

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2022 (COGC-2022)

Semester –V

Course Title: Switchgear & Protection

(Course Code: 4350901)

Diploma programmer in which this course is offered	Semester in which offered
Electrical Engineering	5 th Semester

1. RATIONALE

In power system abnormalities and fault are occurs. This phenomenon causes heavy fault current, damage costlier equipment and it leads power supply interruption. Hence, it is essential to study about switchgear and protection for diploma electrical engineer. It is expected that understanding of selection, principal, operation, testing and maintenance of various protective scheme will help them to maintain reliability of power system while performing the various duties like operator, supervisor, service engineer etc.

2. COMPETENCY

The purpose of this course is to help the student to attain the following competency through various teaching learning experiences

- **To operate and maintain power system protection scheme.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

- a) Interpret the principles of protection and the different components involved in protection
- b) Compare the over-current protection, distance protection and carrier-current protection of transmission line
- c) Use and maintain the various protective schemes of transformer
- d) Use and maintain the various protective schemes of Alternator and Induction Motor
- e) Interpret working, construction and application of circuit breaker
- f) Interpret insulation coordination and protect system against over voltage

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

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

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the Course Outcomes (Cos). Some of the PrOs marked “*” are compulsory, as they are crucial for that particular CO at the ‘Precision Level’ of Dave’s Taxonomy related to ‘Psychomotor Domain’.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Identify and understand working of various input and output ports of numerical relay	1	2
2	Find the polarity and various cores of an instrument transformer (Metering, Protection and PS class cores)	1	2
3	Test and verify the characteristics of a PS class core of an instrument transformer - Knee point Characteristics.	1	2
4	Test the overcurrent and earthfault relay for DMT and IDMT characteristics for different PSM & TMS.	1	2
5	Extract & Analyse the Disturbance Recorder data, Events data & Fault Data from the numerical protection relay after the occurrence of the fault.	2	2
6	Test the protective scheme of radial feeder	2	2
7	Test the protective scheme of parallel feeder	2	2
8	Test the distance protection scheme for transmission line	2	2
9	Test the working of Buchholz Relay and Oil Surge Relay (OSR) for detection of an internal fault of a power transformer.	3	2
10	Test the working of Pressure Release Valve (PRV), OTI & WTI (Thermal Protection Relays).	3	2
11	Test Percentage Biased Differential Protection Relay and Restricted Earth Fault Protection Relay. Plot the characteristics obtained from the tests for different current settings.	3	2
12	Understand the basics & operating principles of NIFPS system for the protection of a power transformer.	3	2
13	Test the various protective scheme of induction motor using numerical relay	4	2
14	Identify various components of a circuit breaker. SF6 CB, Vacuum CB, Tripping Circuit Supervision Relay and Gas Pressure Healthiness Assessment circuit.	5	2
15	Analyse, understand and interpret various electrical protective schemes & wiring diagrams used for the	5	2

	implementation of various types of protections of power system elements.		
16	Test the protective scheme of alternator	5	2
17	Set up a horngap type lightning arrestor	6	2
	Total Hours (Perform any practical worth 28 hours from above depending upon the availability of resources so that most units are covered)		34

Note

- i. A suggestive list of PrOs is given in the above table. More such PrOs can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the Cos.
- ii. The following are some sample 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare experimental setup/layout/line diagram	10
2	Use of the appropriate tools/materials	20
3	Follow safe practices.	10
4	Observation and recording	20
5	Interpretation of result and conclusion	20
6	Answer to sample questions.	20
Total		100

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical in all institutions across the state.

Sr.No.	Equipment Name with Broad Specifications	PrO. No.
1	CT – PT 10-5/1-1 A, 440/110V	03
2	Combine overcurrent earth fault numerical relay	01
3	Numerical transformer relay	01
4	Numerical distance relay kit	01
5	SF6 and Vacuum circuit breaker	01
* For better understanding of concept, it is advised to perform various protection scheme using conventional relay as well as numerical relay		

7. AFFECTIVE DOMAIN OUTCOMES

The following *sample* Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this course competency.

