



Government of Karnataka
DEPARTMENT OF COLLEGIATE AND TECHNICAL EDUCATION

Programme	Electrical and Electronics Engineering	Semester	III
Course Code	20EE33P	Type of Course	Programme Core
Course Name	Switchgear and Protection	Contact Hours	8 hours/week 104 hours/semester
Teaching Scheme	L: T:P: 3:1:4	Credits	6
CIE Marks	60	SEE Marks	40

1. Rationale:

Electrical switch gears and protective devices are the main components of power systems in any type of industry like power sector, manufacturing, process industry, hospitals, hotels, commercial buildings etc. An electrical and electronics diploma graduate should be capable of testing, commissioning, troubleshooting and maintenance of the electrical switchgears and protection devices.

2. Course Outcomes/Skill Sets: On successful completion of the course, the students will be able to

CO-01	Demonstrate the operation and testing of a given switchgear.
CO-02	Select a switchgear for a given application and list the procedures for preventive maintenance of such a switchgear to ensure it performs optimally.
CO-03	Demonstrate the testing of a protection scheme for a given power system including all its elements (alternators, transformers, bus bars and feeders).
CO-04	Identify accessories of a control panel and demonstrate the testing procedure of a given LV control panel.

3. Course Content:

Week No.	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
			3 hours/week Topics/subtopics	1 hour /week	4 hours/week (2 hours/batch twice in a week)
1	1	1,4	1. Meaning of Switch gear, Types- Indoor type and Outdoor type, Essential features of Switchgear, List most commonly used Switchgear equipment and Protective Devices for switching and interruption of current. Importance of power system protection and Necessity of Protective Devices.	Refer table 1	1. Identify various fuse sets viz., HRC, DO, 33KV fuse set, etc.
			2. Sources of Faults, Types of faults, Harmful Effects of short circuit current, Symmetrical and unsymmetrical faults on three-phase systems.		2a. Measure and select the appropriate size of fuse wire. 2b. Test the HRC fuse by performing a Load test.
			3. Fuse - Meaning, List the types of fuses with applications, Fuse Element Materials, Desirable features of Fuse elements, Characteristics of fuse. Important Terms: Current Rating of Fuse element, fusing current, fusing factor, Prospective current, cut off current, Pre-Arcing Time, Arcing Time,		

			Breaking Capacity, Total Operating Time. HRC fuses –list the types and applications, general construction and working, Merits and demerits.		
2	1	1,2,4	<p>1.Circuit Breaker - Meaning, Classification of Circuit Breakers, list the types -LV, HV types with applications.</p> <p>Explain the terminologies – Circuit Breaker Rating, Arc-Voltage, Arching Time, Pre –Arcing Time, Prospective Current, TRV, Recovery Voltage, RRRV, Total Break Time, Making current, Breaking current, Short circuit rating and Short-time current rating.</p> <p>2.Construction, working principle and applications of ELCB, RCCB, MCCB and MPCB.</p> <p>Concept of ACCL (automatic changeover with current limiter).</p> <p>3.MCB- Types, Classification based on trip curves and their application, General construction and working, Characteristics of MCB.</p>	Refer table 1	<p>1a. Identify the various types of CB- MCB, ELCB, RCCB, MPCB and MCCB. Trace and locate MCBs used in your institution and note down their specifications.</p> <p>1b. Dismantle MCCB/ELCB and identify various parts.</p> <p>1c. Test the MCB and plot its inverse time characteristic curve.</p> <hr/> <p>2a. Troubleshooting and servicing of LT circuit breaker.</p> <p>2b. Test any commercially available ACCL.</p>
3	1,2	1,2,4	<p>1.HV Circuit Breaker- working concept.</p> <p>ACB- Working principle, Construction, Merits, Demerits & Applications.</p> <p>2.VACUUM CB- Working principle, Construction, Merits, Demerits & Applications.</p> <p>3.SF6 CB- Working principle, Construction, Merits, Demerits & Applications.</p> <p>Concept of RMU (Ring main unit) and LBS (Load Break Switch)</p>	Refer table 1	<p>Visit to Substation.</p> <p>1a. Identify the parts of circuit breaker and check its operation.</p> <p>1b. Demonstrate test tripping characteristic of circuit breaker for over current and short circuit current.</p> <hr/> <p>2a. Demonstrate Installation operation and maintenance of SF6 circuit breaker, Vacuum circuit breaker.</p> <p>2b. Carry out timer test on circuit breakers.</p> <p>2c. Demo on RMU</p>
4	1	1,4	<p>1.Protective Relay- Definition, Types of relays, Classification of protective relaying with applications, Meaning of Primary and Back up protections, Desired qualities of Protective Relaying, General Features of protective relays.</p> <p>Important Terms: pick up VA, Hold-on VA, drop out VA and Burden</p> <p>Pickup current, current setting, PSM, TSM, Time -PSM Curve.</p> <p>2.Construction. Working principle and application of Earth Leakage relay.</p> <p>Meaning of ZCT (Zero-Phase Current</p>	Refer table 1	<p>1a. Demonstrate various parts of the relay and ascertain the operation.</p> <p>1b. Demonstrate setting of pick-up current/ time setting multiplier for relay operation. Ref.7(7)</p> <hr/> <p>2a. Test the Earth Leakage Relay. (Anyone type).</p> <p>2b. Test the</p>

