GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering
Level: Diploma
Branch: Electrical Engineering
Subject Code: DI05009011
Subject Name: Switchgear and Protection

w. e. f. Academic Year:	2026-27
Semester:	5th
Category of the Course:	PCC

Prerequisite:	Basic knowledge of electrical engineering, power system, and electrical measurements.
Rationale:	This course provides fundamental and advanced knowledge of power system protection, covering protective relays, switchgear, and protection schemes for transmission lines and electrical equipment. It equips students with the skills to analyze faults, select appropriate protection devices, and ensure system reliability and safety. The inclusion of modern trends such as numerical relays, adaptive-based protection, and renewable energy integration prepares students to handle emerging challenges in smart and sustainable power systems.

Course Outcomes: After Completion of the Course, Student will be able to:

No	Course Outcomes	RBT Level*
01	Describe the basic concepts of power system protection and compare different types of relays.	R, U
02	Explain the operating principles, characteristics, and selection criteria of basic switchgear devices	U
03	Analyze protection schemes for transmission networks, bus-bars, and lightning, including relay coordination.	A
04	Apply suitable protection schemes for generators, transformers, and induction motors to ensure safe and reliable operation under fault conditions.	A
05	Implement modern technique to mitigate fault challenges in networks integrated with renewable energy sources.	A

**Revised Bloom's Taxonomy (RBT)*

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Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE(V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Unit 1: Introduction to Protective System and Relay Technology** ● Types of faults, its causes and consequences, Abnormalities ● Need for protective systems, Functions of protective relay schemes ● Zones of Protection, Main and Back up Protection, Essential requirements of a protective system ● Need for Protective CT, PT and CVT, Essential features and standard ratings, Factors to be considered for selection of CTs. ● Basic tripping circuit ● Relay Terminology, Classification of relays ● Static Relay- Merits and demerits of static relays, Basic elements of static relays, Level detector, Time-delay circuit, Output circuit, Auxiliary supply, Comparator ● Numerical relays- Advantages of numerical (digital) relaying, Organization of a numerical relay, Facilities available in commercial numerical relays, Comparison between static relays and numerical relays ● Working and operating characteristics of various relays: - Thermal relays, Instantaneous, Time delayed and Definite-time overcurrent relays, Inverse-time and IDMT overcurrent relays, Differential relays, Biased or Percentage Differential Protection, Directional relays, Impedance relays, Reactance relays, Ohm relays, Mho relays. ● Auxiliary relays	8	18%

2	**Unit 2: Circuit Breakers** ● Circuit Breaker - Function, Parts and Operating mechanism, Fault clearing time of a circuit breaker, Arc voltage and Arc interruption, Restriking voltage and recovery voltage, Resistance switching ● Types of circuit breaker (Construction and working): Oil, Air, SF6, Vacuum and HVDC circuit breaker ● Selection criteria for different application of Circuit Breakers, Ratings of circuit breakers	8	18%
3	**Unit 3: Transmission line & Feeder protection** ● Introduction ● Radial feeder over current & earth fault protection ● Methods of discrimination: Current, Time & and Current-Time discrimination ● Rules for setting the IDMT relay, Relay setting calculation for sample radial feeder, example on PSM and TMS ● Parallel feeder protection: - Need for directional relays - Directional over current and earth fault protection ● Common Problems with Overcurrent Relays ● Transmission Lines protection by Distance Relays - stepped distance characteristics of a distance relay, Problems and limitation in distance relay ● Pilot wire protection, Carrier current Protection ● 11kV, 66kV, 400kV transmission line protective scheme: Power circuit and control circuit with specification ● Fault characteristics of renewable Sources, Protection of transmission and distribution networks in the presence of renewables	12	27%
4	**Unit 4: Generator and Induction Motor Protection** ● Generator Differential Protection, Stator Earth Fault Protection, Rotor earth-fault protection, Field failure protection, Reverse power protection, Pole slipping protection, Over load protection,	10	22%

	Back up impedance protection, Under - Frequency Protection, Block diagram of generator protection by numerical relay • Class A, B and C protections and conditions causing alarm • Hydro & thermal power plant (utility scale) generator protection scheme: Power circuit and control circuit with specification • Induction Motor: Faults and abnormal operating conditions, Thermal Overload Protection, Negative-Phase Sequence Protection, Over current, Earth-Fault Protection, Protection against stalling • Numerical motor-protection relay • 415 V and 6.6 kV Industrial Induction motor protective scheme: Power circuit and control circuit with specification		
5	**Unit 5: Transformer and Bus Bar Protection** • Faults in transformer, Gas operated relay • Transformer Over current & earth fault Protection, Differential Protection, Restricted Earth Fault Protection, PRV & OSR Relay, Transformer Protection Using a Numerical Relay • Protection against over fluxing and over heating • 11/220kV, 220/66kV, 66/11kV transformer protective scheme: Power circuit and control circuit with specifications • Protection requirements for Bus bar • Unit and non-unit schemes of protection for Bus bar • Breaker backup protection • 11kV, 66kV, 400kV bus bar protective scheme: Power circuit and control circuit with specifications • Adaptive Protection, Integrated Protection and Control (SCADA)	7	16%
		45	**100%**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	U Level	A Level	N Level	E Level	C Level
10 %	30 %	60 %	00	00	00

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Reference Books:

1 Power System Protection and Switchgear –B. Oza, N. C. Nair, R. P. Mehta, V. H. Makwana. Tata McGraw Hill Ltd Publishing Company
2 Power System Protection and Switchgear – Badri Ram, D. N. Vishwakarma. Tata McGraw Hill Ltd Publishing Company
3 Fundamentals of Power System Protection – Y. G. Paithankar, S. R. Bhide. Prentice Hall of India
4 Power system Protection and Switchgear – B. Ravindranath, M. Chander. New Age International Publisher
5 Power System Switchgear and Protection– N. Veerappan S.R. Krishnamurthy S. Chand

