SWITCHGEAR AND PROTECTION

Subject Code : EE603PC

Regulations : R16 - JNTUH

Class : III Year B.Tech EEE II Semester

Department of Electrical and Electronics and Engineering

BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY

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I. OBJECTIVE AND RELEVANCE:

The main objective of this subject is to understand and to know the following concepts:

- To understand the types of Circuit breakers and relays for protection of Generators, Transformers and feeder bus bar from Over voltages.
- To describe the important of neutral grounding for overall protection.
- To analyses the phenomenon of over Voltage and its classification.

II. PREREQUISITES:

The knowledge of following subjects is essential to understand this subject:

- Power Systems – I.
- Power Systems – II.

III. COURSE OUTCOME:

S.No	Description	Bloom's Taxonomy Level
1	Understand the types of Circuit breakers and choice of Relays for appropriateprotection of power system equipment.	Knowledge, Understand (Level 1, Level 2)
2	Understand various types of Protective devices in Electrical Power Systems.	Knowledge, Understand, (Level 1, Level 2)
3	Interpret the existing transmission voltage levels and various means to protect the system against over voltages.	Knowledge, Understanding, Applying, Analyzing (Level 1, Level 2, Level 3, Level 4)
4	Understand the importance of Neutral Grounding, Effects of Ungrounded Neutral grounding on system performance, Methods and Practices.	Knowledge, Understanding, Applying, Analyzing (Level 1, Level 2, Level 3, Level 4)

IV. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (PO)		Level	Proficiency assessed by
PO1	**Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization	**3**	**Assignments**

	to the solution of complex engineering problems.		
PO2	**Problem Analysis:**Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	**3**	**Assignments**
PO3	**Design/Development Analysis:**Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	**2**	**Assignments**
PO4	**Conduct Investigations of Complex Problems:**Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	**2**	**Assignments**
PO5	**Modern Toll Usage:**Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	**-**	**--**
PO6	**The Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	**2**	**Assignments**
PO7	**Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	**2**	**--**
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	**-**	**--**
PO9	**Individual and Team Work:** Function effectively as an individual, and as a member or	**-**	**--**

	leader in diverse teams, and in multidisciplinary settings.		
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	**-**	**--**
PO11	**Project Management and Finance:**Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	**-**	**--**
PO12	**Life-long Learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	**2**	**Research**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: None

V. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSO)		**Level**	**Proficiency assessed by**
PSO1	Talented to analyze, design, and implement electrical & electronics systems and deal with the rapid pace of industrial innovations and developments.	**3**	**Lectures, Assignments**
PSO2	Skillful to use application and control techniques for research and advanced studies in Electrical & Electronics Engineering domain.	**3**	**Lectures, Assignments**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: None

VI. SYLLABUS:

JNTUH SYLLABUS

UNITI–**Introduction to Circuit Breakers:**

Circuit Breakers: Elementary principles of arc interruption, Recovery, Restriking Voltage and Recovery voltages. - Restriking Phenomenon, Average and Maximum RRRV, Numerical Problems - Current Chopping and Resistance Switching - CB ratings and Specifications: Types and Numerical Problems. – Autoreclosures.

Description and Operation of following types of circuit breakers: Minimum Oil Circuit

breakers, Air Blast Circuit Breakers, Vacuum, and SF6 circuit breakers

UNITII – **Electromagnetic and Static Relays:**

Principle of Operation and Construction of Attracted armature, Balanced Beam, induction Disc and Induction Cup relays. Types of Over Current Relays: Instantaneous, DMT and IDMT types.Application of relays: Over current/ under voltage relays, Direction relays, Differential, Relays and Percentage Differential Relays.Universal torque equation, Distance relays: Impedance, Reactance, and Mho and Off-Set, Mho relays, Characteristics of Distance Relays and Comparison. Static Relays: Static Relays verses Electromagnetic Relays.

UNITIII – **Protection of Power Equipment:**

Protection of generators against Stator faults, Rotor faults, and Abnormal Conditions. Restricted Earth fault and Inter-turn fault Protection. Numerical Problems on % Winding Unprotected.