			Transformers), CBCT (Core balance CT) - construction, working and application. 3.Construction. Working principle and application of Induction type Electro-mechanical Over Current and Overvoltage Relays. Merits and Demerits of Electro- Mechanical relays. List and explain different Testing Methods for Relays		Electromechanical over current OR over voltage relay.
5	1	1,4	1a. Block diagram and working of Microprocessor/ Microcontroller based Overcurrent Relay. 1b. Causes of over voltages and under voltages, Effects of OV/UV.	Refer table 1	1.Test the Static Over Voltage and Under Voltage Relay and Plot its inverse time – Voltage Characteristics. OR 1.Test static Over Current Relay (Anyone type of static relay).
			2a. Construction, working and application of Static relays- OV/UV relay and OCR relay. 2b. Lightning arresters & surge absorbers - Construction and principle of operation.		2a. Program and test the Numerical Over Current/ Earth Fault Relay for Normal inverse curve for various PSM and TMS and for definite Time operations. 2b. Demonstrate multifunctional numerical relays.
			3a. Construction, working and applications of Numerical Relays. Comparison of Static Relays with Electro-Magnetic Relays and microprocessor/microcontroller-based relays. 3b. Concept of Multifunction Protection numerical Relays.		
6	3	1,4	Transformer protection: 1a. Explain Abnormalities & List different types of Faults. 1b. Construction and working of Circulating Current Scheme for Transformers Protection. Ref.7(10)	Refer table 1	1.Test the operation of Buchholz Relay.
			2a. Construction and working of Earth Fault or Leakage Protection Systems for Transformer. 2b. Construction and working Stator Inter Turn Protection for transformers.		2a. Conduct BDVT on Transformer oil. 2b. Demo on Restricted earth fault protection of Transformer.
			3a. Construction and working of Buchholz Relay. 3b. Transformer oil – Electrical properties, desired properties and applications of Transformer oil , BDVT.		
7	3	1,4	1.Alternator Protection-Types of Protection, Explain Abnormalities and List different types of Faults.	Refer table 1	Simulate/Test Alternator protection scheme.
			2.Construction and working of Differential protection for Alternators.		

			3.Construction and working of Balanced Earth Fault Protection for Alternators.		
8	3	1,4	Feeder Protection: 1a. Explain abnormalities and list different types of Faults. 1b. Time Graded Over Current Protection on transmission line.	Refer table 1	1.Simulate/Test the operation Distance Relay.
			2a. Construction and working of Differential Pilot – Wire Protection. 2b. Discuss Basic principle of Distance Protection.		2.Simulate/Test the operation of Differential Relay.
			Bus-Bar Protection: 3a. Explain Abnormalities & List different types of Faults. 3b. Construction and working of Differential Protection of Bus -Bars.		
9	1,3		1.List Testing methods of Circuit Breaker, Explain type test and routine test & maintenance.	Refer table 1	1.Test the operation of the LV circuit breaker.
			2.List & Explain Testing methods of CT's & PT's and Maintenance of Relays.		2. Demonstrate Substation earthing.
			3.Explain Substation Earthing (Solid, Resistance and Reactance Earthing), - Neutral Earthing-Importance and types -Explain Principle and applications Peterson coil.		
10	4	2,3,4	1.Control Panel -Meaning, Types/various forms, construction of typical control panel. Power gears- Isolators, SFU (switch fuse unit), change over switch, selector switch.	Refer table 1	Typical low voltage power distribution panel- Identify and study the types of contactors- Power contactors and auxiliary contactors. Dis-assemble, perform preventive maintenance, service, assemble and test the contactors. Testing of control panel a. Visual test b. Insulation test c. Testing of control circuit. d. Testing of power circuit e. Conduct Logic tests
			2.Contactors – types, configuration and their specifications, various control accessories like PB switches, Indicators.		
			3.Explain various sections of control panel- Incoming section, outgoing section, busbar section.		
11	4	4	1. Metering section – Energy meter, Trivector meter, multi-function meter.		1.Install and test Multifunction meter.
			2. Various auxiliary relays: lockout, DC failure relay, TCS (trip circuit supervision relay), contact multiplier relay. -Safety interlocks.		2a. Identify and test various Auxiliary relays 2b. Demonstrate(video) Interlocking operation.
			3.Significance and importance of: IEC 61439 standards ANSI Device numbers		