- a) Work as a leader/a team member (while doing a micro-project)
- b) Follow safety practices.
- c) Work as a group member (while performing experiments and taking readings)
- d) Follow ethical practices.
- e) Practice environmentally friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- i. 'Valuing Level' in 1st year
- ii. 'Organization Level' in 2nd year.
- iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Protective relay system	1a. Function of protective relaying scheme 1b. Evaluation of protective relaying technology 1c. Basic tripping circuit with transducer 1d. Main and backup protection 1e. Classification of relays : Conventional relay, numerical relay, tripping relay.	1.1 Types, cause and effect of fault 1.2 Elements of protection system 1.3 Role of CT and PT in protection system 1.3.1 Errors in CT – PT 1.3.2 Characteristic of CT and PT 1.4 Advancement in protection system technology 1.4.1 Numerical relays 1.4.2 Disturbance recorder 1.4.3 Optical Current transformer 1.4.4 Optical potential transformer. 1.5 Basic tripping circuit 1.5.1 Trip circuit supervision. 1.5.2 Basic logic circuit
Unit-II Feeder and Transmission line and busbar protection	2a Basic radial feeder and ring feeder 2b Overcurrent and earth fault protection 2c Directional and Non-directional overcurrent protection 2d Classification of relays for transmission line	2.1 Method of discrimination 2.1.1 Time discrimination 2.1.2 Current discrimination 2.1.3 Current – Time discrimination 2.2 Inverse Definite minimum time protection 2.3 Limitation of overcurrent protection

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
	protection 2e Protection zone, reverse zone protection 2f Busbar protection 2g Carrier aided protection	2.4 Impedance relay, Mho relay, reactance relay protection scheme 2.5 Power line carrier communication for protection 2.6 Auto reclosing 2.7 Requirement of bus zone protection 2.8 Differential protection for busbar 2.9 Breaker protection scheme : Local breaker backup and remote breaker backup 2.10 Travelling wave fault locator relay 2.11 Negative sequence relay for detection of broken conductor in transmission line 2.12 Basics of Centralised Control System - SCADA & IEC 61850 Protocol.
Unit– III Transformer Protection	3a. Fault in transformer 3b. Transformer protection schemes 3c. Numerical relay for transformer protection	3.1 Overcurrent – earth fault protection 3.2 Differential protection of transformer 3.3 Restricted earth fault protection of transformer 3.4 OTI – WTI : overheating protection 3.5 Buchholz protection, Pressure relief valve, Oil surge relay 3.6 Nitrogen injection fire protection system for power transformer. 3.7 Features of numerical differential relay and its advantages 3.8 Inrush Current Protection - Harmonic Restraint.
Unit– IV Rotating machine protection	4a. Faults on Alternator and Induction motor 4b. Protective relaying schemes for Alternator and Induction motor protection 4c. Conditions causing alarms for alternator	4.1 Inter-turn fault, stator earth-fault , rotor earth-fault 4.2 Negative phase sequence, field failure protection, overload protection, over-voltage protection

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
		4.3 Reverse power protection, back-up impedance, under-frequency protection 4.4 Class A, Class B and Class C protections conditions causing alarm and tripping 4.5 IM protection : Overloading, Single phasing, under voltage, stalling, differential protection.
Unit–V Circuit breaker	5a. Functions of circuit breakers 5b. Fundamentals of circuit breaking 5c. Quenching of AC & DC arc 5d. Arc interruption theories	5.1 Type of circuit breaker based on : Actuating mechanism, interrupting medium, based on installation, based on external design 5.2 Isolators 5.3 Making and Breaking capacity 5.4 Restriking voltage and recovery voltage 5.5 Air circuit breaker 5.6 SF6 Circuit breaker 5.7 Vacuum circuit breaker 5.8 Multi break circuit breaker 5.9 HCDC circuit breaker 5.10 Comparisons of different type of circuit breaker 5.11 Operation sequence interlocking
Unit – VI Lightning protection	6a. Cause of overvoltage 6b. Characteristics of LA 6c. Insulation coordination	6.1 Lightning and switching surges 6.2 Classification of LA based-on principle, construction and application 6.3 Basic impulse insulation level

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Protective relay system	08	02	05	03	10
II	Feeder, Transmission line and busbar protection	10	04	07	07	18
III	Transformer Protection	06	02	04	04	10
IV	Rotating machine protection	07	02	05	04	11
V	Circuit breaker	08	06	05	04	16
VI	Lightening protection	03	02	02	02	06

Total	42	18	28	24	70
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Legends: R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)

