7. SUBJECT DETAILS

7.5 SWITCHGEAR AND PROTECTION

7.5.1 Objective and Relevance

7.5.2 Scope

7.5.3 Prerequisites

7.5.4 Syllabus

- i. JNTU
- ii. GATE
- iii. IES

7.5.5 Suggested Books

7.5.6 Websites

7.5.7 Experts' Details

7.5.8 Journals

7.5.9 Finding and Developments

7.5.10 Session Plan

- i. Theory
- ii. Tutorial

7.5.11 Student Seminar Topics

7.5.12 Question Bank

- i. JNTU
- ii. GATE
- iii. IES

7.5.1 OBJECTIVE AND RELEVANCE

Now a days interconnected Power System Operation is complex and vary in sizes and configurations. The technical analysis of transmission line is done to know its performance. An Electric Power System consists of large equipment like generators, transformers and associated transmission and distribution network. Short circuits and other abnormal conditions often occur on a power system which leads to heavy faults resulting damage of the power apparatus. Hence it is mandatory for an Electrical Engineer to be aware of impartance and operation of switch gear and protection.

This course introduces all varieties of circuit breakers and relays for protection of generators, transformers and feeder, bus bars from over voltages and other hazards. It emphasis on Neutral grounding for overall protection.

7.5.2 SCOPE

This subject provides the knowledge on switchgear and protection of various power system elements. This leads to the understanding of how a power plant or electric substation can be maintained for smooth functioning. It also makes one to know about protection of various elements from both internal faults like earth fault, short circuit faults etc. and external faults like lightning faults.

7.5.3 PREREQUISITES

It requires knowledge of Power systems, Network theory, Electrical machines, Prime movers, electrical and mechanical design of transmission lines and applied mathematics.

7.5.4 JNTU SYLLABUS

UNIT-I
OBJECTIVE
Explains the elementary principles of restriking and recovery voltages and arc extinguishing phenomenons.

SYLLABUS
CIRCUIT BREAKERS-I:
Elementary principles of arc interruption, restriking and recovery voltages, restriking phenomenon, average and max. RRRV, numerical problems. Current chopping and resistance switching. CB ratings and specifications: Types and numerical problems, auto reclosures.

UNIT-II
OBJECTIVE
This unit is meant for explaining different types of circuit breakers.

SYLLABUS
CIRCUIT BREAKERS-II:
Description and operation of following types of circuit breakers: Minimum oil circuit breakers, Air blast circuit breakers, Vacuum and SF6 circuit breakers.

UNIT-III
OBJECTIVE
This unit on “Electromagnetic and static relays” gives the details of both electromagnetic and static relays and their necessity, principle of operation and construction

SYLLABUS
ELECTROMAGNETIC AND STATIC RELAYS:

Principle of operation and construction of attracted armature, balanced beam, induction disc and induction cup relays.

Relays classification: 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 comparision.

Static relays: Static relays verses electromagnetic relays.

UNIT-IV
OBJECTIVE

This unit explains about protection of generators against various types of faults.

SYLLABUS
GENERATOR PROTECTION:

Protection of generators against stator faults, rotor faults, and abnormal conditions. Restricted earth fault and inter-turn fault protection, numerical problems % winding unprotected.

UNIT-V
OBJECTIVE

This unit explains about protection of transformer against various types of faults.

SYLLABUS
TRANSFORMER PROTECTION:

Protection of transformers: Percentage differential protection, numerical problem on design of CTs Ratio, Buchholtz relay protection.

UNIT-VI
OBJECTIVE

This unit explains about protection of Feeder and busbars against various types of faults and type of relay protection used.

SYLLABUS
FEEDER AND BUS-BAR 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-VII
OBJECTIVE

This unit explains different types of grounding adopted in practice.

SYLLABUS
NEUTRAL GROUNDING:

Grounded and ungrounded neutral systems. Effects of ungrounded neutral on system performance. Methods of neutral grounding: Solid, resistance, reactance, arcing grounds and grounding practices.

UNIT-VIII
OBJECTIVE

This unit explains protection against over voltages and insulation coordination required for this protection and over voltage phenomenons.

SYLLABUS

PROTECTION AGAINST OVER VOLTAGES:

Generation of over voltages in power systems. Protection against lightning over voltages, valve type and Zinc-oxide lighting arresters. Insulation and coordination, BIL, impulse ratio, standard impulse test wave, volt-time characteristics.

7.5.3.2 GATE SYLLABUS

UNIT-I
Circuit breakers.

UNIT-II
Circuit breakers.

UNIT-III
Solid state relays, over current, differential and distance protection.

UNIT-IV
Differential protection.

UNIT-V
Differential protection.

UNIT-VI
Over current protection, distance and differential protection.

UNIT-VII
Not covered.

UNIT-VIII
Insulation.

7.5.3.3 IES SYLLABUS

UNIT-I
Power system protection, circuit breakers.

UNIT-II
Power system protection, circuit breakers.

UNIT-III
Relays.

UNIT-IV
Power system protection.

UNIT-V
Power system protection.

UNIT-VI
Power system protection.

UNIT-VII

Not covered.

UNIT-VIII
Power system transients.

7.5.5 SUGGESTED BOOKS

TEXT BOOKS

T1 Switchgear and Protection, Sunil S. Rao, Khanna Publishers.
T2 Power System Protection and Switch Gear, Badari Ram, D.N Viswakarma, TMH Publications

REFERENCE BOOKS

R1 Fundamentals of Power System Protection, Paithankar and S.R.Bhide.,PHI, 2003.
R2 Power system protection and switchgear, Bhuvnesh Oza, TMH, 2010.
R3 Electrical Power Systems, C.L.Wadhwa, 2nd Edn.,New Age International (P) Limited.
R4 Principles of Power Systems, V.K. Mehta, Rohit Mehta, S.Chand and Co.
R5 Hand Book of Switchgears, BHEL, TMH Publications.
R6 Power System Protection and Switchgear, Ravindranth & Chander, New Age International (P) Ltd.

7.5.6 WEBSITES

1. www.ntu.ac.sg
2. www.utoronto.ca
3. www.ee.washington.edu
4. www.esca.com
5. www.ne.ac.sg
6. www.iitb.ac.in
7. www.annauniv.edu
8. www.ieeecss.org
9. www.ieee.com
10. www.iee.com
11. www.etinstrumentation.com

7.5.7 EXPERTS' DETAILS

INTERNATIONAL

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2. Mr. Hanumantha Rao
   Dy. Gen. Manager,
   Transmission Systems,
   BHEL, R&D, Hyderabad.
   Andhra Pradesh.

7.5.8 JOURNALS

INTERNATIONAL

1. IEEE Transactions on Power Systems
2. IEEE Transactions on Power Delivery
3. IEEE Transactions on Energy Conversion
4. Institution of Electrical Engineers

NATIONAL

1. Institution of Engineers (India)
2. System Society of India

7.5.9 FINDINGS AND DEVELOPMENTS

1. Study of solving coordination curve intersection of inverse-time over current relays in subtransmission systems, J.L. Cheng and Y. Lu, W.S. Kao, Vol. 23, No. 4, IEEE Transactions on Power Delivery, October 2008.
2. Combined wavelet - SVM Technique for fault zone detection in a series compensated transmission line, U.B. Parikh, B. Das, R.P. Maheswari, Vol.23,No.4, IEEE Transactions on Power Delivery, Oct.2008.
3. A distance protection relay for a 100kv UHV transmission line, Z.Y. Xu, S.F. Huang & L. Ran, Vol. 23, No. 4, IEEE Transactions on Power Delivery, October 2008.
4. Enhanced numerical breaker failure protection, B. Kasztenny, V. Muthukrishnan, T.S. Sidhu, Vol. 23, No. 4, IEEE Transactions on Power Delivery, October 2008.
5. A new strategy for determining fault zones in distance relays, M. Gilany and Y. Madouh, Vol.23, No.4, IEEE Transactions on Power Delivery, October 2008.

