GUJARAT TECHNOLOGICAL UNIVERSITY, AHMEDABAD, GUJARAT

COURSE CURRICULUM
COURSE TITLE: SWITCHGEAR & PROTECTION
(COURSE CODE: 3360901)

Diploma Programme in which this course is offered	Semester in which offered
Electrical Engineering	Sixth

1. RATIONALE

An electrical power system consists of generators, transformers, and transmission and distribution lines. In case of fault, an automatic protective scheme comprising of circuit breakers and protective relays isolate the faulty section providing protection to the healthy section. Safety of machines/equipment and human beings is the major criteria of every protection scheme. It is essential that the diploma pass out students should develop skills of operating various controls and switchgear in power system. They are also required to carry out remedial measures for faults/abnormalities in machines/equipment in power system using appropriate diagnostic instrument/devices. This course attempts to develop these skills in students and hence it is a core course for all electrical engineers.

2. COMPETENCY

The course content should be taught and implemented with the aim to develop required skills in the students so that they are able to acquire following competency:

- **Maintain various controls and switchgear in power systems.**

3. COURSE OUTCOMES (COs)

The theory should be taught and practical should be carried out in such a manner that students are able to acquire different learning outcomes in cognitive, psychomotor and affective domain to demonstrate following course outcomes.

i. Identify various types of faults in Power system
ii. Explain working of different types of circuit breakers in power system.
iii. Explain working of different types of relays in power system.
iv. Maintain the protection of transmission line and feeder from various faults
v. Protect transformer, alternator, motor and bus bar
vi. Protect power system against over voltages

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	**T**	**P**	**C**	**ESE**	**PA**	**ESE**	**PA**	
4	0	2	6	70	30	20	30	150

Legends: L-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit **ESE** -End Semester Examination; **PA** - Progressive Assessment.

5. COURSE DETAILS

Unit	Major Learning Outcomes (in Cognitive Domain)	Topics and Sub-topics
Unit – I Elements of Protection	1a. Describe the functions of basic elements of a protective system 1b. Describe the various types of faults and abnormalities occurring in a power system. 1c. Explain the concept of the Backup protection 1d. Explain the use of Current Transformer (CT) and Potential Transformer(PT) in protection system. 1e. Describe the working of current limiting reactors and their arrangements 1f. Describe various methods of neutral Earthing.	1.1 Need of protective system 1.2 Functions of basic elements of a protective system. 1.3 Types, causes and effects of various Faults. 1.4 Protection zones : Backup protection zones 1.5 Protective Transformers: Specifications and Connection diagram of Current Transformer and Potential Transformer (single phase and 3 phase) 1.6 Current limiting reactors. 1.7 Neutral Earthing
Unit– II Circuit Interrupting Devices	2a. Describe protective system showing different circuit interrupting devices using a line diagram 2b. Explain the sequence of operation of and interlocking of interrupting devices. 2c. Explain the terms associated with fuse and circuit breaker. 2d. Explain characteristics of fuse and circuit breakers. 2e. Explain arc formation and zero current interruption. 2f. Compare arc quenching in A.C. and D.C. Circuit Breaker. 2g. Explain the resistance switching.	2.1 Interrupting devices: Sequence of operation and interlocking 2.2 Fuse, types, characteristics, testing and applications 2.3 Isolators. 2.4 Circuit breaker: Arc phenomena and arc extinction, Construction, working principle of Oil circuit breakers, Air break, Air Blast, Sulphur Hexa Fluoride (SF_6) and vacuum circuit breakers. 2.5 Auto-reclosure 2.6 Testing of circuit breaker 2.7 Resistance switching 2.8 Working principle of arc quenching in HVDC circuit breaker
Unit– III Protective Relays	3a. Describe need for different types of relays. 3b. State the terms related to relays. 3c. Explain concept of over current and directional relays. 3d. Explain setting of relays. 3e. Describe the testing procedure of various relays.	3.1 Protective relay, classification and selection: Terms related to relay 3.2 Principle of working, construction and operation of electromagnetic induction(shaded pole,watt-hour meter and induction cup),Thermal relay 3.3 Settings of various types of relays 3.4 Directional relay 3.5 Distance relay(impedance,

