GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3162420
Switch gear and Fault Analysis
6th SEMESTER

Type of Course: BE

Prerequisite: 1. 3110005 – Basic Electrical Engineering
2. 3110016 – Basic Electronics
3. 3132407 – Electrical Machine and Application
4. 3142404 – Basic Power System Engineering
5. 3132409 - Basic Power Electronics Devices, Circuits and Applications

Rationale: Switchgear and Faut Analysis subject gives general awareness of different Protective Equipment for Power Systems such as Relays, Circuit Breakers, Reactors. It also explains about protective system and protection schemes and methods. High voltage A. C. Circuit-Breaker, switching phenomena and Circuit-Breakers Rating are also discussed in this subject. To teach students theory and applications of the main components used for power system continuity and protection**.** Students will become familiar with various types of Circuit-Breaker used in various dimensions with associated relaying system. Power System Protection zone wise and element protection such as alternator, generator and transformer protection are covered in this subject. Principle and design features of Current Limiting Reactors, Physical arrangements, selection and location of Reactors are significant to reduce the size and cost of Power System as well as to increase the capacity of Power handling Capacity.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Teaching Hours	% Weightage
1.	**Introduction:** • Sub-station Equipment, Faults and Abnormal conditions, Fault calculation, Fault Clearing Process, Protective Relaying, Neutral Grounding and Equipment Grounding, Switchgear Terminology and standard specifications, Electromechanical Relay and Static relay. HRC Fuse and it's applications.	2	05-10
2.	**High Voltage A.C. Circuit Breakers:** • Introduction, The Fault Clearing Process, The Trip Circuit, Recent Advances, Classifications and Technical Particulars of Circuit-Breakers, Assembly and Structure of Circuit Breaker, Operating Mechanism, Interlocks, Indication and Auxiliary Switch, Circuit-Breaker Time, Auto-Reclosure, Trip Free Features. Materials, Design and Development.	4	10-15
3.	**Switching Phenomena and Circuit-Breaker Rating:** • RLC Parameters, Voltage Equation of an RLC Series Circuit, Sudden Short Circuit of RL Series Circuit, Sub-transient Transient and Steady State Conditions, Current Interruption in A. C. Circuit Breaker, TRV, Frequency Transient, Rate of Rise of TRV, Resistance Switching, Damping of TRV, Opening Resistance, Current Chopping, Use of	7	10-15

	Opening Resistors, Interrupting the Terminal Faults, Interrupting Short Line Faults, Phase Opposition Switching.		
4.	**Circuit Breaker:** • **Air-Break Circuit-Breaker:** Introduction, Construction, Arc Extinction, lengthening of Arc, Description, Operating Mechanism, Miniature Circuit-Breaker and it's rating. • **Air Blast Circuit-Breaker:** Introduction, construction, Principle of arc quenching; ABCB with external energy; Resistance switching, Generator Circuit-Breaker; Compressed Air System for ABCB. • **SF_6 Circuit-Breaker:** Introduction, SF_6 gas properties, Arc Extinction, Types of Design, Merits and demerits. • **Minimum Oil Circuit-breaker and Bulk Oil Circuit-Braker:** Introduction, Types, Principle, Pre-arcing phenomenon, Sensitivity to TRV, Contact Assembly. • **Vacuum Circuit-Breaker:** Introduction, Electrical Breakdown in high vacuum, Arc Extinction, Construction, Arc Interruption, merits, demerits	8	20-25
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 and design features of Current Limiting Reactors, Physical arrangements, selection and location of Reactors.	4	10-15
6.	**Relays:** • **Introduction to Protection Relaying:** Importance of Protective Relaying, Protective Zone, Primary and Back-up Protection, Back-up Protection by Time Grading Principle & Monitoring, Desirable Qualities of Protective Relaying, Terminology used in Protective Relaying, Distinction between Relay Unit, Protective Scheme and Protective System, Protective CT and PT, Actuating Quantities, Electromechanical Relay and Static Relays, Power Line Carrier Channel, Programmable Relay, System Security. • **Electromagnetic Relays:** Auxiliary switch, Sealing and Auxiliary Relays, Measurement in Relays, Type of Relay Units, Pick-up, Reset, Drop Off / Pick-up Ratio, Attracted Armature Relay, Balanced Beam Relay, Induction Disc Relay, Induction Cup Relay, PMMC Relay, Rectifier Relay Systems, Thermal Relays, Directional Relays, Polarized Iron Relay, Frequency Relay, Under Voltage Relay, D.C. Relay, All-or-nothing Relay, Plug Setting, Time Setting, Test Facility.	7	10-15
7	**Protection:** • **Protection of Induction Motor:** Abnormal Operating Conditions and Causes of Failure in Induction Motors, Protection Requirements, Protection of low voltage IM, Protection of large Motors, Overload Protection, Protection against unbalance and single-phasing, Phase Reversal Relay, Phase to Phase Fault Protection, Stator Earth-fault Protection, Faults in Rotor Winding. • **Protection of Transformer:** Protection Requirements, Safety Devices with Power Transformers, Low oil level, Gas Actuated Devices, Biased Differential Protection, Percentage Differential Protection, Differential	10	20-25