7.5.10 SESSION PLAN

i. THEORY

Sl. No.	Topics in JNTU Syllabus	Modules and Sub modules	Lecture No.	Suggested Books	Remarks
		UNIT-I (CIRCUIT BREAKERS-1)			
1	Switchgear and Protection	Objective and relevance Overview of the subject Introduction Prerequisites Scope of the subject Present scenario of Power System Protection	L1 L2		
2	Circuit breakers	Sub station equipment Faults and abnormal conditions Fault clearing process Some terms in the test Significance of switchgear and protection	L3	T1-Ch1, T2-Ch9 R1-Ch1, R3-Ch15 R4-Ch19, R5-Ch1 R6-Ch13	GATE IES
3	Elementary principles of arc interruption	Electric arc Initiation of the arc High resistance arc interruption Current zero interruption - Slepain's theory - Energy balance theory	L4 L5	T1-Ch4, T2-Ch9 R3-Ch15, R4-Ch19,R5-Ch1 R6-Ch13	GATE IES
4	Restriking and recovery voltages Restriking phenomenon, average and max. RRRV	Expression for restricting and recovery voltages Average RRRV Maximum RRRV	L6 L7	T1-Ch3, T2-Ch9 R3-Ch15, R4-Ch19,R6-Ch14	GATE IES

5	Numerical Problems.	Problems on restriking and recovery voltages	L8 L9	T1-Ch3, T2-Ch9 R3-Ch15, R4-Ch19,R6-Ch14	GATE IES
6	Current chopping and resistance switching	Circuit analysis Interruption of capacitive currents	L10	T1-Ch3, T2-Ch9 R3-Ch15, R4-Ch19,R6-Ch14	GATE IES
6	CB ratings and specifications: types	Braking capacity Short time current rating Rated voltage, current and frequency Rated operating duty Rated making capacity	L11	T1-Ch3, T2-Ch9 R3-Ch15, R4-Ch19,R6-Ch14	GATE IES
7	Numerical problems	Problems on CB ratings	L12	T1-Ch3, T2-Ch9 R3-Ch15, R4-Ch19,R6-Ch14	GATE IES
8	Auto enclosures	Auto enclosures	L13	T1-Ch2, T2-Ch4 R3-Ch15, R4-Ch19,R5-Ch6 R6-Ch7	GATE IES
UNIT-II (CIRCUIT BREAKERS-2)					
9	Description and operation of following types of circuit breakers Minimum oil circuit breakers	Introduction Description and operation of minimum oil circuit breakers	L14	T1-Ch8, T2-Ch9 R3-Ch15, R4-Ch19,R5-Ch1 R6-Ch15	GATE IES
10	Air blast circuit breakers	Construction and operation Principle of arc quenching Cross blast and axial blast circuit	L15	T1-Ch6, T2-Ch9 R3-Ch15, R4-Ch19,R5-Ch1	GATE IES

		breakers		R6-Ch15	
11	Vacuum circuit breakers.	The vacuum arc Current chopping The vacuum arc recovery Construction of VB Applications	L16	T1-Ch9, T2-Ch9 R3-Ch15, R4-Ch19,R5-Ch1 R6-Ch16	GATE IES
12	SF6 circuit breakers	Properties of SF6 gas Different types of SF6 circuit breakers Construction and operation of SF6 circuit breakers	L15	T1-Ch7, T2-Ch9 R3-Ch15, R5-Ch1	GATE IES
		Merits and demerits Applications	L16	T1-Ch7, T2-Ch9 R3-Ch15, R5-Ch1	GATE IES
UNIT-III (ELECTROMAGNETIC AND STATIC RELAYS)					
13	Principle of operation and construction ofattracted armature and balanced beam relays	Relays introduction Some definitions Relay types Operating principles	L17	T1-Ch25, T2-Ch2 R3-Ch14, R5-Ch9	GATE IES
		Construction and operation of attracted armature and balanced beam relays Time-current characteristics Types Applications	L18 L19	T1-Ch26, T2-Ch2 R3-Ch14, R5-Ch9	GATE IES
14	Induction disc and induction cup relays	Construction and operation of induction disc relay Shaded pole and watt-hour meter types Torque equation	L20	T1-Ch26, T2-Ch2 R3-Ch14, R5-Ch9	GATE IES

		Plug setting and time setting			
		Operation and construction of induction cup relays	L21	T1-Ch26, T2-Ch2 R3-Ch14	GATE IES
15	Relays classification: Instantaneous, DMT and IDMT types.	Time current characteristics Plug Setting Multiplier Problems on Plug Setting Multiplier	L22	T1-Ch27, T2-Ch3 R3-Ch14, R1-Ch2	GATE IES
16	Application of relays: Over current/under voltage relays, direction relays	Construction Phasor diagrams Torque equation Applications	L23	T1-Ch26,27 T2-Ch3 R3-Ch14, R1-Ch2	GATE IES
17	Differential relays	Principle of operation Principle of circulating current differential protection Difficulties Applications	L24	T1-Ch28, R3-Ch14	GATE IES
18	Percentage differential relays	Operating characteristics Applications	L25	T1-Ch28, R3-Ch14	GATE IES
19	Universal torque equation Distance relays: Impedance relay	Introduction Principle of R-X diagram Operating characteristics	L26	T1-Ch29, T2-Ch4 R1-Ch6, R3-Ch14	GATE IES
20	Reactance relay	Torque equation Characteristics	L27	T1-Ch29, T2-Ch4 R1-Ch6, R3-Ch14	GATE IES
21	Mho and Off-set Mho relays	Torque equation Characteristics	L28	T1-Ch29, T2-Ch4 R1-Ch6, R3-Ch14	GATE IES
22	Characteristics of distance relays and comparison	Characteristics of distance relays and comparison	L29	T1-Ch29, T2-Ch4 R1-Ch6, R3-Ch14	GATE IES

23	Static relays: Static relays verses electromagnetic relays	Introduction to static relays General theory of operation Comparison	L30	T1-Ch38, T2-Ch4 R2-Ch1, R3-Ch14 R5-Ch9	GATE IES
		Problems on relays	L31	T1-Ch28, T2-Ch4 R3-Ch14	GATE IES
UNIT-IV (GENERATOR PROTECTION)					
24	Protection of generators against stator faults, Rotor faults	Introduction Stator protection - Differential protection - Percentage differential protection - Stator over heating protection	L32	T1-Ch33, T2-Ch6 R1-Ch8, R3-Ch14	GATE IES
		Rotor protection - Field ground fault protection - Protection against rotor over heating	L33	T1-Ch33, T2-Ch6 R1-Ch8, R3-Ch14	GATE IES
25	Abnormal conditions	Un-balanced loading Over loading Over speed Over voltage Failure of the prime mover Loss of excitation	L34	T1-Ch33, T2-Ch6 R1-Ch8, R3-Ch14	GATE IES
26	Restricted earth fault and inter-turn fault protection	Transverse differential protection Inter turn protection based on zero sequence component	L35	T1-Ch33, T2-Ch6 R3-Ch14	GATE IES
27	Numerical problems on % winding	Numerical problems on % winding unprotected.	L36	T1-Ch33, T2-Ch6	GATE

	unprotected.		L37	R3-Ch14	IES
	Revision on the topics of I-IV units		L		
UNIT-V (TRANSFORMER PROTECTION)					
28	Protection of transformers: Percentage differential protection	Types of faults Percentage differential protection for Star-Delta transformer Grounded and ungrounded transformer protection	L38	T1-Ch32,T2-Ch6 R1-Ch4, R3-Ch14 R5-Ch3	GATE IES
		Biased differential protection Earth fault protection	L39	T1-Ch32,T2-Ch6 R3-Ch14	GATE IES
29	Numericalproblems on design of CT s ratio	Problems on CT ratio	L40 L41	T1-Ch32, R3-Ch14	GATE IES
30	Buchholtz relay protection	Principle Arrangements Installation Limitations	L42	T1-Ch32,T2-Ch6 R1-Ch4, R3-Ch14	GATE IES
UNIT-VI (FEEDER AND BUS-BAR PROTECTION)					
31	Protection of lines: Over current protection	Time graded system Current graded system Time current graded system	L43	T1-Ch34, T2-Ch6 R1-Ch2, R3-Ch14 R5-Ch3	GATE
		Protection of parallel feeders Protection of ring mains	L44	T1-Ch34, T2-Ch6 R3-Ch14, R5-Ch3	GATE
32	Carrier current protection	Block diagram Phase comparison scheme	L45	T1-Ch30, T2-Ch5 R1-Ch7, R3-Ch14	
33	Three-zonedistance relay protection using impedance relays	Impedance characteristics for three-zone protection Contact circuit of three-zone	L46	T1-Ch34, T2-Ch6 R1-Ch6, R3-Ch14	GATE

		impedance relay			
34	Translay relay protection of bus bars: differential protection	Bus zone protection by differential principle Single line diagram	L47 L48	T1-Ch34, T2-Ch5,6 R1-Ch5, R3-Ch14	GATE
UNIT-VII (NEUTRAL GROUNDING)					
35	Grounded and ungrounded neutral systems.Effects of ungrounded Neutral on system performance	Introduction Terms and definitions Effectively grounded system Ungrounded system and Resonant grounding Problems on various groundings	L49	T1-Ch18b, R3-Ch11	
36	Methods of neutral grounding: Solid, resistance, reactance, arcing grounds and grounding practices	Advantages of neutral grounding Solid grounding Resistance grounding Phasor diagrams	L50	T1-Ch18b, R3-Ch11	
		Reactance grounding Phasor diagrams	L51	T1-Ch18b, R3-Ch11	
		Arcing grounds Neutral grounding practices	L52	T1-Ch18b, R3-Ch11,12	
		Numerical problems on arc suspension coil	L53	T1-Ch18b, R3-Ch11,12	
UNIT-VIII (PROTECTION AGAINST OVER VOLTAGES)					
37	Generation of over voltages in power systems	Causes Protection - Horn gap, Rod gap - Surge diverters, Surge absorbers	L54	T1-Ch18A,T2-Ch11 R3-Ch16, R5-Ch8	

