Program Name : Electrical Engineering Program Group

Program Code : EE/EP/EU

Semester : Fifth

Course Title : Switchgear and Protection

Course Code : 22524

1. RATIONALE

In spite of all care and precautions taken in the design, installation and operation of Power system and power equipment, abnormal conditions and faults do occur in the system. Some fault such as short circuits can prove highly damaging, not only to the components but also to the entire power system. However continuity of power supply is needed in day to day life.So study of switchgears and protection schemes is essential. It is expected that the understanding of operational principles, selection and testing aspects of switchgear and protection system must be known by students which ultimately help them to maintain the reliability of electric supply while performing their duties as a supervisor or a technician in substation, manufacturing industries and public service utilities.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain switchgear and protection schemes used in electrical power systems.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Identify various types of faults in power system.
b. Select suitable switchgears for different applications.
c. Test the performance of different protective relays.
d. Maintain protection systems of alternators and transformers.
e. Maintain protection schemes for motors and transmission lines.
f. Maintain protection schemes for power system against over voltages.

4.TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical				
				Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
L	T	P			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	2	6	3	70	28	30*	00	100	40	25#	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment 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, **ESE** -End Semester Examination; **PA** - Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

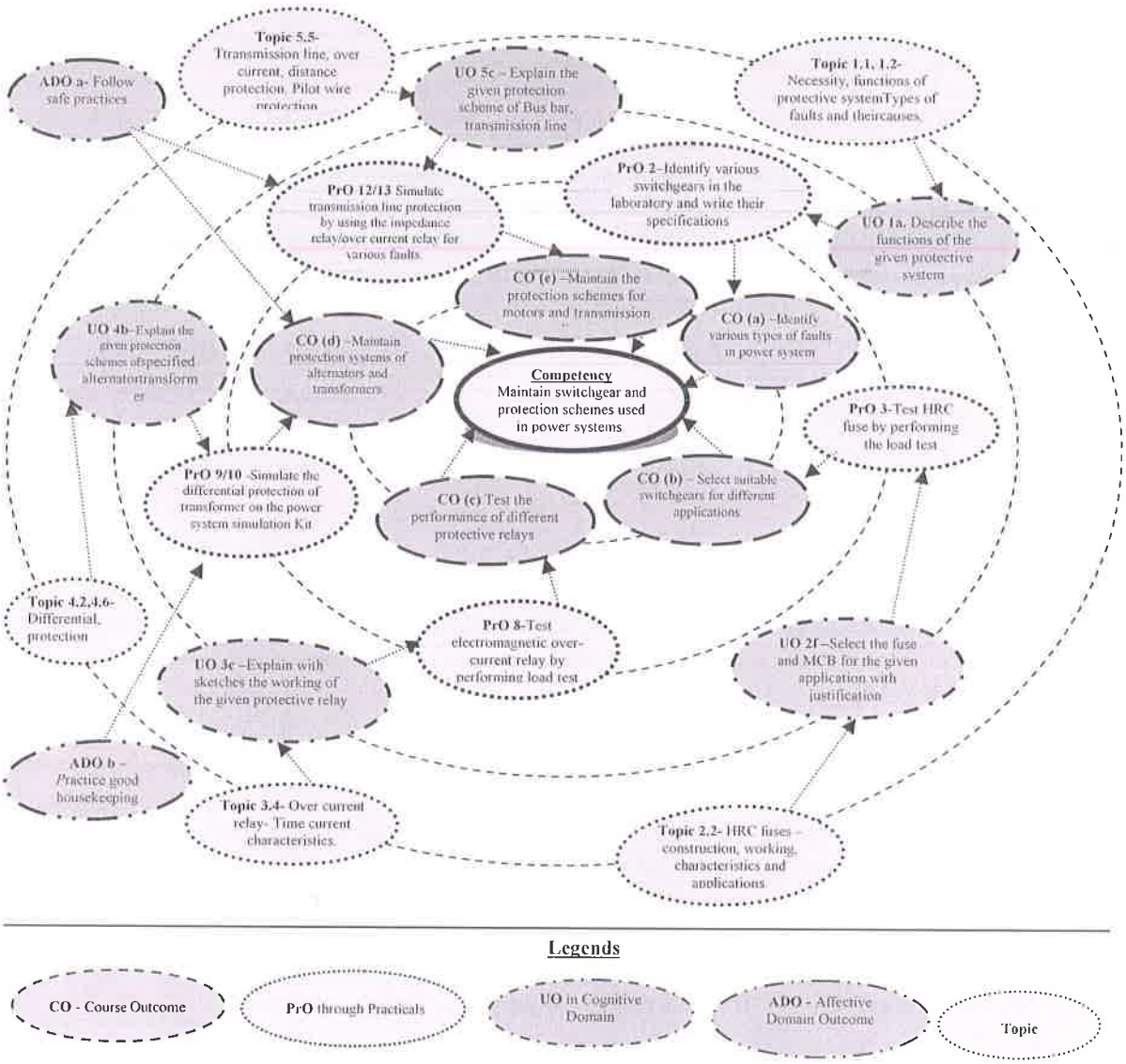

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Use switchgear testing kits.	I	02*
2	Identify various switchgears in the laboratory and write their specifications.	I	02*
3	Test HRC fuse by performing the load test.	II	02*
4	Test MCB by performing the load test	II	02*
5	Dismantle MCCB/ELCB and identify various parts.	II	02*
6	Video show on /Dismantle ACB/VCB and identify different parts.	II	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