Protection of transformers: Percentage Differential Protection, Numerical Problem on Design

of CT s Ratio, Buchholtz relay Protection.

Protection of Lines: Over Current, Carrier Current and Three-zone distance relay protection

using Impedance relays. Translay Relay.

Protection of Bus bars – Differential protection.

UNIT IV –**Neutral Grounding:**

Grounded and Ungrounded Neutral Systems. - Effects of UngroundedNeutral on system performance. Methods of Neutral Grounding: Solid, Resistance, Reactance- Arcing Grounds and Grounding Practices.

UNIT V –**Protection Against Overvoltages:**

Generation of Over Voltages in Power Systems.- Protection against Lightning Over Voltages - Valve type and Zinc-Oxide Lighting Arresters - Insulation Coordination -BIL, Impulse Ratio, Standard Impulse Test Wave, Volt-Time Characteristics.

GATE SYLLABUS:

Power generation concepts, ac and dc transmission concepts, Models and performanceof transmission lines and cables, Series and shunt compensation, Electric field distributionand

insulators, Distribution systems, **Per-unit quantities,Bus admittance matrix, Gauss-Seidel and Newton-Raphson load flow methods,** Voltage and Frequency control, Powerfactor correction, **Symmetrical components, Symmetrical and unsymmetrical fault analysis,**Principles of over-current, differential and distance protection; Circuit breakers, **System stability concepts, Equal area criterion.**

- **IES SYLLABUS:**

Basic power generation concepts, steam, gas and water turbines, transmission line models and performance, cable performance, insulation, corona and radio interference, power factor correction, **symmetrical components, fault analysis,**principles of protection systems, basics of solid-state relays and digital protection; Circuit breakers, Radial and ring-main distribution systems,

SUGGESTED BOOKS:

TEXT BOOKS:

1. "Badri Ram , D. N Viswakarma", "Power System Protection and Switchgear", TMH Publications, 2011

2. "Sunil S Rao", "Switchgear and Protection", Khanna Publishers, 2008.

REFERENCE BOOKS:

1. "Paithankar and S. R. Bhide", "Fundamentals of Power System Protection", PHI, 2003.

2. "C R Mason", Art & Science of Protective Relaying – Wiley Eastern Ltd, 1966.

3. "C. L. Wadhwa", "Electrical Power Systems", New Age international (P) Limited, Publishers, 6th Edition 2007.

VII. COURSE PLAN (WEEK-WISE):

PLAN (WEEK-)	Week	Unit	Topics	Course Learning Outcomes	Reference
UNIT I–Circuit Breakers					
1	1	1	Necessity of switchgear protection in power system	**Know** about overall subject	T1, T2 R2
2			UNIT - I Introduction to Circuit Breakers:	**Gain** the knowledge and **understand** about Circuit Breaker	T2, R1
3			Circuit Breakers: Elementary principles of arc interruption		

4	2		Recovery, Restriking Voltage		
5			Recovery voltages&Restriking Phenomenon,	**Demonstrate** and **Acquire** the knowledgeabout Restriking phenomenon.	T2, R2
6			Average and Maximum RRRV		
7			Numerical Problems	**Gain** the knowledge about RRRV	T1, T2
8			Numerical Problems		
9	3		**Tutorial / Bridge Class # 1**	**To clarify the doubts**	
10			Current Chopping and Resistance Switching	**Understanding**the **knowledge** of Circuit Breaker rating and specification.	T2, R1
11			CB ratings and Specifications: Types		
12			Numerical Problems		
13			Autore-closures	CB rating and specification	T2, R1
14			Description and Operation of following types of circuit breakers: Minimum Oil Circuit breakers	**Understanding the knowledge** of Circuit Breaker types.	T2, R1
15	4		Air Blast Circuit Breakers	**Understanding the knowledge** of Circuit Breaker types.	T2, R1
16			Vacuum circuit breakers.		
17			SF6 circuit breakers.		
18			**Revision and Problems on Unit I**	**Overview**	
19			**Mock Test – I**	**To Test the knowledge and preparing students for final examination**	
UNIT – II Electromagnetic and Static Relays					
20	4	2	Principle of Operation and Construction of Attracted armature	**Understanding** the concept of Relays and its components	T1, T2, R2
21	5		Principle of Operation and Construction of Balanced Beam	**Understanding** the concept of Relays and its components	T1, T2, R2
22			Principle of Operation and Construction of Induction Disc	**Understanding** the concept of Relays and its components	T1, T2, R2
23			Principle of Operation and Construction of Induction Cup relay	**Understanding** the concept of Relays and its	T1, T2, R2