	Protection of Three-winding Transformer & Auto Transformer, Earth-fault Protection, Restricted Earth Fault Protection, Protection of Transformer in Parallel, Overcurrent Protection of Power Transformer, Thermal over-heating Protection of Large Transformer, • **Protection of Generator:** Abnormal conditions and Protection Systems, Percentage Differential Protection of Alternator Stator Winding, Restricted Earth-fault Protection, Overcurrent and Earth-fault Protection, Stator Earth-fault Protection, Rotor Earth-fault Protection, Negative Sequence Protection, Stator-heating Protection, Loss of Field Protection, Reverse Power Protection, Over Speed Protection, Field Suppression and other Protections. • **Station Bus-Zone Protection:** Bus Protection by various protection methods and principle, Selection, Biased Differential Bus-zone Protection, High Impedance Protections, Locations of CT's, Monitoring of Secondary Circuits, Interlocked Overcurrent Protection, Non-Auto Reclosure, Bus Transfer Schemes for Auxiliary & Industrial Switchgear.		

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks (Revised Bloom's Taxonomy)				
Remembrance R Level	**Understanding U Level**	**Application A Level**	**Analyze N Level**	**Evaluate E Level**
20%	30%	30%	10%	10%

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.

Reference Books:

1. Sunil S Rao, "Switchgear Protection and Power Systems"
2. J. B. Gupta, "Switchgear & Protection"
3. Bhuvanesh A. Oza, Nair, Mehta & Makwana, " Power System Protection and Switchgear"
4. Badri Ram & D. N. Vishwakarma, " Power System Protection and Switchgear"
5. Paithankar and S. R. Bhide, "Fundamental of Power System Protection"
6. T. S. Madhav Rao, " Power System Protection: Static Relays"
7. C L Wadhwa, " Electrical Power System"
8. Handbook of Switchgear by BHEL

Course Outcome:

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.

Sr. No.	**CO statement** **At the end of this course, students will demonstrate the ability to**	**CO-Topic Mapping**	**Marks % weightage**
CO-1	acquire the knowledge of various abnormal conditions that could occur in power system	1-2	15
CO-2	predict the use of appropriate circuit breaker in the power system	3-4	25
CO-3	Categorize the application of relay for appropriate circuit breaker and protection scheme.	6	20
CO-4	design protection scheme for power system elements to protect equipment.	7	25
CO-5	evaluate fault current and fault MVA for power system installation.	5	15

List of Experiments:

This is for guideline only. As far as possible, the term work given should be in digitized form.

1. To study the selection criteria of Circuit Breaker & it's rating.
2. To become familiar with Renewable HRC Fuse and Drop-out Fuse.
3. To familiarize with construction, characteristics and working of Air Blast Circuit-Breaker.
4. To study the operation of Bulk Oil & Minimum Oil Circuit-Breaker.
5. To become familiar with construction and working principle of SF6 circuit-Breaker
6. To study Vacuum Circuit-Breaker.
7. To be familiar with low voltage Air Brake Circuit-Breaker.
8. To familiarize with protection scheme of Generator.
9. To know-how protection technique of high voltage Transformer.
10. To study the protection scheme for different abnormal conditions in Induction Motor.
11. To become familiar with magnetic inrush current in a Transformer and its Protection.
12. To study the construction, principle and working of various Electromechanical Relay.
13. To know the Importance of Protective Relaying, Protective Zone, Primary and Back-up Protection, Back-up Protection by Time Grading Principle & Monitoring system.
14. To know the significance of Reactors in Power Systems, Principle and design features of Current Limiting Reactors, Physical arrangements, selection and location of Reactors.

Design based Problems (DP)/Open Ended Problem:

1. Develop Protection Circuit for Transformer, Generator or Transmission Line
2. Transmission of data using Power line carrier communication System
3. Construct working prototype of the Static Relay
4. Design the working prototype for the emulation of LG, LLG, LLLG fault of transmission
5. Prepare the prototype or PoC for the Arc quenching process in Circuit Breaker.

List of Equipment:

1. HRC and Drop Out Fuses
2. Timer
3. CT and PT
4. IDMT relay
5. Auxiliary D.C. supplies = 110V 4)
6. 1 phase Dimmer stat = 230V, 10A
7. Ammeter AC (0-15A) , Voltmeter AC (500- 1000 V)
8. Rheostat (38 ohm, 8.5 Amp)
9. MCB
10. Circuit Brakers : Working and cut section
11. Electromagnetic and numerical Relays
12. Transmission Line model is consisting of four sections .

List of Learning Resources :

Web-based tools for design: -
https://etap.com/
http://www.rpowerlabs.org/
Circuit Lab: - https://www.circuitlab.com/editor/
Open source Math Tools: - http://maxima.sourceforge.net/
http://www.sagemath.org/
http://www.scilab.org/
http://www.gnu.org/software/octave/
List of Open Source Software/learning website:

https://nptel.ac.in/courses/108105067/1
https://nptel.ac.in/courses/108102047/
https://nptel.ac.in/courses/108101040/download/lec-18a.pdf
https://nptel.ac.in/courses/108108078/1
https://docs.google.com/a/vgecg.ac.in/viewer?a=v&pid=sites&srcid=dmdlY2cuYWMuaW58cG93ZXJlbGVjdHJvbmljc3xneDo5N2UyYzhhMWNmODExODQ