12	1,4	4	1. Motor Control Centre (MCC): working, typical specification and application: Motor protection relay		1. Test the Motor Protection Relay.
			2a. Working, typical specification and application: Thermal Overload Relays 2b. Working, typical specification and application: Bimetal Relays -Direct / CT operated.		2. Test the operation of Thermal OLR
			3. Scope of IEC standard IEC 60947-4-1		
13	4	4	1.APFC (Automatic power Factor Control panel) - construction and working.		1. Test the operation of APFC.
			2.AMF (Automatic mains failure) panel - Construction and working.		2. Test the operation of AMF panel.
			3.STP (Standard Temperature Pressure Control) panel- Construction and working.		
Total in hours			39	13	52

*PO= Program Outcome as listed and defined in year 1 curriculum and CO-PO mapping with strength (Low/Medium/High) has to be mapped by the course coordinator. (Above only suggestive).

Table 1: Suggestive Activities for Tutorials: (The List is only shared as an Example and not inclusive of all possible activities of the course. Students and Faculty are encouraged to choose activities that are relevant to the topic and on the availability of such resources at their institution).

Sl No	Week	Activity
1	1	I. Explain the Phenomena of Short Circuit and overload with the help of a general circuit diagram. II. 1. Explain various parameters considered in selecting a fuse 2. Explain specification of fuse for a particular application 3. Explain different mounting methods
2	2	Document and present 1.Selection of MCB for various applications. 2.Gradation of MCBs rating for a particular application/circuit. 3.Specifications of MCB for a particular application.
3	3	Document and present the maintenance schedule of ACB, SF6 and VCB circuit breaker.
4	4	1. Explain the specifications of ELR and Electro- mechanical over current Relay 2. Draw and explain wiring of the trip circuit of MCCB/ ACB.
5	5	1.Explain Numerical OCR wiring diagram. 2.Explain the concept of Restricted Earth fault protection. 3.Explain the concept of Voltage restrained Overcurrent relay.

6	6	Calculate Fault current at each stage of following, given Electrical System SLD having details of. 1. Main Incoming HT Supply Voltage is 6.6 KV. 2. Fault Level at HT Incoming Power Supply is 360 MVA. 3. Transformer Rating is 2.5 MVA. 4. Transformer Impedance is 6%.
7	7	1.Explain the features of the Numerical differential protection relay. 2.Explain Inadvertent/Back Energization of Generator
8	8	Study commercially available numerical Distance relay (SIPROTEC 7SA61) 1. List the features of digital Distance relay 2. List functions of digital Distance relay
9	9	Document and present on Testing and maintenance of LV Circuit Breaker, CT and PT.
10	10	Study the Metering section, Bus Bar section, CT, PT, Contactors and relays in the control panel. Draw the SLD, list the components and Write the specification of a typical control panel and its accessories. Draw the metering circuit wiring diagram. Read control panel wiring and identify ANSI codes of components.
11	11	Study the latest technological changes in this course and present the impact of these changes on industry 1. Case study on "Medium voltage (MV) switchgear "
12	12	Study the latest technological changes in this course and present the impact of these changes on industry
13	13	Study the latest technological changes in this course and present the impact of these changes on industry

4. CIE and SEE Assessment Methodologies

Sl. No	Assessment	Test Week	Duration In minutes	Max marks	Conversion
1.	CIE-1 Written Test	5	80	30	Average of three tests 30
2.	CIE-2 Written Test	9	80	30	
3	CIE-3 Written Test	13	80	30	
4.	CIE-4 Skill Test-Practice	6	180	100	Average of two skill test reduced to 20
5	CIE-5 Skill Test-Practice	12	180	100	
6	CIE-6 Portfolio continuous evaluation of Tutorial sessions through Rubrics	1-13		10	10
Total CIE Marks					60
Semester End Examination (Practice)			180	100	40
Total Marks					100

5. Format for CIE written Test

Course Name	Switchgear and Protection	Test	I/II/III	Sem	III/IV
Course Code	20EE33P	Duration	80 Min	Marks	30

Note: Answer any one full question from each section. Each full question carries 10 marks.