38	Protection against lightning over voltages	Lighting phenomina Over voltages due to lightening	L55	T1-Ch18A, T2-Ch11 R3-Ch12	
39	Valve type and Zinc-oxide lighting arresters	Operation Volt time characteristics Location and rating of lighting arresters	L56	T1-Ch18A, T2-Ch11 R3-Ch16, R5-Ch8	
40	Insulation and coordination, BIL Impulse ratio standard impulse test wave Volt-time characteristics	Introduction Terms and definitions Volt-time curve PF test wave Impulse test wave Stages of insulation coordination Basic impulse insulation level	L57 L58	T1-Ch18A, T2-Ch11 R3-Ch16	GATE
	Revision on the topics of V-VIII units		L		

ii. TUTORIAL

S. No	Topics scheduled	Salient topics to be discussed
T1	Circuit breakers, Elementary principles of arc interruption, Restriking and recovery voltages, Restriking phenomenon, average and max. RRRV, Numerical Problems, Current chopping and resistance switching	Numerical problems on restriking and recovery voltages
T2	Unit-I Assignment questions	Discussion on assignment questions of Unit-I, Circuit Breakers-I
T3	Description and operation of following types of circuit breakers, Minimum oil circuit breakers, Air blast circuit breakers, Vacuum circuit breakers, SF6 circuit breakers	Review on various circuit breakers
T4	Unit-II Assignment questions	Discussion on assignment questions of Unit-II, Circuit Breakers-II

T5	Principle of operation and construction of attracted armature and balanced beam relays, Induction disc and induction cup relays, Relays classification: Instantaneous, DMT and IDMT types, Application of relays: Over current/ under voltage relays, direction relays, Differential relays	Discussion on various relays
T6	Universal torque equation, Distance relays: Impedance relay, Reactance relay, Mho and Off-set Mho relays	Review on distance relays
T7	Unit-III Assignment questions	Discussion on assignment questions of Unit-III, Electro Magnetic and Static Relays
T8	Protection of generators against stator faults, Rotor faults Abnormal conditions, Restricted earth fault and inter-turn fault protection, Numerical problems on % winding unprotected.	Numerical problems on % winding unprotected.
T9	Unit-IV Assignment questions	Discussion on assignment questions of Unit-IV, Generator Protection
T10	Unit-V Assignment questions	Discussion on assignment questions of Unit-V, Transformer Protection
T11	Protection of lines: Over current protection, Carrier current protection, Three-zone distance relay protection using impedance relays, Translay relay protection of bus bars: differential protection	Review on feeder and bus-bar protection
T12	Unit-VI Assignment questions	Discussion on assignment questions of Unit-VI, Feeder and Bus-Bar Protection
T13	Unit-VII Assignment questions	Discussion on assignment questions of Unit-VII, Neutral Grounding
T14	Unit-VIII Assignment questions	Discussion on assignment questions of Unit-VIII, Protection against over voltages

7.5.11 STUDENT SEMINAR TOPICS

1. Protective devices emergence of type B devices, Aravind Ramachandran, Electrical India, Vol. 48, No.9, Page 106, Sep. 2008
2. Grounding material "Steel as grounding material, study of corrosion process", K.S. Sindhu, Electrical India, Vol. 48, No.9, Page 42, Sep. 2008.
3. Relay testing: "Relay interoperability testing", R. Sriraman and K.S. Swarup, Electrical India, Vol. 48, No.7, Page 66, July 2008.
4. Switch gear industry stector focus, A. Gokhale, Electrical India, Vol. 48, No.7, Page 86, July 2008.
5. LV switchgear and specification, K. S. Vakaar, Electrical India, Vol. 48, No.7, Page 92, July 2008.
6. Switchgear and switch boards, N.P. Jhaveri, Electrical India, Vol. 48, No.7, Page 106, July 2008.
7. Surge over voltages: The slow poision in power supply, Electrical India, Vol. 48, No.5, Page 114, July 2008.
8. Challenges in time protection philosophies, B. Bhalija and R.P. Maheswari, Electrical India, Vol. 48, No.4, Page 58, April 2008.
9. Earthing of electrical equipment, S. George, Electrical India, Vol. 48, No.3, Page 96, March 2008.
10. Soil conditioning for electrical earthing, K.S. Sidhu, Electrical India, Vol. 48, No.2, Page 70, Feb. 2008.

7.5.12 QUESTION BANK

UNIT-I

1 . i. Explain how the arc is initiated and sustained in a circuit breaker when the circuit breaker contacts separated

ii In a short circuit test on a 132 kV three phase system the breaker gave the following results: p.f of the fault: 0.4, recovery voltage 0.90 of full line value. The breaking current is symmetrical and the re-striking transient had a natural frequency of 20 kHz. Determine the average rate of rise of re-striking voltage.
Assume that the fault is grounded. **(May 13)**

2. i. Define the terms:
a. restriking voltage
b. recovery voltage
c. RRRV
ii. Derive an expression for the restriking voltage in terms of system voltage, inductance and capacitance across a C.B. contact when a 3-phase fault takes place. Assume the neutral of the system to be solidly grounded.
iii. Discuss the principle of arc interruption in an oil circuit breaker. **(May 12)**

3. i. Explain how the arc is initiated and sustained in a circuit breaker when the circuit breaker contacts separated.
ii. In a short circuit test on a 132 kV three phase system the breaker gave the following results: p.f of the fault : 0.4 , recovery voltage 0.95 of full line value. The breaking current is symmetrical and the re-striking transient had a natural frequency of 16kHz.Determine the rate of rise of re-striking voltage. Assume that the fault is grounded. **(Jan 12)**

4. i. Define the terms:
a. restriking voltage
b. recovery voltage
c. RRRV

Derive an expression for the re-striking voltage and RRRV in terms of system resistance, inductance and capacitance across a C.B. contact when a three phase fault takes place.

ii. In a short circuit test on a 132 kV three phase system the breaker gave the following results: p.f of the fault: 0.4 , recovery voltage 0.90 of full line value. The breaking current is symmetrical and the re-striking transient had a natural frequency of 20 kHz. Determine the average rate of rise of re-striking voltage. Assume that the fault is grounded. **(Jan 12)**

5. i. What is arc quenching? Explain different arc quenching theories.
   ii. What is current chopping? Explain. **(Jan 12)**

6. i. Explain the various testing of circuit breakers.
   ii. Discuss about the ratings of circuit breakers. **(Jan 12)**

7. Calculate the RRRV of a 220kV circuit breaker with earthed neutral. The short circuit test data obtained is as follows:
   The current breaker is symmetrical and the restriking voltage has an oscillatory frequency of 15 kHz. The power factor of the fault is 0.2. Assume the short circuit to be an earthed fault. **(May 10)**

8. i. Explain about current zero interruption and what are its advantages?
   ii. In a system the r.m.s voltage is 19.1kV, L is 10mH, C is 0.02□F. Determine the average rate of rise of restriking voltage, when the circuit breaker opens. **(May 10)**

9. Write a short notes on the rate of restriking voltage and explain its importance in arc extinction. **(May 10)**

10. A Circuit Breaker is rated as 2500A, 1500MVA, 33kV, 3 secs, 3-phase oil circuit breaker .Determine the rated symmetrical breaking current, rated making current, short time rating and rated service voltage.
    (May 10)

11. For a 132kV system, the reactance and capacitance up to the location of circuit breaker is 3□ and 0.015□F, respectively. Calculate the following: **(May 10, Sep 08, Apr 05, Jan 03)**
    i. The frequency of transient oscillation.
    ii. The maximum value of restriking voltage across the contacts of the circuit breaker.
    iii. The maximum value of RRRV