Unit	Major Learning Outcomes (in Cognitive Domain)	Topics and Sub-topics
		reactance and mho) 3.6 Negative phase sequence relay 3.7 Static relay, Construction and types 3.8 Principle and working of Microprocessor based relay 3.9 Maintenance and testing of relays
Unit–IV Protection of Transmission Line and Feeder	4a. Compare various protection scheme of transmission line. 4b. Describe the criteria to selection the protection scheme 4c. Explain simple Impedance relay. 4d. Explain need of carrier aided protection. 4e. State the types of auto reclosing. 4f. Explain protection of feeders and ring mains and Bus bar.	4.1 Transmission line protection scheme 4.2 protection scheme -Overload protection, Over-current and earth fault protection, Time graded and current graded protection, Current balance differential protection 4.3 Carrier aided protection, Carrier inter-tripping, acceleration and blocking scheme 4.4 Distance /Impedance protection 4.5 types of Auto reclosing 4.6 Protection of parallel feeders and Ring Mains
Unit-V Protection of Transformer, Alternator, Motor and Busbar	5a. Explain various protection scheme for transformer. 5b. Describe the inrush current phenomenon in transformer. 5c. Explain the protection offered by Buchholz Relay.	5.1 Over current, Percentage differential and restricted earth fault protection of Transformers 5.2 Inrush phenomenon and over fluxing phenomenon in Transformer 5.3 Buchholz Relay, analysis of trapped gases
	5d. Explain the faults and abnormalities in alternator. 5e. Explain various faults occurring in motor and their protection schemes. 5f. Explain Differential protection of Bus bars.	5.4 Various faults and abnormal operating conditions in Alternator and its protection schemes 5.5 Various faults and abnormal occurring in the Motor and its protection schemes 5.6 Differential Protection of Bus bars
Unit-VI Over Voltage Protection	6a. State the causes of over voltage. 6b. Explain the characteristics of Lightning Arrestor. 5g. Describe the Insulation co-ordination and basic impulse insulation Level	6.1 Causes of over voltages 6.2 Methods of reducing over voltages 6.3 Operating principles, construction and applications of lightning arrester 5.7 Insulation co-ordination, volt- time characteristic and basic impulse insulation level

6. SUGGESTED SPECIFICATION TABLE WITH HOURS and MARKS (Theory)

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Elements of Protection	08	04	02	02	08
II	Circuit interrupting Devices	10	05	06	04	15
III	Protective Relays	12	05	06	04	15
IV	Protection of Transmission Line	12	04	08	03	15
V	Protection of Transformer, Alternator, Motor and Bus Bar	10	04	06	02	12
VI	Over Voltage Protection	04	03	02	00	05
	Total	**56**	**25**	**30**	**15**	**70**

Legends: R = Remember; U= Understand; A= Apply and above levels (Bloom's revised taxonomy)
Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

7. SUGGESTED EXERCISES/PRACTICALS

The practical should be properly designed and implemented with an attempt to develop different types of skills **(outcomes in psychomotor and affective domain)** so that students are able to acquire the competencies/programme outcomes. Following is the list of practical exercises for guidance.

Note*: Here only outcomes in psychomotor domain are listed as practical. However, if these practical are completed appropriately, they would also lead to development of certain outcomes in affective domain which would in turn lead to development of* ***Course Outcomes*** *related to affective domain. Thus over all development of* ***Programme Outcomes (****as given in a common list at the beginning of curriculum document for this programme) would be assured.*

Faculty should refer to that common list and should ensure that students also acquire outcomes in affective domain which are required for overall achievement of Programme Outcomes/Course Outcomes.

S. No.	Unit No.	Practical Exercises (Outcomes in Psychomotor Domain)	Approx. Hours. Required
1	I	Check the Polarity of Current Transformer and Potential Transformer and connect it with the relay.	02
2	II	Identify various switchgear equipment available in the lab and write its specification and symbols.	02
3	II	Identify parts of various circuit breakers and their specification	02
4	II	Find the fusing factor of a given fusing material.	02
5	II	Dismantle a Vacuum circuit breaker.	02
6	II	Identify the various components of SF_6 circuit breaker.	02
7	III	Test overload relay and plot Time-Current characteristic	02
8	III	Use Buchholz relay for transformer protection.	02
9	III	Test thermal overload relay for protection of motor and set the relay properly.	02
10	III	Test static relay for the protection of motor	02
11	IV	Apply balance current protection scheme using appropriate switch gear	02

S. No.	Unit No.	Practical Exercises (Outcomes in Psychomotor Domain)	Approx. Hours. Required
12	IV	Interpret various protective scheme used for transmission lines and feeders (from Blue print and visit).	04
13	IV	Draw schematic diagram of protective schemes for 66 KV/ 132 KV/220 KV Substation nearby area. (after visit)	04
14	IV	Visit a substation and prepare its technical report emphasizing on control side	04
15	V	Interpret the protection scheme for an alternator in power station (from Blue print and visit).	04
16	V	Interpret different protective scheme for transformer.	02
17	VI	Set up a Horn gap lightning arrester.	02
Total			**42**
Note :Perform any of the practical exercises from above list for a minimum of 28 hours depending upon the availability of resources so that skills matching with the most of the outcomes of every units are included.			

8. SUGGESTED STUDENT ACTIVITIES

Following is the list of proposed student activities like:

i. Prepare line diagram of substation (any one of 220/132/66 kV)
ii. Prepare chart of basic elements of protective system.
iii. List different types of relays, circuit breakers and collect literature from dealers/Manufactures/users and their websites (such as SEIMENS, BHEL, GE, L&T, Crompton, Power Grid Corporation etc)
iv. Prepare display chart for various types of fuse.
v. Prepare the chart for Combined Earth Fault and Phase Fault Protective scheme.
vi. Download the video of functioning of HVDC circuit breaker, Lightning arrester.