Section	Assessment Questions	Cognitive Levels	Course Outcome	Marks
I	1			
	2			
II	3			
	4			
III	5			
	6			

Note for the Course coordinator: Each question may have one, two or three subdivisions. Optional questions in each section carry the same weightage of marks, Cognitive level and course outcomes.

6. Rubrics for Assessment of Activity (Qualitative Assessment)

Sl. No.	Dimension	Beginner	Intermediate	Good	Advanced	Expert	Students Score
		2	4	6	8	10	
1	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	8
2	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	6
3	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	2
4	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	2
Average Marks= (8+6+2+2)/4=4.5							5

Note: Dimension and Descriptor shall be defined by the respective course coordinator as per the activities

7. Reference:

Sl. No.	Description
1	Principles of Power System" by V. K. Mehta, Rohit Mehta S. Chand, 4th revised edition 2008
2	Power System Protection and Switchgear by Buvanesh A Oza, Nirmalkumar C Nair, Rases P Mehta and Vijay H Makwana, McGraw HILL Education (India Pvt. Ltd) Newdelhi
3	J.B.Gupta "Switchgear & Protection", (edition), Katson Publisher,2008
4	MadhavaRao T.S., 'Power System Protection - Static Relays', McGraw Hill, New Delhi,2nd Edition, 21st reprinted, 2008.
5	Handbook of Switchgears by BHEL
6	Testing, commissioning, operation and maintenance of electrical equipment by Sunil S Rao, Khanna Publications
7	Protection relay: Power system protection - YouTube
8	Transmission Line Protection (21) - YouTube
9	Restricted Earth Fault Protection REF relay working principle - YouTube

10	<u>TRANSFORMER PROTECTION ELECTRICAL TECHNOLOGY AND INDUSTRIAL PRACTICE - YouTube</u>
11	<u>MOTOR PROTECTION PROTECTION OF INDUCTION MOTOR ELECTRICAL TECHNOLOGY AND INDUSTRIAL PRACTICE - YouTube</u>
12	<u>Bus Bar Protection Busbar Differential Protection How busbar is protected - YouTube</u>
13	<u>Directional Over current relay Protection of parallel lines Directional over current protection - YouTube</u>
14	<u>Distance Protection Transmission Line Protection Impedance protection Protection of line - YouTube</u>
15	<u>Differential protection in power transformer - YouTube</u>
16	<u>Protection of transformer - YouTube</u>
17	<u>Differential protection - YouTube</u>
18	<u>Transformer Differential Protection: Challenges and Solutions - YouTube</u>
19	<u>GENERATOR PROTECTION PART 1 GENERATOR CONNECTION GENERATOR EARTHING GENERATOR FAULTS - YouTube</u>
20	<u>Earth Leakage Relay - ELR / How to Wire ELR & CBCT with MCCB / Working Principle of ELR - YouTube</u>
21	<u>Over current relay CDG 31 - YouTube</u>
22	<u>Smart WiFi Circuit Breaker Automatic Remote-Control Protection for Solar and any other appliances</u> https://www.youtube.com/watch?v=m1r-78m51ds

8.1 CIE-4 Skill Test Scheme of Evaluation

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions(week1-week6)		10
2	1. Identify different types of Fuses and their applications. 2.Identify different types of LV circuit breakers and their applications	1	10
3	Demonstrate preventive maintenance of given Circuit breaker	2	20
4	Demonstrate the operation of a given Switchgear and plot its characteristics i. Drawing of the Circuit diagram using the right symbols ii. Demonstrate testing of (relay/fuse/MCB) for a Given operation iii. plotting the characteristics	15 30 15	1 50
5	Viva voce		10
Total Marks			100

8.2 CIE-5 Skill Test Scheme of Evaluation

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions (week7-week 12)		10
2	identify and test given relay / auxiliary relay	1	10
3	Demonstration of protection scheme i. Drawing of the Circuit diagram using the right symbols ii. Simulate/ Demonstrate working of protection scheme	05 25	3 30