(b) Open-Source Software and Website:

Topic	Resource Type	Link
Power Flow, Fault Studies, Basic ProtectionConcepts	Software	https://matpower.org/
Distribution System & Protection Studies	Software	https://sourceforge.net/projects/electricdss/
Dynamic System Simulation	Software	https://openmodelica.org/
Switchgear, Relays, Circuit Breakers	Website	https://electrical-engineering-portal.com/
Power System Protection	Website	https://nptel.ac.in/courses/108105167
Modern Protection Techniques	Website	https://energy.sandia.gov/programs/electric-grid/advanced-grid-modeling/power-system-protection/
Series of Lecture of Power System Protection (Prof. B. A. Oza)	YouTube	https://www.youtube.com/@edupme/playlists
Substation Automation Lab	Virtual Lab	https://sa-nitk.vlabs.ac.in/
Power Lab	Virtual Lab	https://vp-dei.vlabs.ac.in/Dreamweaver/

Suggested Course Practical List: Each week includes one lab sessions (2 hours), designed such that they complement theory topics, means each experiment directly supports the classroom teaching.

Sr. No.	Practical Outcome/Title of experiment	Unit/ CO	Approx. Hours
1	To check the polarity and ratio of protective transformer (CT & PT)	1	2
2	To perform and plot the magnetization curve of current transformer (CT)	1	2
3	To test the electromechanical type overcurrent relay for DMT and IDMT characteristics for different PSM & TMS.	1	4
4	To test a typical numerical type over current/earth fault relay.	1	2
5	To test the numerical percentage biased differential relay for transformer protection.	5	2
6	To perform the numerical IDMT overcurrent relay for radial feeder protection.	3	2
7	To perform the parallel feeder protection using directional and non-directional overcurrent relay.	3	2
8	To test the reverse power relay for generator protection	4	2
9	To perform the numerical protection of induction motor.	4	2
10	To perform the differential protection of generator using static differential relay.	4	2
11	To perform the distance relay operation for transmission line protection	3	2

Subject In-charge can add performance experiment only

List of Laboratory/Learning Resources Required:

Category	Equipment / Tool	Specifications / Notes
A. Measuring Instruments	Ammeter	AC/DC, 0-1 A, 0-5 A, 0-10 A
	Voltmeter	AC/DC, 0-75 V, 0-300 V, 0-600 V
	Digital Multimeter	0–600 V AC/DC, 10 A
	Wattmeter	0–1 kW / Digital (single & three-phase)
	Stopwatch	0–60 sec (digital)
	Clamp-on Digital Meter	0–600 V AC/DC, 10 A
B. Electrical Apparatus/ Equipment	Current Transformer- CT Potential Transformer-PT	50-25-10-5/1-5 A 440-230/110 V
	Variac (Auto-transformer)	1-phase, 0–300 V, 0-15 A
	AC Power Supply DC Power Supply	1-Phase: 230 V, 3-Phase: 415 V 0-230 V, 15 A Regulated
	Air Circuit Breaker (ACB) Model	400 A – 1600 A, 415 V (demo model preferred)
	Relay Test Kit (Secondary Injection)	0–50 A current, 0–300 V voltage injection
	Electromechanical Overcurrent Relay	Plug setting: 50%–200%, TMS: 0.1–1.0, IDMT type
	Radial Feeder Protection Trainer	Numerical relay IDMT overcurrent Panel Mounted
	Parallel Feeder Protection Trainer	Directional (0.5-2 A, 50 Hz, CT sec. 1A) & non-directional overcurrent relay (0.5-2 A, 50 Hz, CT sec. 1 A) Panel Mounted
	Numerical Relay Overcurrent and Earth fault	1A& 5A, 50 Hz, IDMT type, Panel Mounted
	Reverse Power Relay Protection Trainer	Generator reverse power protection
	Transformer Numerical Biased Differential Protection Trainer	Biased characteristics & Differential operation
	Generator static differential Protection Trainer	Characteristics & Differential operation
	Buchholz Relay	5 A at 230 V AC/ 110 V DC

	Induction motor Numerical Protection Trainer	3-phase, 415 V, 50 Hz AC
	Three-phase Induction Motor	0.5 HP – 3 HP, 415 V
	Loading Rheostat	Multiple range (0–10 A, 0-500 W)
	Distance relay	1 A/ 5 A, 110 V AC, 50 Hz Panel Mounted

Suggested Activities for Students:

To enhance the learning outcomes of the "Switchgear and Protection" course, students are encouraged to participate in co-curricular activities that develop practical understanding and analytical skills in power system protection by applying theoretical concepts to real-world problems.

- Prepare a seminar or presentation on recent advancements in protection technology.
- Visit a substation or power plant to observe practical protection schemes.
- Analyze fault conditions in systems with renewable energy integration.
- Conduct a case study on smart grid protection techniques.
- Analyze a historical power grid blackout to understand cause and consequences.

Suggested Project List: Suggested Project List as given below:

Individual Level - Fundamental Activities

- Prepare list of switchgear equipment available in the sub-station/generating station and write its specification and symbols.
- Visit a substation and prepare its technical report emphasizing oncontrol side.
- Draw schematic diagram of protective schemes for 66 KV/ 132KV/220 KV Substation.

Group Level - Hands-on Projects / Circuit Implementation and Testing

- Build a basic trip circuit of power system protection.
- Prepare an interlocking circuit among the isolator, circuit breaker and earthing switch.

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