction to Arc Phenomenon, Fundamentals of Arc Extinction, Theory and Principles, Techniques for Increasing Arc Resistance, Applications, Advantages and Limitations.	2			
	3.3 Arc Phenomena, Restriking & Recovery Voltages	E, DV, NUM	Arc Phenomena, Restriking vs. Reignition, Effects of Restriking, Prevention of Restriking, RV, RRRV, dielectric recovery, power frequency recovery	1.5			
	3.4 Low Voltage (LV) Circuit Breakers: Construction, operating principle, arc extinction, merits & demerits, application area of MCB, MCCB, RCCB, ACB	E, DW, I	Construction, Operating Principle, Advantages and Disadvantages, arc extinction, trip characteristics, applications of MCB, MCCB, RCCB, ACB.	2.5			
	3.5 High Voltage (HV) Circuit Breakers: construction, operating principle, merits & demerits, arc extinction and application area of ABCB, BOCB, MOCB, VCB, SF6 Circuit Breaker	E, DW, I	Construction, Operating principle, Arc extinction method, merits/demerits, applications application area of ABCB, BOCB, MOCB, VCB, SF6 Circuit Breaker.	4			
	3.6 HVDC Circuit Breakers – Principle, applications, challenges in DC arc extinction.	E	Principle, challenges of DC arc extinction, Applications of HVDC Circuit breakers.	1			
	3.7 Auto-reclosure in Circuit Breakers – Importance in transmission lines, single-shot & multiple-shot reclosing.	E, I	Introduction to Auto- Reclosure, Types (single/multiple shot), importance in transmission lines,	1			
	3.8 Testing of Circuit Breakers: Type Tests, Routine Tests and Duty Cycle Test.	E, DW	Purpose of Testing, Test methods, Type Tests, Routine Test, Duty Cycle Test	1			
	Evaluation	MT					

Unit	Topic/Sub topic	Depth Code	Description	Actual Plan			Week
				L	T	P	
4	Earthing and Protection Against over Voltage						

	4.1 Earthing: definition, purpose, system earthing and body earthing	E, D	Definition, Purpose of Earthing, Types of Earthing, System earthing, equipment earthing, Differences Between System and Equipment Earthing	1	1		
	4.2 Methods of earthing, earthing resistance, earth loop impedance	E, DW, NUM	Plate, Rod, Strip, Chemical earthing. earthing resistance, earth loop impedance measurement	1			
	4.3 Causes of overvoltage in power system, lightning phenomena	E, I	External overvoltage, Internal overvoltage, Switching surge, lightning mechanism,	1			
	4.4 Overvoltage protection-overhead earth wire, angle of protection, horn-gap and rod gap lightning arrestors, surge absorbers.	E, I	Construction, Working Principle, Protection Method, Application - Overhead Earth Wire, Angle of Protection, Horn-Gap Lightning Arrester, Rod Gap Arrester, Surge Absorber,	1.5			
	4.5 Neutral earthing: Isolated neutral, solid neutral, resistance earthing, reactance earthing, Peterson coil earthing	E, I, NUM	Effect on fault level, applications in system protection, Fault Current	1.5			
	Evaluation	QA					

Unit	Topic/Sub topic	Depth Code	Description	Actual Plan			Week
				L	T	P	
5	Instrument Transformers for Protection						
	5.1 Current Transformers (CTs): Construction, types, operation, ratios, burden, polarity, errors, knee-point voltage, selection, applications	E, DW, NUM	Construction, ratio, burden, knee-point voltage, errors, selection	2			
	5.2 Potential Transformers (PTs): Construction, types, operation, ratios, accuracy, applications	E, DW, I	Construction, accuracy class, application in metering & protection	2			
	Evaluation	QA					

Unit	Topic/Sub topic	Depth Code	Description	Actual Plan			Week
				L	T	P	
6	Relay and Protection schemes						
	6.1 Protective relay: classification and selection	E, I	Definition and role of protective relays in power systems, Classification by operating principle: electromagnetic, static, digital, numerical	1	4		
	6.2 Distance relay: impedance, reactance and mho.	E, DV, I	Operating Principle, Application and characteristics of Impedance Relay, Reactance relay and Mho relay	1.5			
	6.3 Electromagnetic attraction relays: principle and applications	E	Construction, Operating principle, Torque production and operating mechanism, Application	1			
	6.4 Electromagnetic induction relays: principle and applications	E, DW	Induction disc, cup relays, Disc torque equation and factors affecting operating time	1.5			
	6.5 Universal relay torque equation	DV, NUM	Derivation & application, Operating condition, Use of the torque equation	1			

	6.6 Overcurrent Protection: Construction and operation of instantaneous overcurrent relay.	E, DW	Construction of instantaneous overcurrent relay: solenoid and attracted armature types, Operating principle: instantaneous pickup without intentional time delay, Application in radial feeder protection as high-set instantaneous elements, Coordination with IDMT relays in graded protection schemes	1			
	6.7 Inverse Definite Minimum Time (IDMT) Relays	E, NUM	Inverse characteristics, Types: normal, very inverse, extremely inverse, Applications	1			
	6.8 Time graded vs current graded protection schemes	E, I	Time grading, Current grading, Time-current coordination	0.5			
	6.9 Directional Overcurrent Relay: construction, torque equation, applications.	E, DW	Need for directional protection, Construction and working, Torque equation, applications	1			
	6.10 Distance and Carrier Aided Protection	E	Importance of communication-assisted protection	1			
	6.11 Unit Protection Schemes (Differential Protection), Biased (percentage), differential protection, Voltage balance relay	E, DW	Principle of differential protection, Percentage (biased) differential protection: operating coil and restraining coil, Biased differential, voltage balance relay, Bias characteristic: operate current vs restraining current; percentage bias setting, Voltage balance relay: Merz-Price voltage balance scheme for feeder protection, Applications: generator stator protection, transformer, busbar, motor protection	1.5			
	6.12 Protection Schemes: Generator Protection, Transformer Protection, Busbar Protection, Feeder Protection	E, I	Generator protection, Transformer protection, Busbar protection, Feeder protection	1.5			
	6.13 Earth Fault Protection: Restricted and unrestricted earth fault protection.	E	Types of earth faults, Restricted earth fault protection, Unrestricted earth fault protection	0.5			
	Evaluation	QA					

