GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Power Electronics
Subject Code: BE05024051
Subject Name: Switch Gear & Protection

w.e.f.Academic Year:	2024-25
Semester:	5
Category of the Course:	Professional Elective Course - 1

Prerequisite:	Power Electronics Devices, Circuits and Applications
Rationale:	This course provides fundamental knowledge of fault behaviour, protective devices, relay coordination, and circuit-breaker operation, essential for ensuring the reliability and safety of electrical power systems. It develops the analytical skills required to evaluate system responses under abnormal conditions, aligning directly with industry needs for competent protection engineers. The concepts learned support advanced study in Power Electronics by enabling students to understand switching transients, protection of converters, and coordination of protective devices with power-electronic switching equipment. By integrating theory with real-world applications and simulation-based analysis, the course develops strong problem-solving and critical-thinking skills.

Course Outcomes:

Sr. No.	CO statement	Marks% weightage
CO1	Explain the basic concepts of power system protection, types of faults, grounding methods, and key protective devices used in substations.	5
CO2	Describe the working principles and constructional features of different high-voltage circuit breakers used in power systems.	35
CO3	Analyze switching transients and interpret the behaviour of circuit breakers under conditions such as TRV, short-line faults, and current chopping.	15
CO4	Apply per-unit methods and standard fault analysis techniques to calculate short-circuit currents and understand the role of current-limiting reactors.	10
CO5	Compare various relay types—including electromechanical, static, and numerical relays—based on their characteristics and applications in protection schemes.	15
CO6	Explain the protection requirements and commonly used schemes for major power system components such as generators, transformers, induction motors, transmission lines, and busbars.	20

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					Total Credits	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	PBL *	Total no of hours per semester		ESE (E)	PA / CA (M)	PA/ CA (I)	PBL (I)	ESE (V)	
45	0	30	15	90	3	70	30	20	30	50	200

**** Problem-Based Learning (PBL) aims to accommodate learning beyond the syllabus as per clause 9.4 of NBA manual.***

Where L = Lecture, T= Tutorial, P= Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, ESE = EndSemester Examination, PA = Progressive Assessment.

Content:

Sr.No	Content	Total Hrs
1	**Introduction to Power System Protection** Role and objectives of power system protection, Substation equipment overview, Types of faults and abnormal system conditions, Fault current calculation and fault clearing process, Principles of protective relaying, Neutral grounding methods and equipment grounding, Switchgear terminology, standards, and specifications, Electromechanical, static, and numerical relays, HRC fuses – construction, characteristics, selection, and applications	2
2	**High Voltage A.C. Circuit Breakers:** Circuit breaker fundamentals and interruption process, Trip circuits, control circuits, and auxiliary components, Classification, constructional features, and operating mechanisms, Interlocking schemes, indication systems, and auxiliary switches, Timing characteristics, auto-reclosing, and trip-free mechanisms, Modern developments, materials, and design considerations	4
3	**Switching Phenomena and Circuit-Breaker Rating:** Transient phenomena in switching, RLC representation of power system components, Voltage and current behaviour under short-circuit conditions, Sub-transient, transient, and steady-state components, Arc interruption theory for AC breakers, Transient Recovery Voltage (TRV), its rate of rise, damping, and control, Resistance switching, opening resistors, and current chopping, Interruption of terminal faults, short-line faults, and phase-opposition switching	8
4	**Circuit Breaker:** **Air-Break Circuit Breakers:** Arc extinction, arc chute design, operating mechanism, Miniature circuit breakers (MCB): characteristics and ratings **Air-Blast Circuit Breakers:** Principle, construction, arc quenching, resistance switching, Generator circuit breakers; compressed air system design **SF_6 Circuit Breakers:** Properties of SF_6 gas, Arc interruption mechanism, puffer and self-blast designs, Merits, demerits, environmental considerations **Oil Circuit Breakers (Minimum & Bulk Oil):** Types, construction, thermal and dielectric properties of oil, Pre-arcing, post-arcing, TRV behaviour, contact assembly **Vacuum Circuit Breakers:** Vacuum arc characteristics, Design, construction, arc behaviour, advantages, limitations	8
5	**Fault Analysis:** Introduction: Procedure of Fault calculation, Representation of Power System, Per Unit Method and its Advantages, Selection of Bases. Symmetrical Faults and Current Limiting Reactors: Fault MVA and fault current, Reactors in Power Systems, Principle Current limiting reactors: design features, types, placement Impact on fault level reduction and system stability	4
6	**Relays:** Fundamentals: Protective zones, primary & backup protection, Relaying terminology and desirable characteristics, Protective CTs and PTs, actuating quantities, Electromechanical, static, numerical relays, Carrier-aided protection, programmable relays, system security Relay Types: Auxiliary and sealing relays, attracted armature, balanced beam, induction disc & cup relays, PMMC, thermal, rectifier, and frequency relays, Directional relays (polarized, non-polarized), Under-voltage, over-current, DC relays, Plug setting, time setting, testing methods	8
7	**Protection:** Induction Motor Protection: Abnormal operating conditions and failure causes, Overload, unbalance, single-phasing protection, Phase reversal, phase-phase fault & earth-fault protection, Rotor winding faults Transformer Protection: Protection requirements, safety devices, Buchholz relay, oil &	10