7	Carry out plug and time setting (with PSM, TSM) of induction type electromagnetic relay.	III	02*
8	Test electromagnetic over-current relay by performing load test.	III	02*
9	Simulate differential protection scheme forO/	IV	02*
10	Simulate differential protection scheme for transformer on the power system simulation Kit. Part- II	IV	02
11	Test the working of the single phasing preventer using a three phase induction motor.	V	02*
12	Simulate transmission line protection by using the impedance relay/over current relay for various faults. (On transmission line protection simulation Kit). Part- I	V	02
13	Simulate transmission line protection by using the impedance relay/over current relay for various faults. (On transmission line protection simulation Kit). Part- II	V	02
14	Video show on/Dismantle Thyrite type arrester and identify different parts.	VI	02*
15	Video show on/Perform neutral earthing at different substations / locations. Part- I	VI	02*
16	Video show on/Perform neutral earthing at different substations / locations. Part- II	VI	02*
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S.No.	Performance Indicators	Weightage in %
a.	Preparation of experimental set up	20
b.	Setting, collection of data and operation	20
c.	Safety measures	10
d.	Observations and Recording	10
e.	Interpretation of result and Conclusion	20
f.	Answer to sample questions	10
g.	Submission of report in time	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Practice energy conservation.
d. Demonstrate working as a leader/a team member.

e. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'CharacterisingLevel' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTSREQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Switchgear testing kit–(0-500V),(1-100A), variable AC and DC, with timer	1, 3,4
2	Cut sections and charts of MCB, MCCB, ELCB, HRC Fuse, ACB, Contactors and Induction type Over current/Earth fault, Microprocessor, Numerical relays.	2
3	HRC Fuses:5A, 10A, 16A, 32A, 100A.	3
4	MCB (SP/SPN/TP/TPN): 5A, 10A, 16A, 20A	4
5	MCCB: 32A, 63A.	5
6	ACB or VCB: 200A.	6
7	Over-current Induction type electromagnetic relay: 10A	7,8
8	Transformer protection simulation Kit.	9,10
9	Three phase induction motor with Single phasing preventer: 3HP.	11
10	Transmission line protection simulation Kit.	12,13
11	Thyrite type Lightning arrester.	14
12	Earth tester 500 V, hand driven or digital type.	15, 16