Unit	Topic/Sub topic	Depth Code	Description	Actual Plan			Week
				L	T	P	
7	Static and Numerical Relays						
	7.1 Concept of static relays vs electromagnetic relays	E, C, I	Evolution of protective relay, Concept of static relays (solid-state components), Comparison	0.5	1		
	7.2 Advantages and limitations of static relays	E	Advantages, Limitations:	0.5			
	7.3 Comparator Techniques	E, DV	Amplitude, phase, coincidence comparator	1			
	7.4 Static Relays for Protection - Differential Relays, Directional Relays, Impedance Relays, Admittance Relays, MHO Relays	E, DW	Overview of static relays in protection systems, Functional blocks of static relays, Amplitude comparison relays, Phase comparison relays, Principle of operation (voltage-current phase angle comparison), Applications, Principle: Measurement of impedance, Reactance and Mho Relay	1.5			
	7.5 Numerical Relays	E, DW, I	Basic Working Principle , A/D conversion, microprocessor blocks, Advantages and Limitations of Numerical Relays, Applications	1	2		
	7.5.1 Description and architecture of numerical relays	E, DW, I	Description, Architecture of Numerical Relays, Block Diagram, Advantages of this Architecture, Applications	1			

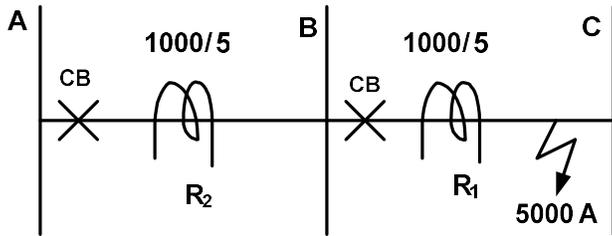
7.5.2 Functional blocks: analog input module, A/D conversion, microprocessor, output relays.	E, DW, I	Analog Input Module, Analog-to-Digital (A/D) Conversion, Microprocessor / Digital Processing Unit, Output Relays / Trip Mechanism	1			
7.5.3 Relaying Algorithms & Applications	E, DW, I	Introduction to Relaying Algorithms, Algorithm Structure & Flow, Applications of Relaying Algorithms	1			
7.5.4 Advantages of Numerical and Microprocessor-Based Relays	E, DW, I	Block diagram, Advantages, Practical Applications	1			
7.5.5 Applications in Power System Protection	E, DW, I	Modern digital protection schemes in Transmission Line, Transformer, Generator, Feeder, Busbar Protection.	1			
Evaluation	FA					

Model Question

Attempts All questions

1. a) What do you understand by a zone of protection? Discuss various zones of protection for a modern power system. (3)
- b) Explain basic principle of power system protection with an example. (3)
2. a) In relation to a fuse, explain what do you mean by (i) prospective current (ii) cut-off current (iii) time delay fuse (4)
- b) Define and discuss isolator and its area of application. (4)
3. a) In a 220 kV system the reactance and capacitance up to the location of circuit breaker is 8Ω and $0.025 \mu\text{F}$, respectively. A resistance of 600Ω is connected across the contacts of the circuit breaker. Determine the following: (i) Natural frequency of oscillation, (ii) Damped frequency of oscillation, (iii) Critical value of resistance which will give no transient oscillation and (iv) The value of resistance which will give damped frequency of oscillation, one-fourth of the natural frequency of oscillation. (6)
- b) Explain the construction, operating principle and application area of vacuum circuit breaker. (6)
4. a) A 60 km long 66 kV, 50 Hz 3 phase overhead line has line to earth capacitance of each equal to $0.02 \mu\text{F}/\text{km}$. Determine the inductance and kVA rating of the arc suppression coil. (3)
- b) Define neutral earthing. Briefly discuss different types of neutral earthing. (3)
- c) Explain the working principles of a Current Transformer (CT) and a Potential Transformer (PT). (4)
5. a) What are the fundamental requirements of protective relaying? Explain the construction and operation of the induction disc type over current relay. (4)
- b) Two relays R_1 and R_2 are connected in two sections of a feeder as shown in figure. CTs are of ratio $1000 / 5 \text{ A}$. The plug setting of relay R_1 is 100 % and R_2 is 125 %. The operating time characteristic of the relays is given below. The time multiplier setting of the relay R_1 is 0.3. The time grading scheme has a discriminative time margin of 0.5 s between relays. A three-phase short circuit at F results in a fault current of 5000 A. Find the actual operating times of R_1 and R_2 . What is the time multiplier setting (TMS) of R_2 . (6)

Plug setting multiplier	2	4	5	8	10	15	20
Time in seconds for a time multiplier of 1	10	5	4	3	2.8	2.6	2.4



c) Explain the working principle of an induction disc relay with a neat sketch. (4)

6. a) Name different types of static relays. Discuss the advantages and disadvantages of static relays as protective device. (5)

b) Discuss static distance relay (i) impedance relay (ii) reactance relay (iii) Mho relay with neat sketch. (5)

(Note: Number of questions and distribution of marks are indicative only.)