				components	
24			Types of Over Current Relays: Instantaneous DMT and IDMT types Over Current Relays	**Understanding** the concept of Relays and its components	T1, T2, R2
25					
26			Types of Over Current Relays: Instantaneous DMT and IDMT types Over Current Relays	**Understanding** the concept of Relays and its components	T1, T2, R2
27	6		Application of relays	**Understanding** the **Knowledge** of Relays and its components	T1, T2, R2
28			Universal torque equation Distance relays: Impedance, Reactance	**To Gain** the **knowledge** about Torque equation.	T1, T2, R2
29			Mho and Off-Set Mho relays	**Understanding** the concept of Relays and its types	T1, T2, R2
30			Universal torque equation Distance relays: Impedance, Reactance	**To Gain** the **knowledge** about Torque equation.	T1, T2, R1,R2,
31			Mho and Off-Set Mho relays	**Understanding** the concept of Relays and its types	T1, T2, R2
32			Characteristics of Distance Relays and Comparison	**To Gain** the **knowledge** about characteristics and comparison.	T1, T2, R2
33	7	2	Static Relays: Static Relays verses Electromagnetic Relays.	**Understanding the knowledge** about characteristics of static relays.	T1, T2, R2
34			**Revision and Problems on Unit II**	**Overview**	
35			**Mock Test – II**	**To Test the knowledge and preparing students for final examination**	
UNIT-III Protection of Power System Equipment					
36	8	3	Protection of generators against Stator faults, Rotor faults, and	**To Understand** the concept of fault in	T1, T2, R2

			Abnormal Conditions	Generator.	
37			Restricted Earth fault Protection	**To Gain** the knowledge about earth fault protection.	T1, T2, R2
38			Inter-turn fault Protection	**To Understand and Gain** the knowledge about inter-turn fault and protection.	T1, T2, R2
39			Numerical Problems on % Winding Unprotected	**To Understand and Gain** the knowledge about Fast decoupled load flow method	T1, T2, R2
40			Numerical Problems	**Applying** the concepts to solve the problems	T1, T2
41			Protection of transformers: Percentage Differential Protection	**To Know** the concept of Protection of transformers	T1, T2, R2
42	9		Numerical Problem on Design of CT s Ratio	**To Apply and Gain the Knowledge** by solving different problems	T1, T2, R2, R3
			Buchholtz relay Protection	**Understanding the knowledge** of relay protection	T1, T2, R2
43		3	Protection of Lines: Over Current		
44			Carrier Current relays		
45			Three-zone distance relay protection using Impedance relays	**Understanding the knowledge** of relay protection.	T1, T2, R2
46			Protection of Bus bars – Differential protection.		
47			**Revision and Problems on Unit II**	**Overview**	
UNIT IV –Neutral Grounding					
48	10	4	Ungrounded Neutral Systems	**Understanding the knowledge** of Undergrounded Neutral system	T1, T2 R2
49			Effects of Ungrounded Neutral on system performance	**To Understand and Gain the Knowledge** about Undergrounded Neutral system	T1, T2 R2
50			Methods of Neutral Grounding	**To Understand** the	T1, T2