9. SPECIAL INSTRUCTIONAL STRATEGIES (if any)

i. Show video/animation film to demonstrate the working principles, constructional features, testing and maintenance of different types of relays and circuit breakers
ii. Arrange expert lectures by engineers of power distribution companies/suppliers of protection and switchgear equipments.
iii. Arrange a visit to nearby substation and manufacturer site of protection panel
iv. Arrange a visit to a relay testing laboratory.

10. SUGGESTED LEARNING RESOURCES

A) Books

S. No.	Title of Book	Author	Publication
1.	Fundamentals of Power System Protection	Paithankar Y. G.and Bhide S. R	PHI, New Delhi (Latest Edition)
2.	Power System Protection and Switchgear	Ram B and Vishwakarma D. N.	TMH, New Delhi (Latest Edition)
3.	Electrical Power	Uppal S.L.	Khanna Publications (Latest Edition)
4.	Electrical Power System	Mehta V. K.	S. Chand Publications (Latest Edition)

S. No.	Title of Book	Author	Publication
5.	Switchgear and Protection	Rao S. S.	Khanna Publications, New Delhi (Latest Edition)
6.	Electrical Power Systems	Rao S. S and Uppal S. L	Khanna Publications (Latest Edition)
7.	Switchgear and Protection	Gupta J. B.	Katariya Pub. New Delhi (Latest Edition)
8.	Power system Protection and Switchgear	Ravindranath B. and M. Chander	Wiley Eastern Ltd, Delhi. (Latest Edition)
9.	Art and Science of Protective relaying	Wadhwa. C. L.	C.R.Mason, John Wiley, New Delhi

B) Major Equipment/ Instrument with Broad Specifications

1. Numerical relay panel with all protection

Time-overcurrent protection (definite-time/inverse-time/user-def.) , Sensitive earth-fault detection, Inrush restraint, Motor protection(Undercurrent monitoring, Starting time supervision, Locked rotor, Overload protection, Temperature monitoring, Load jam protection

2. Static earth fault relay

Ratings : 5 A , 50 Hz, VA rating : 3 VA typical
Setting ranges : Low-set : 0.1 A to 5.0
High-set : 0.1 A to 50 A

3. VCB with operation simulation panel

VCB along with variable earth leakage relay, Over voltage / under voltage relay, loading facility, over / under frequency relay, overload relay, to operate under various abnormal conditions.

4. Panel for Biased Differential protection of Transformer

•Test setup is equipped with single-phase type static relay connected with single- phase auto transformer, provides facility to vary current using a variac and rheostats.

5. Current Transformer (Metering)

LT Current transformers for metering -ring or window type

1.	Class of Accuracy	0.5
2.	Rated Burden	5.00 VA
3.	Power Frequency Withstand Voltage	3KV
4.	Highest System Voltage	433 V
5.	Nominal System Voltage	400 V
6.	Frequency	50 Hz
7.	Supply System	3 Ph. Solidly grounded Neutral System

Transformation ratio specified from the following standard ratings as per requirement :

Ratio	**50/5**	**150/5**	**300/5**	**400/5**	**1000/5**

6. Current Transformer (protection)

Typical specification for a 11 kV CT
System voltage:11 kV
Insulation level voltage (ILV) : 12/28/75 kV
Ratio: 200/1 - 1 - 0.577 A
Core 1: 1A, metering, 15 VA/class 1, ISF<10
Core 2: 1 A, protection, 15 VA/5P10

		Core 3: 0.577 A, Class PS, KPV>= 150 V, Imag at Vk/2 <=30 mA, RCT at 75 C<=2 ohms Short time rating:20 kA for 1 second
7.	Potential Transformer	**Typical specification for a 11 kV VT** System voltage: 11 kV Insulation level voltage (ILV) : 12 /28/75 kV Number of phases: Three Vector Group: Star / Star Ratio: 11 kV/ 110 V Burden: 100 VA Accuracy: Class 0.5 Voltage Factor: 1.2 continuous and 1.5 for 30 seconds With provision for fuse
8.	Buchholz Relay	Buchholz Relay set up consisting of following: - Digital AC Ammeter and Voltmeter -Gas actuated Buchholz Relay -Gas compressor for Relay -Duly wired built in control and protection unit -Built in power on indicator trip status indicator -Terminals for all the relay and necessary patch chords required to perform the experiment

C) Software/Learning Websites

i. WWW.nptel.iitm.ac.in
ii. http://electrical-engineering-portal.com/download-center/electrical-software
iii. http://electrical-engineering-portal.com/testing-commissioning-current-transformer#2

11. COURSE CURRICULUM DEVELOPMENT COMMITTEE

Faculty Members from Polytechnics

- **Prof. S. V. Jagani**, Lecturer in Electrical Engineering ,Government Polytechnic, Dahod
- **Prof. T. A. Patel**, Lecturer in Electrical Engineering , Government Polytechnic, Dahod
- **Prof. H. C. Chawda**, Lecturer in Electrical Engineering, R.C. Technical Institute, Ahmedabad

Coordinator and Faculty Members from NITTTR Bhopal

- **Dr. (Mrs.) C.S. Rajeshwari**, Professor, Department of Electrical and Electronics Engineering.
- **Prof. A.S. Walkey**, Associate Professor, Department of Electrical and Electronics Engineering.