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– I Basics of protection	1a. Describe the functions of elements of the given protective system. 1b. Explain with sketches the given types of faults and abnormalities in a power system. 1c. Explain with sketches the concept of the Backup protection for the given protection zone. 1d. Calculate the short circuit	1.1 Necessity, functions of protective system. 1.2 Normal and abnormal conditions. 1.3 Types of faults and their causes. 1.4 Protection zones and backup protection 1.5 Short circuit fault calculations in lines fed by generators through transformers 1.6 Need of current limiting reactors and their arrangements.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	currents of symmetrical faults. 1e. Select suitable current limiting reactors for the given situation with justification.	
Unit– II Circuit Interrupti on Devices	2a. Explain with sketches the operation of given isolators. 2b. Explain with sketches the given terms related to the specified fuse (s). 2c. Explain with sketches arc formation, high resistance and zero current interruption in the given type of circuit breaker. 2d. Explain with sketches the operation of the given circuit breaker(s). 2e. Compare the given circuit interrupting devices on the specified parameters. 2f. Select the relevant fuse and MCB for the given application with justification. 2g. Select the relevant circuit breaker and MCCB for the given application with justification. 2h. Explain the Insulation coordination for the given installation/machine.	2.1 Isolators- Vertical break, Horizontal break and Pantograph type. 2.2 HRC fuses – Construction, working, characteristics and applications. 2.3 Arc formation process, methods of arc extinction (High resistance and Low resistance). 2.4 Arc voltage, Recovery voltage, Re-striking voltage, RRRV. 2.5 HT circuit breakers (Sulphur-hexa Fluoride (SF6), Vacuum circuit breaker) - Working, construction, specifications and applications. 2.6 L.T. circuit breaker(Air circuit breakers (ACB), Miniature circuit breakers (MCB), Moulded case circuit breakers (MCCB), MPCB , RCBO and Earth leakage circuit breaker(ELCB)) - Working and applications. 2.7 Selection of LT and HT circuit breakers (ratings). 2.8 Selection of MCCB for motors. 2.9 Gas insulated switchgear. 2.10 Insulation Coordination : Type1 & Type2 coordination 2.11 Introduction to ETAB
Unit-III Protective Relays	3a. Explain the given terms related to protective relays. 3b. Explain need of the given type of relay in power system. 3c. Explain with sketches the working of the given protective relay. 3d. Select relevant protective relay for required application with justification. 3e. Explain the steps for the specified settings of the given relay.	3.1 Fundamental quality requirements: Selectivity, Speed, Sensitivity, Reliability, Simplicity, Economy. 3.2 Basic relay terminology- Protective relay, Relay time, Pick up, Reset current, current setting, Plug setting multiplier, Time setting multiplier. 3.3 Protective relays: Electromagnetic disc relay operation, Thermal relay. Block diagram and working of Static relay, over voltage relay. 3.4 Over current relay-Time current characteristics. 3.5 Microprocessor based protection relays: Block diagram, workingand protection features. 3.6 Distance relaying- Principle

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
		3.7 Directional relay: Need and operation with block diagram. 3.8 Operation of current and voltage differential relay.
Unit –IV Protection of Alternator and Transformer	4a. Describe the causes and remedies of the given faults in the specified machine. 4b. Explain with sketches the given protection schemes of the specified machine. 4c. Calculate CT ratio of the specified transformer protection scheme. 4d. Calculate percentage of winding protected for the specified alternator.	**Alternator Protection** 4.1 Faults 4.2 Differential protection : over current, earth fault, overheating and field failure protection. 4.3 Reverse power protection. **Transformer Protection** 4.4 Faults. 4.5 Differential, over current, earth fault, over heating protection. 4.6 Limitations of differential protection. 4.7 Buchholz relay: Construction, operation, merits and demerits. 4.8 Introduction to Microprocessor based transformer protection.
Unit-V Protection of Motors, Bus-bar And Transmission Line	5a. Describe the causes and remedies of the given faults in specified equipment. 5b. Explain with sketches the given protection scheme of the specified motor. 5c. Explain with sketches the given protection scheme of given component of the power system.	**Motor** 5.1 Faults. 5.2 Short circuit protection, Overload protection, Single phase preventer. **Bus bar and Transmission line** 5.3 Faults on Bus bar and Transmission Lines. 5.4 Bus bar protection: Differential and Fault bus protection. 5.5 Transmission line: Over current, Distance and Pilot wire protection. 5.6