12. In a 132kV system, the reactance per phase up to the location of the circuit breaker is 5 ohms and capacitance to earth is 0.03□F. Calculate
    i. the maximum value of the restriking voltage,
    ii. the maximum value of RRRV and
    iii. the frequency of transient oscillations. **(Apr 09)**

13. Write a short notes on the rate of restriking voltage and explain its importance in arc extinction. **(Apr 09)**

14. A generator connected through a 3-cycle Circuit Breaker to a transformer is rated 10MVA, 13.8kV with reactances of X”d = 10%, X’d=15% and Xd =100%. It is operating at no load and rated voltage when a 3-phase short circuit occurs between the breaker and the transformer. Determine
    i. the sustained short circuit current in breaker;
    ii. the initial symmetrical rms current in the breaker;
    iii. the maximum possible d.c component of the short circuit current in the breaker;
    iv. the momentary current rating of the breaker;
    v. the current to be interrupted by the breaker and
    vi. the interrupting kVA. **(Apr 09, 08)**

15. i. Why is current interruption easier in an a.c circuit than in a d.c circuit?
    ii. An OCB is rated for 1000MVA, 2 kA, 66 kV, 3 phase, 3 sec. what are its
    a. Rated operating voltage
    b. Rated operating current

c. Rated symmetrical breaking current. **(Apr 09)**

16. Explain Slepian's theory of arc interruption and discuss its limitations. How does energy balance theory, explain the process of arc interruption? **(Sep, Apr 08)**

17. Explain the terms recovery voltage, restriking voltage and RRRV. Derive the expression for the restriking voltage in terms of system capacitance and inductance. **(Sep 08, Jan 03)**

18. i. Discuss the performance of a circuit breaker when capacitive currents are interrupted? **(Sep 08)**
 ii. Ina system of 132kV, the line to ground capacitance is 0.01μF and the inductance is 5H. Determine the voltage appearing across the pole of a Circuit Breaker. If a magnetizing current of 5ampes (instantaneous value) is inter-rupted. Determine also the value of resistance to be used across the contacts to eliminate the restriking voltage.

19. Discuss the recovery rate theory and energy balance theory of arc interruption in a circuit breaker. **(Sep 08, Apr 07, 05, 03)**

20. Explain resistance switching in detail with relevant diagrams and derive the expression of damped oscillation. **(Sep 08, Apr 06, 04, 03, Nov 03)**

21. Write short notes on the following.
 i. Making capacity
 ii. Short time current rating
 iii. Rated voltage, current and frequency
 iv. Rated operating duty **(Sep 08, 06, Apr 04, Nov, Apr, Jan 03)**

22. i. Explain briefly about various Switch gear components. **(Apr 08)**
 ii. Give the importance of ratings and specifications of Circuit Breaker.

23. Calculate the RRRV of a 220kV circuit breaker with earthed neutral. The short circuit test data obtained is as follows: The current breaker is symmetrical and the restriking voltage has an oscillatory frequency of 15 kHz. The power factor of the fault is 0.2. Assume the short circuit to be an earthed fault. **(Apr 08)**

24. A 50 Hz, 11 Kv, three phase alternator with earthed neutral has a reactance of 5 ohm/phase and is connected to the bus-bar through a circuit breaker. The capacitance to earth between the alternator and the circuit breaker is 0.02 microfarad per phase. Assume the resistance of the generator to be negligible. Calculate the following.
 i. Maximum value of voltage across the contacts of the circuit breaker.
 ii. Frequency of ossillation
 iii. The average rate of rise of restriking voltage upto first peak **(Apr 08)**

25. In a 132 kV system, inductance and capacitance upto the location of the circuit breakers are 0.4H and 0.015 microfarad respectively. Determine **(Apr 08)**
 i. The maximum value of restriking voltage across the contact of the circuit breakers.
 ii. Frequency of transient oscillations and the maximum value of RRRV.

26. i. Explain the Phenomenon of current chopping in a circuit breaker. What measures are taken to reduce it.
 ii. A circuit interrupts the magnetizing current of a 100MVA transformer at 220kV. The magnetizing current is 5% of the full load current. Determine the maximum voltage which may appear across the Gap of the breaker when the magnetizing current is interrupted at 53% of its peak value. The stray capacitance is 2500 microfarad. The inductance is 30H **(Apr 07, 04, Nov 03)**

27. Explain the following in detail:
 i. Symmetrical breaking capacity
 ii. Asymmetrical breaking capacity
 iii. Rating of circuit breakers. **(Sep 06, Nov, Apr 03)**

28. i.In a 132kV system, the reactance and capacitance up to the location of the circuit breaker is 5 ohms and 0.02microfarad respectively, a resistance of 500 ohms is connected across the break of the circuit breaker. Determine the natural frequency and damped frequency of oscillation and also find its critical resistance.

ii. Explain the terms recovery voltage and restricting voltages. **(Sep 06)**

29. Explain the reason for initiation of electric arc during contact separation. Also discuss which of these is primarily responsible for creation of arc in circuit breakers and why? **(Apr 05, 03)**

30. i. Explain the following.

a. Classification of restriking transients

b. Restriking voltage characteristics

ii. Explain with a neat diagram the factors affecting the restriking voltage characteristics. **(Apr 05, 03)**

31. In a 132kV system, the inductance and capacitance per phase up to the location of the circuit breaker is 10H and 0.02 microfarad, respectively. If the circuit breaker interrupts a magnetizing current of 20A (instantaneous), current chopping occurs. Determine the voltage which will appear across the circuit breaker. Also determine the resistance that should be connected across the contacts of the circuit breaker to eliminate restriking voltage. **(Apr 04)**

32. A 3-phase oil circuit breaker is rated at 1000A, 1500 MVA, 33 KV, 4S. Find the rated normal current, symmetrical breaking current, making current and short time current rating. **(Jan 03)**

33. A 3-phase oil circuit breakaer is rated 25000 A, 1200 MVA, 33 kV, 3 seconds. Determine the rated symmetrical breaking current, rated making current, short time rating and rated service voltage. **(Jan 02)**

34. In a short circuit test on a 3-pole, 132 kV, circuit breaker the following observations are made :
Power factor of fault 0.4. The recovery voltage 0.9 times full line value, the breaking current symmetrical, the frequency of oscillations of restriking voltage 16 kHz. Assume that the neutral is grounded and the fault does not involve ground. Determine the average rate of restriking voltage. **(Jan 02)**

35. A 66 kV 50 Hz, 3-phase alternator has an earthed neutral. The inductance and Capacitance of the system per phase are 7 mH and 0.01 mf respectively. The short-circuit test gave the following results: power factor of fault 0.25, fault current symmetrical recovery voltage is 90% of full line voltage. Assuming that the fault is isolated from the ground, calculate the RRRV. **(Jan 01)**

36. Explain how an arc is initiated and sustained in a circuit breaker when the circuit breaker contacts separate. **(Jan 00)**

37. The interrupting time of a circuit breaker is the period between the instant of

i. Initiation of short circuit and the arc extinction on an opening operation
ii. Energizing of the trip circuit and the arc extinction on an opening operation
iii. Initiation of short circuit and the parting of primary arc contacts
iv. Energizing of the trip circuit and the parting of primary arc contacts **(GATE 03)**

38. Three sections of a feeder are provided with circuit breakers CB1, CB2, CB3, CB4, CB5 and CB6. For a fault F as indicated in Fig.

i. CB5 must be set to trip after CB1 trips
ii. CB5 must be set to trip after CB3 and CB4 trips
iii. CB5 must be set to trip after CB2 trip

iv. CB5 must be set to trip before CB1, CB2, CB3 and CB4 trips **(GATE 99)**

39. A shunt reactor of 100 MVAr is operated at 98% of its rated voltage and at 96% of its rated frequency. The reactive power absorbed by the reactor is:
a. 98 MVAr b. 104.02 MVAr
c. 96.04 MVAr d. 100.04 MVAr **(GATE 98)**

40. Reactance relay is normally preferred for protection against
a. earth faults b. phase faults
c. open-circuit faults d. None of the above **(GATE 97)**

41. The synchronous reactance of a 200 MVA, 10 kV, 3-phase, 50 Hz generator is 1.0 p.u. at its own base. Its p.u. reactance at 100 MVA, 20 kV base will be……… **(GATE 97)**