Sr.No	Content	Total Hrs
	winding temperature protection, Percentage and biased differential protection, Restricted earth fault, protection of parallel transformers, Thermal overload protection Generator Protection: Stator & rotor faults, differential protection, Negative sequence, earth-fault, loss of excitation, Reverse power, overspeed, field suppression Bus-Zone Protection: Busbar protection philosophy, High impedance and biased differential protection, CT location & secondary monitoring, Interlocked over-current protection, Bus transfer schemes for industrial and auxiliary switchgear	
	TOTAL	**45**

Suggested Specification table with Marks(Theory):(ForB.E.only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	25	20	15	10	10

R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate; C: Create and above Levels (Revised Bloom's 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 the above table.

The course *Switchgear & Protection* is directly aligned with SDGs 7, 9, and 13 through its focus on fault detection, protective relaying, and reliable power system operation, ensuring efficient and resilient energy infrastructure. It is indirectly aligned with SDGs 8, 11, and 12, as these systems enhance power reliability, optimize resource utilization, and support economic and urban development.

SDG 7	Affordable & Clean Energy – direct alignment Topics like protective relays, circuit breakers, fault analysis, and transformer/generator protection ensure reliable and uninterrupted power delivery, which is essential for efficient and accessible energy systems.
SDG 8	Decent Work and Economic Growth — Indirect Alignment Knowledge of protection systems, relays, and switchgear technologies supports power sector industries, enhancing system reliability and workforce demand in utilities and infrastructure.
SDG 9	Industry, Innovation & Infrastructure -direct alignment Study of numerical relays, advanced circuit breakers (SF_6, vacuum), and protection schemes supports modern, resilient, and automated electrical infrastructure.
SDG 11	Sustainable Cities & Communities -indirect alignment Reliable operation of substations, switchgear, and protection systems ensures continuous power supply for urban infrastructure like transport, buildings, and utilities.
SDG12	Responsible Consumption & Production -indirect alignment Concepts such as fault limitation, equipment protection, and proper rating/selection of switchgear extend equipment life, minimize resource wastage, and improve system efficiency.
SDG 13	Climate Action -indirect alignment Efficient fault detection and isolation using protective relaying, switching control, and fault current limitation reduce equipment damage, energy losses, and support stable integration of renewable energy systems.

Reference Books:

1. Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education, New Delhi
2. Ned Mohan, Tore M. Undeland and William P. Robbins, Power Electronics: Converters, Applications and Design, John Wiley & Sons, Inc., New York
3. L Umanand, Power Electronics, Essentials & Applications, Wiley India
4. B. K. Bose, *Power Electronics and Motor Drives: Advances and Trends*, Academic Press (an imprint of Elsevier), Waltham, MA.
5. P. S. Bhimra, *Power Electronics*, Khanna Publishers
6. Philips T. Krein,Power Electronics, Oxford.
7. R. W. Erickson and D. Maksimović,*Fundamentals of Power Electronics*, Springer
8. B. K. Bose,*Modern Power Electronics and AC Drives*, Pearson.
9. Abraham I. Pressman and Keith Billings, *Switching Power Supply Design*, McGraw-Hill
10. Fang Lin Luo & Hong Ye,*Advanced DC to DC Converters*, CRC Press
11. M. S. Jamil Asghar,*Power Electronics*, PHI.
12. Research Papers on IEEE/IET/Science Direct etc.

List of Experiments:

1. Study of single-phase half-wave uncontrolled rectifier with R and RL loads.
2. Study of single-phase full-wave uncontrolled rectifier with R and RL loads.
3. Performance analysis of three-phase uncontrolled bridge rectifier.
4. Single-phase half-wave-controlled rectifier with R and RL load.
5. Single-phase full-wave controlled bridge rectifier with RLE load and freewheeling diode.
6. Study of effect of firing angle on output voltage and power factors.
7. Experimental verification of dual converter operation (simulation-based if hardware is limited).
8. Study of step-down (Type-A) chopper using pulse control.
9. Study of step-up (Type-B) chopper and regenerative operation.
10. Analysis of two-quadrant (Type-C/Type-D) chopper characteristics.
11. Performance evaluation of four-quadrant (Type-E) chopper (simulation-based).
12. Study of Buck, Boost, and Buck-Boost converters (CCM operation).
13. Study of Ćuk / SEPIC / Zeta converter waveforms and voltage conversion ratio.
14. Simulation of flyback and forward converters (MATLAB/PSIM/PLECS).
15. Performance comparison of resonant vs PWM converters under soft-switching conditions.