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FORQUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Basics of Protection.	08	04	04	02	10
II	Circuit Interrupting Devices.	16	04	06	06	16
III	Protective Relays.	16	04	06	06	16
IV	Protection of Alternator and Transformer.	16	04	06	06	16
V	Protection of Motor, Busbar and Transmission Line.	08	02	04	06	12
Total		**64**	**18**	**26**	**26**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may 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 conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Collect specifications of different switchgear equipment used in electrical power system through market survey/visit and write a technical report.
b) Visit 400/220/132/66/33kV substation and take the help of sub-station in-charge to understand various switchgears, protective schemes and occurrences of faults.
c) Collect data of different protective schemes used for alternator, transformer, bus bar and transmission lines through internet/ industrial visit.
d) Write all the safety precautions which are to be taken while working with different switchgears and protective schemes.
e) Collect data of Lightning arresters used for substation through internet/ industrial visit.

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:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** 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 presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Correlate subtopics with power system protection and electrical equipments.
g) Use proper equivalent analogy to explain different concepts.
h) Use Flash/Animations to explain various Switchgears and protection schemes.
i) Use open source MATLAB models to explain different concepts of protective schemes.

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-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, 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 total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects isgiven here. Similar micro-projects could be added by the concerned faculty:

a) **Installation and commissioning of MCB:**Calculate load current anddecide specifications of MCBsrequired for a load circuit of 5 kW or more and install it.
b) **Case study of past major grid power failure:**Prepare a report after surveying in the power failure or present the findings.
c) **Installation and commissioning of ELCB:** Calculate load current and decide specifications of ELCB required for a residential load circuit upto 5 kW and install it.
d) **Alternator/Transformer protection schemes:**Prepare power point presentation on Alternator/Transformer protection schemes used in generating station/substations.
e) **Motor protection schemes:** Prepare the detailed protection schemes for the 20HP motor.

13. SUGGESTED LEARNING RESOURCES:

S. No.	Title of Book	Author	Publication
1	Principles of Power System	Mehta V. K ; Rohit Mehta .	S.Chand and Co., New Delhi., 2016 ISBN: 978-81-2192-496-2.
2	Switchgear and Protection	Rao.Sunil S.	Khanna Publishers, New Delhi, 2015 ISBN: 978-81-7409-232-3.
3	Switchgear and Power System Protection	Singh, R. P.	PHI Learning, New Delhi,2015 ISBN: 978-81-203-3660-5.
4	Switchgear and Protection	Gupta. J. B.	S. K. Kataria and Sons, New Delhi, 2015ISBN: 978-93-5014-372-8.
5	Switchgear and Protection	Veerapan, N., Krishnamurty, S. R.	S .Chand and Co., New Delhi. 2014 ISBN: 978-81-2193-212-7.
6	Power System Protection and Switchgear	Ram, Badri Vishwakarma D. N.	McGraw-Hill, New Delhi. 2015 ISBN : 978-07-107774-X

14. SOFTWARE/LEARNING WEBSITES

a. www.cgglobal.com
b. www.youtube.com /switchgears
c. www.dreamtechpress.com /eBooks
d. www.nptelvideos.in/electrical engineering/ relays
e. www.electrical4u.com
f. www.en.wikipedia.org
g. www.abb.co.in/ProductGuide/
h. https://play.google.com/store/apps/