42. A 3-phase transformer bank consists of three identical 2300/230V, 15 kVA single-phase transformers connect in delta/delta. The bank supplies a 20 kVA, unity p.f. 3-phase load. If one of the single-phase transformer develops a fault, and is removed, the load carried by each of the two transformers now operating in open delta will be .... kVA.**(GATE 97)**

43. In the power system circuit diagram shown in Fig., the current limiting reactor X is to be chosen such that the feeder breaker rating does not exceed 425 MVA. The system data is as follows:
Feeder transformer reactance: 10% on 50 Mva base.
The generating source A, B, C have individual fault levels at 1000 MVA with respective generator breakers open. Ignore pre-fault currents and assume 1.0 p.u. voltages throughout before fault. Assume common base of 1000 MVA. **(GATE 96)**

UNIT-II

1. Explain the construction and operation of SF6 circuit breaker with a neat sketch.
What are the advantages of SF6 circuit breaker over other circuit breakers? **(Jan 13)**

2. With a neat sketch explain the operation of
i. Minimum oil circuit breaker and
ii. Vaccum SF_6 circuit breaker. **(May 12)**

3. Explain the construction and operation of minimum oil circuit breaker with a neat sketch. Discuss its performance characteristics. **(Jan 12)**

4. Explain the construction and operation of SF_6 circuit breaker with a neat sketch. **(Jan 12)**

5. Explain the construction and operation of Vacuum circuit breaker with a neat sketch. **(Jan 12)**

6. Explain the construction and operation of air blast circuit breaker with a neat sketch. **(Jan 12)**

7. i. Compare the arc rupture in oil and air blast circuit breakers and summarize the relative advantages and disadvantages of these types of switch gear.
ii. Explain the operating duty of a circuit breaker. **(May 10, Sep, Apr 08)**

8. Distinguish between oil circuit breakers and SF_6 circuit breakers? **(May 10)**

9. Explain the process of current chopping in SF_6 circuit breakers. **(May 10, Jan 03)**
10. How eoes the current effect the arcing time in **(May 10)**

i. Oil circuit breaker
ii. Air blast circuit breaker

11. i. With the help of neat sketches, describe the principle of resistance switching units in an Air blast circuit breaker.
ii. Describe the construction of a vacuum interrupter and vacuum circuit breaker. **(Apr 09)**

12. Describe the principle of air blast circuit breaker with the help of neat sketches, explain the construction of a typical EHV air blast circuit breaker. **(Apr 09)**

13. Distinguish between Air Blast circuit breaker and oil circuit breakers? **(Apr 09)**

14. i. What are the key features of SF_6 Circuit Breaker over other circuit breakers.
ii. Write a short notes on the maintenance of Oil circuit breaker. **(Apr 09)**

15. What are the necessary auxiliaries of ABCB? Describe compressed air system for supplying compressed air to the air blast circuit breakers? **(Sep 08)**

16. Explain current chopping in VCB. Explain the function of RC surge suppressors used with vacuum switchgear for motor switching. **(Sep 08)**

17. Explain the principle of arc extinction and What are the different methods of arc extinction. **(Apr 08)**

18. Classify the types of circuit breakers when the arc quenching medium is the criterion? **(Sep 08, Apr 08, 07, 05, 03)**

19. Mention the voltage range for which a particular type of circuit breaker is recommended. **(Sep 08, Apr 08, 07, 05, 03)**

20 i. Why is current chopping not a serious problem with vacuum circuit breakers. **(Apr 07, 03)**
ii. How does SF6 breakers differ from an air blast circuit breakers?
iii. What are the possible applications of vacuum circuit breakers?

21. In what aspects is a minimum oil circuit breaker an improvement over the bulk oil breakers. **(Nov, Jan 03)**

22. Explain how SF_6 gas in ideally suitable for circuit breaker. **(Nov 03)**

23. Expplain the factors which are influencing the performance of an air blast circuit breaker. **(Nov 03)**

24. Explain with a neat sketch the working of a Air blast circuit breaker. **(Nov 03)**

25. Discuss the performance of a circuit breaker when capacitive currents are interrupted. **(Nov, Jan 03)**

26. Explain the operation of SF_6 circuit breaker with relevant sketch in a detailed manner. **(Nov, Jan 03)**

27. What are the various types of SF_6 circuit breakers. Explain them in detail with a neat sketch. **(Jan 03)**

28. What are the merits and demerits of SF_6 breakers. **(Jan 02)**

29. Describe the construction, principle of operation and application of SF_6 circuit breaker. **(Jan 01)**

30. Draw the constructional details of a minimum oil circuit breaker and explain it in detail along with its operation. **(Jan 00)**

31. Explain the process of arc quenching in SF_6 breaker and its applications. **(Jan 00)**

32. Describe the principle of operation of an airblast circuit breaker with a near sketch. **(Jan00)**

33. Explain briefly the following types of air-blast circuit breaker.
    i. Axial-blast type
    ii. Cross-blast type

34. What are the applications of SF_6 gas?

35. Explain precautions to be taken to avoid dust, moistore, and leakage in case of SF6 circuit breaker?

36 Describe the behavior of electric arc in high vaccum?

37. Explain the process of arc extinction in high vaccum?

UNIT-III

1. i. Explain the different structures used for mho relay.
   ii. Explain the characteristics of mho relay.
   iii. Differentiate between static and electromagnetic relays. **(May 13)**

2. i. Write the comparison between static relays and electromagnetic relays.
   ii. What is Universal torque equation? Using this equation derive the characteristics of reactance relay.
   iii. Write the applications of
   a. impedance relay b. mho relay c. over current relay
   d. under voltage relay and e. percentage differential relay. **(May 12)**

3. i. What is universal torque equation? Using this equation derive the following characteristics:
   a. Impedance relay b. Reactance relay c. Mho relay.
   ii. Explain the characteristics of IDMT realy. **(Jan 12)**

4. Explain the principle and operation of Directional over current relay. Discuss its various characteristics. **(Jan 12)**

5. i. Define the following:
   a. Relay b. Pick-up level c. Reset level d. Operating time. e. Over-reach
   ii. What are the functional characteristic of protective relays?
   iii. Differentiate between static and electromagnetic relays. **(Jan 12)**

6. i. Explain the different structures used for mho relay.
   ii. Explain the characteristics of mho relay.
   iii. Explain the basic connection for phase fault relays. **(Jan 12)**

7. Discuss with a neat sketch the general principle of operation of a distance protection scheme. **(May 10)**

8. What is the effect of ‘arc-resistance’ on the performance of impedance relay? and explain how it is Overcome in case of reactance relay? **(May 10)**

9. Discuss the Directional Impedance relay and Explain the Directional Impedance relay by means of its characteristic on R-X plane. **(May 10)**

10. A 6.6 kV, 4000 kVA star connected alternator with a transient reactance of 2 ohm/phase and negligible resistance, is protected by a circulating current protective system. The alternator neutral is earthed through a resistor of 7.5 ohm. The relays are set to operate when there is an out of balance current of 1A in the secondary windings of the 500/5 A current transformer. What percentage of each phase winding is protected against an earth fault?

(May 10)

11. A 20MVA transformer which may be called upon to operate at 30% over load, feeds 11kV busbar through a circuit breaker. Other circuit breakers supplies out going feeders. The transformer circuit breaker is equipped with 1000/5A CTs and the feeder circuit breakers with 400/5A CTs and all sets of CTs feed induction type over current relays. The relay's on the feeder circuit breakers have 125% plug setting and a 0.3 time setting. If a 3-phase fault current of 5000A flow from transformer to one of the feeders, find operating time of the feeder relay, the minimum plug setting of transformer relay and its time setting. Assuming a discriminative time margin of 0.5sec. **(May 10)**

12. State the various applications of over-current relaying. Distinguish between 'inverse characteristic' and 'definite characteristic'. **(Apr 09)**

13. Why are the differential relays more sensitive than over current relays, Explain? **(Apr 09)**

14. Explain the 'Differential protection'. State the various applications of differential protection. **(Apr 09, 08)**

15. i. Expain the following terms with respect to switch gear protection
   a. Pick up level
   b. operating time
   c. Reach
   d. Under Reach
   e. Over Reach.

   ii. An earth fault setting relay has a setting of 20%, current rating 5A, it is connected to a C.T of ratio 500:5. Calculate pick up current in primary for which the earth fault relay operates. **(Apr 09)**

16. Define the following terms and explain their significance in distance protection **(Sep, Apr 08)**
   i. Reach of a distance relay.
   ii. Under reach.