				concept of methods etc.	R2
51			**Tutorial / Bridge Class # 2**	**To Test the knowledge and preparing students for final examination**	
52	11		Solid Grounding	**Understanding the knowledge** of Solid grounded	T1, T2 R2
53			Resistance Grounding	**To Gain** the Knowledge about Resistance grounding.	T1, T2 R2
54			Reactance - Arcing Grounds	**Understand the Knowledge of Arc grounding.**	T1, T2 R2
55			Grounding Practices.	**To Understand and Gain** the knowledge of grounding Practices.	T1, T2 R1,R2
56			**Revision and Problems on Unit IV**	**Overview**	
57			**Mock Test – III**	**To Test the knowledge and preparing students for final examination**	
UNIT V –Protection against Over Voltage					
58	12	5	Generation of Over Voltages in Power Systems	**To Know** about generation of Over Voltages.	T1,T2, R2
59			Protection against Lightning Over Voltages	**To Understand** the concept of Protection against Lightning	T1,T2, R2
60			Valve type Lighting Arresters	**Understand the** knowledge of Lighting Arresters.	T1,T2, R2
61	13		Zinc-Oxide Lighting Arresters	**Understand the** knowledge of Lighting Arresters.	T1,T2, R2
62			**Tutorial / Bridge Class # 3**	**To Test the knowledge and preparing students for final examination**	
63			Insulation Co-ordination	**Understand the concept of Insulation Co-**	T1,T2, R2

				ordination .	
64	14		BIL, Impulse Ratio	**To Understand** the concept of Impulse Ratio.	T1,T2, R2
65			Standard Impulse Test Wave	**To Understand and Gain** the knowledge of Standard Impulse Test Wave	T1, T2, R2
66			Volt-Time Characteristics	**To Understand and Gain** the knowledge of Volt-Time Characteristics.	T1, T2, R2
67			**Mock Test – IV**	**To Test the knowledge and preparing students for final examination**	
68			**Revision**	**Overview**	
Extra Classes			**Tutorial / Bridge Class # 4**	**To clarify the doubts**	
			Unit I – Unit V: Revision	**Overview**	
Contents Beyond the Syllabus: Protection Circuit in Power Electronics Components					
II Mid Examinations (Week 15)					

	Program Outcomes												**Program Specific Outcomes**	
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO 1	**3**	**2**	**1**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**1**	**1**
CO 2	**3**	**3**	**2**	**2**	**-**	**1**	**1**	**-**	**-**	**-**	**-**	**2**	**2**	**2**
CO 3	**3**	**3**	**2**	**2**	**-**	**2**	**2**	**-**	**-**	**-**	**-**	**2**	**3**	**2**
CO	**3**	**3**	**2**	**2**	**-**	**2**	**2**	**-**	**-**	**-**	**-**	**2**	**3**	**2**

4														
CO 5	**3**	**3**	**2**	**2**	**-**	**2**	**2**	**-**	**-**	**-**	**-**	**2**	**3**	**3**
AVG	**3**	**2.8**	**1.8**	**1.6**	**-**	**1.4**	**1.4**	**-**	**-**	**-**	**-**	**1.8**	**2.4**	**2**

VIII. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OFPROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

IX. QUESTION BANK:

UNIT I

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Brief discuss the different methods of arc interruption in case of circuit breakers?	Knowledge	2
2	In a short circuit test on 220 kV, 3-phase system with breaker gave the results as: P.f of the fault is 0.6 and recovery voltage is 0.85 times the full line voltage. The breaking current is symmetrical and restriking transient has a natural frequency of 10kHZ. Calculate the RRR V for i) Grounded fault and ii) Ungrounded fault	Derive	3
3	What is meant by circuit breaker? Discuss the phenomenon of arc formation in a CB.	Knowledge	2
4	Explain the concepts of recovery voltage and restriking voltages?	Knowledge	2
5	Discuss the air blast circuit breakers' ratings and its advantages	Knowledge	2
6	Explain the types of SF6 circuit breakers with neat diagrams?	Knowledge	2

7	List out the merits and limitations of air blast circuit breaker?	Knowledge	2
8	Explain the properties of SF6 gas and how it is used for circuit breakers?	Knowledge	2
9	Explain the concept of resistance switching of a circuit breaker with an equivalent circuit?	Applying	2
10	In a short circuit test on a CB, the following readings were obtained on single frequency transient. i) Time to reach the peak restriking voltage is 50μ sec. ii) The peak restriking voltage is 100kV. Find the average RRRV and iii) Frequency of oscillations	Derive	4
11	Describe the principle of operation of air blast circuit breakers?	Knowledge	2
12	Compare the operation of vacuum circuit breaker with SF6 circuit breaker?	Knowledge	2