4	Testing of control panel wiring in LV control panels i. Reading electrical drawings and demonstrate control panel wiring	10	4	40
	ii. cable size and bus bar rating selection for given application.	10		
	iii. Testing control panel – Tracing control wiring, identifying components as per IEC and ANSI codes, test the components	20		
5	Viva voce			10
Total Marks				100

8.3 SEE Scheme of Evaluation

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions (week1- week13)		10
2	i. Selection of switch gears and its ratings for given application. ii. Selection of MCB rating and class as per applications / selection of fuse rating and type for given application.	2	10
3	Demonstrate the operation of a given Switchgear and plot its characteristics i. Drawing of the Circuit diagram using the right symbols ii. Demonstrate testing of (relay/fuse/MCB) for a Given operation iii. plotting the characteristics OR Demonstration of protection scheme i. Drawing of the Circuit diagram using the right symbols ii. Simulate/ Demonstrate working of protection scheme OR Testing of control panel wiring in LV control panels i. Reading electrical drawings and demonstrate control panel wiring ii. cable size and bus bar rating selection for given application. iii. Testing control panel – Tracing control wiring, identifying components as per IEC and ANSI codes, test the components.	15 30 15 05 55 15 15 30	1/3 /4 60
4	Viva voce		20
Total Marks			
100			

9. Equipment/software list with Specification for a batch of 20 students

Sl. No.	Particulars	Specification	Quantity
1	Different types of fuses (kit-kat fuse, cartridge fuse, glass fuse etc.) (For identification experiment)		2 no. Each
2	Single pole MCB	6 A ,220 V	6
3	Single-phase ELCB	6A ,220 V 30 mA	2
4	MCCB (for study / identification experiment only)	125 A 415V	1
5	MPCB (Motor Protection Circuit Breaker) of any low current rating (for study / identification experiment only)	3 Phase 415 V	1
6	Automatic changeover with current limiter (ACCL)		5

	Air circuit breaker		1
8	DPST and SPST knife switches or 2 pole, 3way, 6A selector switch		6
9	DPST and SPST knife switches or 2 pole, 3way, 6A selector switch	10A or 16 A or 32 A, 415 V	5
10	3 phase auxiliary contactor - any model with 2NO + 2 NC.	10 A , 415 V	5
11	Single-phase Auto transformer	Single-phase Auto transformer	6
12	Transformer (for voltage injection purpose)	240V/500V	4
13	Transformer (for current injection purpose)	240V/24V, 20A	4
14	Rheostats	45ohms 8.5 A, 100 ohms 5 A, 300 ohms 2.5 A	2
15	Thermal Overload Relay	3 Phase 415 V, 0-4.5 or 0-6 A or 0-10 A	4
16	Motor Protection Relay	3 HP, 3 Ph Induction Motor.	2
17	Digital Time Interval Meter (Digital stop watch may also be used as alternative)	0-999 ms, 0-99.9 sec, 0-99.9 min	
18	Single-phase preventer (phase failure relay)		2
19	Lock out relay with 2 NO and 2 NC (any low rating model).		2
20	Electro-mechanical Relay Trainer Kit or module with 4 mm banana pin sockets and patch cords. (TYPE - Over Load Relay or Over Voltage Relay or Under Voltage Relay or Earth Fault Relay		1 set
21	Static Relay (OLR or OVR or UVR or EFR – ANY ONE) Trainer Kit or module with 4 mm banana pin sockets and patch cords.		1 set
22	Numerical relay or Digital relay (OLR or OVR or UVR or EFR – ANY ONE)-Trainer Kit or module with 4 mm banana pin sockets and patch cords.		1 set
23	Buchholz Relay		1
24	AUX. Current source / current injection kit suitable for the above trainer kits with 4 mm banana pin sockets and patch cords.	15A	3
25	AUX Voltage source / voltage injection kit suitable for the above trainer kits with 4 mm banana pin sockets and patch cords.	220 V AC /110 V DC	3
26	Fuse and MCB testing- trainer kit		2
27	P-spice/ GNU-Octave/MatLab		20 License
27	Multifunction meter		1
28	Trivector meter	3- phase	1
29	TCS(trip circuit supervision relay 24/30/48 V DC 110-125/220-250 V DC/AC		1
30	Lock out Relay		1