17. Explain the terms **(Sep 08)**
   i. Current setting
   ii. Plug setting multiplier
   iii. Time- setting multiplier
   iv. Primary protection and back up protection.

18. Distinguish between Over current relays, Directional relays and Differential relays? **(Sep 08)**

19. i. Explain in detail the role of protective relays in a power systems. **(Sep 08)**
   ii. Discuss in detail the causes and types and frequency of faults encountered in a power system.

20. Explain the merits and demerits of static relays. **(Sep 08, Nov 07, Apr 06)**

21. i. What is meant by directional feature of a directional over current relay? Describe the construction, principle of operation and application of a directional over current relay.
   ii. What is the difference between a polarized mho and simple mho relay. What are self-polarized and cross-polarized mho relays? **(Sep 08, 06, Nov 07, Apr 04, Jan 03)**

22. i. Discuss the choice between impedance, reactance and Mho type relays. **(Sep 08, Nov 07)**
   ii. Transformer: 5MVA, Y/δ , X=6% The transmission line sections AB and BC are to be protected by Mho distance relays. The system is as shown in the figure. If the C.T. ratio is 300/5 and C.T. ratio is

166000/110V and a 3-phase short circuit fault of zero impedance occurs at F, find the impedance seen by the relays and determine the setting of the relays for high speed protection of line AB and backup protection for line BC, when the relays are located atend A.

23. With the help of neat sketch explain the principle of operation of Differential relays. **(Sep 08)**

24. Write short notes on
    i. Reactance relay
    ii. Mho relay
    iii. Directional Impedance relay. **(Sep 08, Apr 05, Apr 04)**

25. Describe the various types of construction of attracted armature type relay. Why can they operate in a.c and d.c?. State its salient features. **(Apr 08)**

26. i. Describe the construction of an induction disc relay. State its principle of operation. What are the advantages to induction relays. How is the current setting and time setting obtained? **(Apr 08)**
    ii. With a neat sketch, describe the difference between definite characteristic and inverse characteristic of relays.

27. i. Where are the relays having extremely inverse and very inverse characteristics used? What types of characteristics are used for protecting rectifiers, and for replacement off uses?
    ii. Explain how the mho characteristic realized using a sampling comparator? **(Nov 07, 03, Apr 07, 05)**

28. i. What type of protection will you recommend for a power line operating at **(Nov 07)**
    a. 11 K.V. b. 33 K.V. c. 66K.V.
    ii. Discuss in detail with relevant diagrams the shaded pole type I.D.M.T. relay used in practice.

29. Determine the time of operation of the relays placed at location No. 1 and 2 assuming that fault current is 2000amps,C.T.ratio 200/1, relay 1 set at 100% and 2 at 125%and that the relay No.1 has a time multiplier of 0.2. The time grading margin between the relays is 0.5. sec for discrimination. Assume the relay to have 2.2 seconds I.D.M.T. Characteristic. As shown in figure. **(Apr 07, 06)**

30. i. Describe briefly some important types of electromagnetic attraction relays.
    ii. Describe the various steps for calculating the actual relay operating time. **(Sep 06, Apr 03)**

31. i. Explain how to provide directional feature of Impedance and Reactance relay.
    Explain why the directional feature provided for Impedance relay.
    ii. Explain why attracted armature type relays are noisy? What measures are take to minimize the noise.
    (Apr 06, Nov 03)

32. i. Describe the principle of impedance type distance relay and explain its characteristics on V-I And R-X planes.
    ii. Derive expression for torque developed by a double activating quantity distance relay.Show that the relay operates when fault is within the protected distance of line.
    (Apr 05)

33. i. Explain the process of fault clearing with the help of a neat sketch.
    ii. Classify the various types of over current relays and give their application along with approximate characteristics. **(Apr 05)**

34. i. Discuss the effect of power surges on the performance of different types of distance relays.
    ii. Discuss in detail the applications of over current relays. **(Apr 05)**

35. i. Discuss the principle of operation of an Induction disc relay with relevant diagrams.

ii. What are the advantages of Induction cup relays over Induction disc relays. What is the purpose of shading in an Induction disc relay? **(Apr 05, 04, Jan 03)**

36. i. What are the different types of Distance relays ? Compare their merits and demerits.
    ii. What is an angle impedance relay? Discuss how its characteristics are realized using the phase comparison technique. **(Apr 04, Jan 03)**

37. i. Explain clearly the basic principle of percentage differential relay for **(Apr 03)**
    a. Internal fault
    b. Through fault
    ii. Explain what you understand by pick-up and reset value of the actuating quantity. Explain the term selectivity in protective relays.

38. i. What are the various types of over current relays? Discuss their area of applications. **(Apr, Jan 03)**
    ii. What are the various over current protective schemes? Why IDMT relays are widely used for over current protection.

39. i. Write a note on the following: **(Apr 03)**
    a. Definite distance relay
    b. Time distance relay
    ii. Discuss the fundamental requirements of protective relaying

40. i. Explain the characteristics of an HRC fuse and discuss how they are useful in circuit breaking.
    ii. With a neat circuit schematic, explain the working of a static over-current relay with inverse time characteristic. **(Jan 03)**

41. Explain the principle of operation of differential protection. What are its limitations ? What modifications are required to make it free from mal operation ? **(Jan 03)**

42. i. What are the basic requirements of relays ?
    ii. Explain with necessary sketches the principle and operation of an electromagnetic induction relay to be used for overcurrent protection with directional property. **(Jan 02)**

43. i. Explain the principle of operation of distance relays. What is R-X diagram ?
    ii. A three phase, 10MVA, 6.6 kV alternator supplies a load of 8 MVA at 0.8 powerfactor and is being protected through Merz-price circulating current system and its relays are so set that they do not operate until out of balance current exceeds 20% of full load Current. Calculate the value of earth resistance to be provided in order to ensure that only 10% of alternator winding remains unprotected. Assume alternator reactance of 10% Neglect resistance. **(Jan 01)**

44. i. Give the constructional features and operating characteristics of an impedance relay.
    ii. Draw the block diagram of static over current relay and explain the functions of each block.
    (Jan 01)

45. i. Explain the classification of distance relays in detail.
    ii. Derive the torque equation of an induction disc relay. **(Jan 00)**

46. Discuss the advantages and disadvantages of static relays. **(Jan 00)**

47. A 50 Hz, bar primary CT has a secondary with 500 turns. The secondary supplies 5A current into a purely resistive burden of 1 Ohm. The magnetizing ampere-turns is 200. The phase angle between the primary and secondary current is
    a. 4.6^0 b. 85.4^0 c. 94.6^0 d. 175.4^0 **(GATE 04)**

48. The core flux in the CT of Prob Q 28, under the given operating condition is
a. 0 b. 45.0 mWb c. 22.5 mWb d. 100.0 mWb **(GATE 04)**

49. A list of relays and the power system components protected by the relays are given in Group I and Group II respectively. Choose the correct match from the four choices given below : **(GATE 03)**

Group - I	Group - II
P Distrance relay	1 Transformers
Q Under frequency relay	2 Turbines
R Differential relay	3 Bushers
S Buchholz relay	4 Shunt capacitors
	5 Alternators
	6 Transmission lines

a) P-6, Q-5, R-3, S-1 b) P-4, Q-3, R-2, S-1
c) P-5, Q-2, R-1, S-6 d) P-6, Q-4, R-5, S-3

50. The transmission line distance protection relay having the property of being inherently directional is
i. impedance relay
ii. MHO relay
iii. OHM relay
iv. reactance relay **(GATE 03)**

51. In an inverse definite minimum time, electromagnetic type over-current relay the minimum time feature is achieved because of
i. saturation of the magnetic circuit
ii. proper mechanical design
iii. appropriate time delay element
iv. electromagnetic damping **(GATE 00)**

52. The plug setting of a negative sequence relay is 0-2A. The current transformer ratio is 5.1. The minimum value of line to line fault current for the operation of the relay is : **(GATE 00)**

53. A 50 MVA, 132/66 KV, D/Y, 3-f power transformer is protected by percentage differential relays. If the current transformer (CTS) located on the delta and star sides of the power transformer are 300/5A and 1200/5A respectively, determine
i. The output current at full load
ii. The relay current at full load
iii. The minimum relay current setting to permit 25% overload **(GATE 91)**

54. Reactance relay is normally preferred for protection against
i. earth faults
ii. phase faults
iii. open-circuit faults
iv. None of the above **(GATE 97)**