Major Equipment:

1. Power Electronics Trainer Kits (Chopper trainer kits, DC–DC Converter, AC-DC Converter Trainer kits)
2. Isolated DC–DC Converter Trainer (Flyback / Forward / Push–Pull)
3. Digital Storage Oscilloscope (DSO) – with isolation probes
4. MATLAB/Simulink Software with Simscape Electrical Toolbox

List of Open-Source Software:

1. Scilab (https://www.scilab.org/) – An open-source alternative to MATLAB
2. PSIM (Free Version) / OpenModelica (https://openmodelica.org/) – For modelling and simulating power electronics circuits

List of learning websites:

1. MIT Open CourseWare (https://ocw.mit.edu/courses/electrical-engineering-and-computer-

science/)

2. CircuitLab (Free with limited access) (https://www.circuitlab.com/) – Web-based circuit simulator
3. Virtual Labs by IITs (Government of India Initiative) (https://vlab.co.in/) – Simulations and experiments related to Power electronics.
4. Reputed Research Journal Website

List of suggested activities for Problem-based Learning (PBL):

Sr. No.	PBL Category	Name of the activity	No. of hours	Evaluation Criteria
1	Industry / Research Laboratory Visit	Industry/Research laboratory Visit	Visit = 5hrs, Report preparation = 5hrs Total = 10hrs	Based on the report submitted. The report should contain observations and calculations based on industry/ lab data.
2	Video Based Learning	Technical Video-based learning related to the subject (MOOC/NPTEL Video)	Duration of video = 5hrs Report preparation = 5hrs Total = 10hrs	Report /presentation based on the video learning outcomes.
		Self-learning online course	Minimum duration of the course should be 10 hours.	Examination-based assessment at the end of the course. Based on the certificate produced.
		Annotated Video Explanation of Concept/Problem	10hrs (Preparation + Recording + Submission)	Based on the accuracy of explanation, clarity, and presentation style.
3	Assignment/ Technical Writing / Research Writing	Assignment writing. Numerical-basedassignment is preferable.	5 assignments of 2hrs each. Total = 10hrs	Based on the assignment submitted.
		Blog or Technical Article Writing	10hrs (Research – 6hrs, Writing – 4hrs)	Based on originality, technical content, references cited, and clarity of communication.
4	Complex Problem-Solvingtargeting relevant SDGs. / Mini Project	Complex problem solving	Maximum 2 problem. Study of the problem and solution finding, Total = 15 hrs	Based on the depth of the solution submitted.
5	Research Paper Review / Analysis	Discussion on a research paper based on a relevant subject (SCOPUS Index/any reputed Journal)	5 research paper = 20 hrs	Summarise the research paper and evaluation of critical parameters
6	Poster/ Chart/ Power point presentation	Poster/chart/power point preparation on technical topics	Duration = 6 hrs	Based on poster/chart preparation and presentation skills
7	MicroProject	Working/non-working model on technical	Working = 10hrsnon-working	Based on inter-department/external

Sr. No.	PBL Category	Name of the activity	No. of hours	Evaluation Criteria
		topics	= 10hrs	evaluation
8	Group Discussion / Quiz / Simulation	Group Discussion on emerging/trending technical topics based on the subject	Duration = 1 hrs each	Based on performance in group discussion, technical depth,knowledge etc.
		Online Technical Quizzes/Simulations	Multiple quizzes summing up to 10 hours	Based on quiz scores and the reflection report after each quiz.
9	Case Study Analysis / Seminar	Real-world case studies-based learning	Duration of data collection/study = 5hrs Report preparation = 5hrs Total = 10hrs	Based on in-depth study, technical depth, data collected, fact finding, etc.
10	Other	Patent Search and Innovation Gap Identification	10hrs (Search + Report)	Based on number of relevant patents analyzed and identification of innovation scope.

Note:

1. In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject **Switchgear & Protection**incorporates;
   - Mini Project – 10 Marks
   - Micro Project – 5 Marks

These activities are incorporated as integral Project-Based Learning (PBL) components. These activities are designed to foster experiential learning, encourage innovation, and strengthen problem-solving skills by engaging students in practical applications of power converter design, simulation, and analysis. The inclusion of PBL ensures that learners develop higher-order cognitive abilities mapped to Bloom's taxonomy, while simultaneously enhancing teamwork, communication, and research competencies essential for professional engineering practice.

2. The hours allocated to specific activities should be proportionate to the total no. of PBL hours and marks.

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