UNIT II

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	What is an impedance relay? Discuss its principle of operation. Show its characteristics R-X diagram. List out its merits for transmission line protection.	Derive	4
2	Explain the hinged armature type	Knowledge	2

	relay with neat sketch?		
3	Explain about the principle of operation of biased differential relay with necessary equations?	Applying	3
4	Explain about MHO relay and OFF SET MHO relays with their characteristics?	Applying	3
5	Discuss the operating principle of an impedance relay and the draw its Characteristics on R-X plane?	Knowledge	2
6	Explain functions of induction disc relay with neat diagram?	Knowledge	2
7	Explain the operation of induction cup relay with neat diagram?	Knowledge	2
8	What are the various types of over current relay? Discuss the IDMT relays characteristics	Knowledge	2

UNIT III

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Explain the restricted earth fault protection by differential system in the protection of an alternator winding?	Understanding	2
2	A 11 kV, 100 MVA alternator is grounded through a resistance of 10 ohms. The current transformers have a ratio of 1000/5. The relay is set to operate when there is an out of balance current of 0.5 A. Find the percentage of generator winding protected by percentage differential protection?	Solving	3

3	Discuss the various faults occurred in the transformer and write the protection scheme for each fault?	Knowledge	3
4	Explain the protection device for a transformer that gives protection from internal Faults.	Applying	3
5	A 3 phase, 11/33KV star delta connected power transformer is protected by differential protection. The CTs on the LV side have a current ratio of 300/5. What must be the ratio of CTs on the HV side? Draw the connection diagram?	Applying, Solving	5
6	Explain how the rotor of an alternator will be protected by field ground fault protection?	Knowledge	3
7	Describe the stator protection of alternator by percentage differential protection with neat sketch?	Knowledge	3
8	plain how the transformer is protected from overheating problem?	Knowledge	3
9	Explain how the transformer is protected from overheating problem?	Knowledge	3
10	A 3φ, transformer having line voltage ratio 0.4/11 kV is connected in star delta and protective transformer on the 400 V side have a CT ratio of 500/5. What must be the ratio of the protective transformers on the 11kV side?	Applying, Solving	4
11	Explain transverse percentage differential protection for multi winding generators	Knowledge	3

12	A Star connected 3-φ, 25MVA, 11kV generator has a per phase reactance of 12%. It is protected by merz-price circulating current principle which is set to operate for fault current not less than 170 A. Find the value of earth resistance to be provided in order to ensure that only 12% of the generator winding remains unprotected.	Applying, Solving	5
13	Explain the protection against magnetizing inrush current of a transformer?	Knowledge	3
14	Draw and explain the connection of current transformer secondaries for differential protection of star delta connected power transformer?	Knowledge	3

UNIT IV

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Explain the differences between grounded and un grounded neutral systems?	Solving	4
2	Explaineffects of Ungrounded Neutral on system performance?	Solving	4
3	What are the different methods of Neutral Grounding?	Solving	4
4	Explain Solid Grounding method? Write its merits and demerits?	Applying	4
5	Explain Resistance Groundingmethod? Write its merits and demerits?	Applying	4
6	Explain Reactance - Arcing Groundsmethod? Write its merits and demerits?	Solving	4
7	What are the different Grounding		

	Practices?		

UNIT V

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Explain about the valve type and zinc oxide type lightning arresters?	Applying	3
2	Why is insulation coordination needed in a large power system? What is meant by basic impulse level of equipment?	Solving	3
3	Explain the resistance grounding with circuit diagram and phasor diagrams? List out its merits and demerits.	Solving	3
4	plain the concept of arcing grounds in the power system and derive the necessary expressions.	Derive	4
5	Draw the volt time characteristics of impulse test wave and mark the flash over voltages?	Applying	3
6	Explain how the over voltages are generated in the power system?	Applying	3
7	hat are the methods that are used to give protection against over voltages in the power system?	Applying	3