UNIT-IV

1. i. A 6.6 kV, 5 MVA star connected generator has a reactance of 1.5 ohm per phase and negligible resistance. Merz-Price protection scheme is used which operates when the out of balance of the current exceeds 25% of the full load current. The neutral of the generator is grounded through a resistance of 8 ohms. Determine the proportion of the winding which remains unprotected against earth fault. Show that the effects of alternator reactance can be ignored.

ii. Discuss the generator protection schemes for

i) Loss of excitation ii) Overload iii) loss of prime mover. **(May 13)**

2. i. What is restricted earth fault protection for alternators? Why is this form of protection used for alternators even though it does not provide protection for the complete winding?
   ii. With a neat sketch explain the protection of alternator against stator faults and rotor faults. **(May 12)**

3. Why generators are to be protected? Explain the protection schemes for the following Faults
   i. Unbalanced loading
   ii. Failure of prime mover
   iii. Restricted earth fault
   iv. Over speed protection. **(Jan 12)**

4. i. Discuss the various types of faults associated with generator.
   ii. Discuss the generator protection schemes for
   a. Loss of excitation b. overload c. Inter-turn fault. **(Jan 12)**

5. Explain the following protection mechanism for generators.
   i. Stator protection
   ii. Inter-turn fault protection
   iii. Rotor protection
   iv. Failure of prime mover. **(Jan 12)**

6. i. A 6.6 kV, % MVA star connected generator has a reactance of 1.5 ohm per phase and negligible resistance. Merz-piece protection scheme is used which operates when the out of balance of the current exceeds 25% of the full load current. The neutral of the generator is grounded through a resistance of 8 ohms. Determine the proportion of the winding which remains un-protected against earth fault. Show that the effects of alternator reactance can be ignored.
   ii. Explain the alternator protection schemes for (i) Inter turn faults ii) Over voltage protection. **(Jan 12)**

7. An 11 kV, 100MVA generator is grounded through a resistance of 6 ohms The C.T.s have a ratio 1000/5.The relay is set to operate when there is an out of balance current of 1 A. What percentage of the generator winding will be protected by the percentage differential scheme of protection. **(May 10, 07, 04)**

8. i. Explain how the inclusion of a resistance in the neutral earthing circuit of an alternator affects the performance of the differential protection of the three-phase stator.
   ii. Describe how protection is provided in large turbo alternators against earth fault in the rotor.
   (May 10, 09, 08, 07, Sep 08)

9. i. Enumerate the relaying schemes which are employed for the protection of modern alternator.
   ii. Describe with a neat, the percentage differential protection of a modern alternator. **(May 10)**

10. A 6.6 kV, 4000 kVA star connected alternator with a transient reactance of 2 ohm/phase and negligible resistance, is protected by a circulating current protective system. The alternator neutral is earthed through a resistor of 7.5 ohm. The relays are set to operate when there is an out of balance current of 1A in the secondary windings of the 500/5 A current transformer. What percentage of each phase winding is protected against an earth fault? **(May 10)**

11. The neutral point of a 3-□, 20MVA, 11kv alternator is earthed through a resistance of 5W, the relay is set to operate when there is an out of balance current of 1.5 A. The C.T.s have a ratio of 1000/5. What percentage of winding is protected against an earth fault and what should be the minimum value of earthing resistance to protect 90% of the winding? **(May 10, Jan 03)**

12. Discuss the unbalanced loading and overload protection in alternators. 'Overload protection is not necessary for alternators' ? Justify yourself? **(Apr 09, Sep 08)**

13. What are Restricted earth faults and Inter-turn faults in generators? Explain the protection schemes employed for these faults. **(Apr 09)**

14. Discuss the different types of faults that can occur on a generator and the protection schemes employed. **(Apr 09)**

15. Explain with a diagram, the application of the Merz-Price circulating current system to the protection of alternators. What precautions must be taken in installing this system? **(Sep, Apr 08)**

16. Explain a scheme of protection for failure of alternator excitation. **(Sep 08, Apr 08, 07)**

17. Explain with neat diagram the Merz price protection for generator. **(Sep 08, Apr 07)**

18. i. Enumerate the relaying schemes which are employed for the protection of a modern alternator.
    ii. A 11KV, 100MVA generator is provided with dierential scheme of protection. The percentage of the generator winding to be protected against phase to ground fault is 80% . The relay is set to operate when there is 15% out of balance current. Determine the value of the resistance to be placed in the neutral to ground connection. **(Sep 08, Apr 06)**

19. Show in detail, the protection arrangement of a 60 MW generator provided with :
    i. Differential protection
    ii. Back-up over - current protection through faults
    iii. Standby earth fault protection in neutral connection. **(Apr 08, 06, 05, 04)**

20. i. 3300V, 3-phase turbo alternator has a maximum continuous rating of 2000 kW at 0.8 p.f. and reactance is 12.5%. It is equipped with Merz-Price circulating current protection which is set to operate at fault currents not less than 200A. Find what value of the neutral earthing resistance leaves 10% of windings unprotected.
    ii. Describe percentage differential protection for transformers. State the advantages. **(Apr 08)**

21. Discuss any one of the stator protection schemes for generators above 1MW. **(Apr 08)**

22. A 11KV,100MVA alternator is provided with differential protection. The per-centage of winding to be protected against phase to ground fault is 85%. The relay is set to operate when there is 20% of out of balance current. Determine the value of the resistance to be placed in the neutral to ground connection. **(Apr 07)**

23. i. What is a direct connected generator? **(Apr 06)**
    ii. Mention protective schemes for a direct connected generator. Explain any one of these schemes.

24. What is restricted earth fault protection for alternators? Explain the difference between primary protection and back up protection. **(Apr 06, Jan 03)**

25. Explain briefly with schematic diagram,the protective gear for alternators connected to grid against
    i. Fault between phases and
    ii. Fault between turns in one of the phase windings. **(Sep 06, Apr 03)**

26. i. Discuss the protection employed against the loss of excitation of an alternator.
    ii. Is there any back up protection employed for the protection of an alternator. If yes, discuss the scheme, which is used for this purpose. **(Sep 06, Apr 05, Nov 03)**

27. What is the effect of balanced load on the generator ? Which part is damaged due to sustained unbalanced currents ? **(Apr 04)**

28. i. What are the abnormal conditions in a large synchronous generator against which protection is necessary?
ii. Draw neatly the differential protection scheme of an alternator. Discuss its limitations and suggest remedies to overcome them. **(Nov 03, Jan 03)**

29. i. State the protections commonly provided for a 100 MW generator.
ii. A 3-phase, 11 kV, 15,000 kVA star connected alternator has differentail protection. The neutral is earthed through a resistance of 8 ohms. The relay operates for out of balance of 18% full load. Calculate percentage of winding unprotected against ground fault? **(Apr 03)**

30. i. Why resticed earth fault protection is provided to alternators though it does not provide pretection against earth fault to the complete winding? What is the justification of providing this protection? **(Apr 03)**
ii. Calculate the required value of neutral resistance for a 3-phase, 11 KV alternator so as to protect 70% of the winding against earth fault by a relay with pick up current of 1A. The neutral CT has a ratio of 250/5.

31. Describe the prime mover failure protection schemes of an alternator. **(Jan 03)**

32. Write short notes on Prime mover failure protection scheme of generators. **(Jan 03)**

33. Explain the protection scheme employed for the protection of an alternator by Rotor Protection against loss of excitation. **(Jan 02)**

34. Describe with a neat diagram differential method of protection of generators. **(Jan 00)**

35. A 20 MVA, 6.6 kV, 3-phase alternator is connected to a 3-phase transmission line. The per unit positive sequence, negative sequence and zero sequence impedances of the alternator are j0.1, j0.1 and jo.04 respectively. The neutral of the alternator is connected to ground through an inductive reactor of j0.05 P.U. The per unit positive, negative and zero sequence impedances of the transmission line are j0.1, j0.1 and j0.3 respectively. All per unit values are based on the machine ratings. A solid ground fault occurs at one phase of the far end of the transmission line. The voltage of the alternator neutral with respect to ground during the fault is : **(GATE 03)**

36. The neutral of 10 MVA, 11 kV alternator is earthed through a resistance of 5 ohms. The earth fault relay is set to operate at 0.75A. The CT's have a ratio of 1000 : 5. What percentage of the alternator winding is protected?
(a) 85% (b) 88.2% (c) 15% (d) 11.8% **(GATE 98)**

UNIT-V

1. Describe the construction, principle of operation with a neat sketch and applications of Buchholz's Relay. Why this form of protection is ideal for transformer? **(Jan 13)**