Note: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related **co-curricular** activities which can be undertaken to accelerate the attainment of the various outcomes in this course. Students should perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidence for their (student's) portfolio which may be useful for their placement interviews:

- Visit EHV substation / Power station
- Prepare report on market survey of various relays and circuit breaker.
- Prepare technical report on construction of conventional relays.
- Collect data of lightening arrestor.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

- Massive open online courses (**MOOCs**) may be used to teach various topics/subtopics.
- Guide student(s) in undertaking micro-projects.
- 'L' in section No. 4** means different types of teaching methods that are to be employed by teachers to develop the outcomes.
- About **15 to 20% of the topics/subtopics** which is relatively simpler or descriptive in nature is to be given to the students for **self-directed learning** and assess the development of the COs through classroom presentation.
- With respect to item No. 10, teachers need to ensure to create opportunities and provisions for **co-curricular activities**.
- Field visit/Industrial visit.
- Show animation/video related to course content
- Guide students on how to address issues on environment and sustainability regarding SF6 circuit breaker.
- Introduce E-waste recycling technology among the students.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should **not exceed three**.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based, or field-based. Each micro-project should encompass two or more COs

which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **12-14 (fourteen to sixteen) student engagement hours** during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This must match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

- a) **Case study:** Major electrical black out and role of protection system.
- b) **Alternator / Induction motor protection schemes:** Prepare the detailed protection schemes
- c) **Presentation:** Protection system of malfunctions .
- d) **Transmission and distribution line :** Prepare the detailed protection schemes
- e) Explore unique features of numerical relay.

13. SUGGESTED LEARNING RESOURCES

Sr. No	Title of Book	Author	Publication with place, year and ISBN
1	Fundamentals of Power System Protection	Y. G. Paithankar, S.R. Bhide	Prentice Hall, India, 2003 ISBN: 978-8120341234
2	Power System Protection and Switchgear	B. A. Oza, N.C. Nair, R.P. Mehta, V.H. Makwana	McGraw Hill Education Ltd, 2010 ISBN: 978-0070671188
3	Power System Protection and Switchgear	B. Ram, D N Vishvakarma, S R Mohanty	S.K. Kataria and sons; New Delhi Reprint Edition. 2013, ISBN:13:9789350142790
4	Network Protection and Automation Guide	Alstom Grid	Alstom, 2011

14. SOFTWARE / LEARNING WEBSITES

WEBSITES

- Web course on “Power System Protection” by Prof. S. A. Soman, IIT, Bombay available on NPTEL at <http://nptel.ac.in/courses/108101039>
- Power System Protection and Switchgear by Prof. Bhavesh Bhadja
https://www.youtube.com/watch?v=QsGn7H_14VY&list=PLLy_2iUCG87BIJ6ZliVIRCx2Crf9_fJMB
- https://www.youtube.com/watch?v=3xsDFeTOC6w&list=RDQMIXdOHuLWmGw&start_radio=1

15. PO-COMPETENCY-CO MAPPING:

Semester V	SWITCHGEAR & PROTECTION						
	POs						
Competency & Course Outcomes	PO 1 Basic & discipline specific knowledge	PO 2 Problem analysis	PO 3 Design/development of solution	PO 4 Engineering tools, experimentation & Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	Carry out Electrical wiring estimating, costing and contract for various electrical installations.						
CO1 Interpret the principles of protection and the different components involved in protection	3	2	-	2	2	-	2
CO2 Compare the over-current protection,	3	2	-	-	2	-	2

distance protection and carrier-current protection of transmission line							
CO3 Use and maintain the various protective schemes of transformer	3	2	2	-	2	-	2
CO4 Use and maintain the various protective schemes of Alternator and Induction Motor	3	2	2	-	2	-	2
CO5 Interpret working, construction and application of circuit breaker	3	2	2	-	2	2	2
CO6 Interpret insulation coordination and protect system against over voltage	3	2	2	-	2	-	2

Legend: '3' for high, '2' for medium, '1' for low and '-' for no correlation of each CO with PO.

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
1.	B B Chauhan Lecturer Electrical Engg.	Government Polytechnic, Jamangar	+91 99252 10010	bbc.gpjam@gmail.com
2.	J A Sutariya Lecturer Electrical Engg.	RCTI, Ahmedabad	+91 95122 84422	