2. i. Explain the principle of Merz-piece protection scheme used for power transformers. What are the limitations of this scheme? How they are overcome?
ii. A 3-phase, 66/ 11 kV star delta connected transformer is protected by Merz-piece protection scheme. The CTs on the LT side have a ratio of 420/5 amps. Find the ratio of CTs on the HT side. **(Jan 13)**

3. i. Describe with a neat diagram, a circulating current protection scheme 3-phase . 1MVA, 11 kV/400 V delta-star transformer. If the current transformers have a nominal secondary current of 5 amps, calculate their ratios.
ii. Explain the biased differential protection scheme used for transformers. **(Jan 12)**

4. i. A 3-phase , 33/ 11 kV star delta connected transformer is protected by Merz-piece protection scheme. The CTs on the LT side have a ratio of 1000/5 amps. Find the ratio of CTs on the HT side.
ii. Explain the construction and operation of Bucchholz's relay. **(Jan 12)**

5. i. A 3-phase 66/11 kV star-delta connected transformer is protected by Merz-price protection system. The C.Ts on the L.T side have a ratio of 420/5 amps. Show that the C.Ts on the H.T side will have a ratio of 70:5/”3.
   ii. With a neat sketch explain the principle of operation of Buchholtz relay.
   iii. Discuss the percentage differential protection of transformer. (**May 11)**

6. Explain with a neat circuit diagram , about the percentage differential protection scheme to protect Y - Δ transformer. **(May 10)**

7. i. Discuss about differential protection scheme for transformers.
   ii. A 3-phase transformer rated for 33kV/6.6kV is connected star/delta and the protecting current transformer on the low voltage side have a ratio of 400/5. Determine the ratio of the current transformer on the HV side. **(May 10)**

8. For protecting a 132/33kV, 50 MVA power transformer from internal faults, what are the different protection schemes normally used? Discuss one of the them in brief, with sketch. **(May 10)**

9. i. Discuss earth fault protection for transformers. **(Apr 09, Sep 08)**
   ii. A 3-phase transformer rated for 33kV/6.6kV is connected star-delta and the protecting current transformer on the low voltage side have a ratio of 400/5. Determine the ratio of the current transformer on the HV side.

10. Draw the connection diagram of a differential relay for the protection a star-delta transformer. How does bias the winding of a differential relay restricts malfunctioning of the relay against
   i. CT mismatch
   ii. Onload changing and
   iii. Magnetising current? What is magnetising Inrush current? What is the principle used to make a differential relay insensitive to magnetizing inrush current. **(Apr 09)**

11. Describe with a neat sketch, the operation of Buchholtz relay. **(Sep 08)**

12. What is Buchholtz relay? Which equipment is protected by it? For what types of faults is it employed? Discuss its working principle. **(Sep 08)**

13. Discuss the percentage dierential protection scheme of a transformer. **(Sep 08, Apr 06)**

14. i. A 3-phase, 66/11kV star-delta connected transformer is protected by Merz- price protection system. The CTs on the LT side have a ratio of 420/5 ampr. Show that the CTs on the HT side will have a ratio of 70: .
   ii. Explain with reasons the connections of C.T.s for protecting a delta/star transformer. Write the scheme of protection for
   a. Internal fault and
   b. External fault. **(Apr 08, 07, Sep 06, Jan 03)**

15. i. Discuss biased differential protection for transformers. **(Apr 08)**
   ii. A 3-phase, 33/6.6 kV transformer is connected in star/delta and the protecting current transformer on the LV side have a ratio of 300/5. What will be the ratio of the current transformer on the HV side?

16. Write short notes on the following: **(Apr 08)**
   i. Different transformer faults
   ii. Biased differential protection for transformer
   iii. Buchholtz Relay

17. Explain with a neat circuit diagram of the percentage differential protection scheme to protect Y - transformer.. **(Apr 08, Jan 03)**

18. What is Buckhholz relay? Discuss its working principle. **(Nov 07)**

19. Describe the principle of dierential Protection applied to a power transformer.What are the diculties experienced and how are they overcome? **(Sep 06)**

20. Three phase 33/6.6 kV transformer is connected star- delta and current transformers on the low voltage side have ratio 300: 5. What will be the ratio of CT on the high voltage side of Merz Prize protection is to be adopted. **(Sep 06, Apr 03)**

21. i. What are the difficulties in the design of C.T for restricted earth fault protection? How are these difficulties overcome in high impedance protection?
    ii. What are switched distance-relaying schemes? Explain them in detail? **(Apr 06)**

22. i. Define ‘differential protection’ Describe the principle of circulating current differential protecting
    ii. State the various applications of differential protection. **(Apr 05)**

23. i. What protective devices other than the differential protection are used for the protection of a large transformer? Briefly describe them.
    ii. Show that the torque on the disc of an induction disc relay is maximum when the phase difference between the two fluxes is 90^0. **(Apr 05)**

24. With the help of neat sketches explain the protections of a star - delta power transformer,against the following abnormal conditions
    i. Phase to phase fault
    ii. Earth fault
    iii. High voltage surges **(Apr 05, 04)**

25. What is differential protection ? What is percentage differential protection ? Why it is superior to simple differential protection. Explain the characteristics. **(Apr 04)**

26. A star-delta, 11kV/6.6 kV transformer is protected by means of differential protection system. The 6.6 kV delta connected side has CT of ratio 600/5. Calculate CT ratio of HT side. **(Apr 03)**

27. Explain the principle of Merz-Price system of protection used for power transformers. **(Jan 02)**

28. With the help of neat diagram, explain the protection of Star/Delta transformer using percentage differential relay. How do you prevent the operation of the relay during magnetic in-rush currents ? **(Jan 00)**

29. In the protection of transformers, harmonic restraint is used to guard against
    i. Magnetizing inrush current
    ii. Unbalanced operation
    iii. Lightning
    iv. Switching over-voltages **(GATE 01)**

30. What factors cause difficulty in applying circulating current to a power transformer? **(T1-Ch32)**

31. How many faults develop in a power transformer? **(T1-Ch32)**

32. A star-delta, 11KV/6.6KV transformer is protected by means of differential protection system. The 6.6KV delta is connected side has C.T of ratio 600/5 calculate CT ratio of HT side? **(T1-Ch32)**

UNIT-VI

1. i. Explain three zone protection scheme using impedance relays.
   ii. Explain carrier current protection scheme with neat diagrams. **(Jan 13)**

2. i. What is meant by 3- zone protection ? With a neat diagram Explain such scheme of protection for long lines.
ii. Explain Translay protectin scheme of busbars. **(May 12)**

3. Explain the three zone protection scheme for a transmission line using
i) Impedance relay ii) Reactance relay **(Jan 12)**

4. i. Explain the carrier current protection scheme for transmission lines.
ii. Discuss about the settings of the distance relay. **(Jan 12)**

5. Explain the time graded protection system for feeders. **(Jan 12)**

6. Explain the differential protection systems for various types of feeders. **(Jan 12)**

7. i. What are the requirements of protection of lines? **(Apr 09, Sep 08, 06)**
ii. Write short notes on the following:
a. Fault bus protection
b. Translay scheme.

8. i. Explain over current protection of feeder. **(Apr 09, 08)**
ii. Explain a scheme of protection for a ring mains.

9. i. Explain bus bar protection need special attention. Why? **(Apr 09, 08)**
ii. What is back up protection of bus bars?

10. i. What is the main drawback of differential over current protection for bus bars and how is it overcome.
ii. Explain about voltage differential protection of bus bars. **(Apr 09)**

11. With a neat sketch discuss the differential scheme for bus zone protection. **(Sep 08)**

12. i. Write a neat sketch, discuss the differential scheme for bus zone protection.
ii. Discuss the working principle of frame leakage protection. **(Sep 08, Apr 04)**

13. i. Explain over-current protection of feeders. **(Sep, Apr 08)**
ii. How is the protection system graded with respect to the time of operation of relays.

14. Explain the principle of distance relaying applied to protection of radial transmission lines. Distinguish between reactance, impedance and mho relays as regards their applications to distance protection.
(Sep 06)

15. i. Explain how the selection of current and time settings is done in a time current graded system.
ii. Give schemes of protection for a parallel feeder fed from
a. one end
b. both the ends. **(Sep 06, Apr 05, 03)**

16. Write short note on the following:
i. Bus Fault protection
ii. Merz-price voltage balance system for protection of feeders. **(Sep 06)**

17. Give various schemes of protection for feeders. **(Sep 06)**

18. i. Discuss the considerations which determine the need for a busbar protection.
ii. Discuss any one busbar protection scheme in detail. **(Apr 06)**

19. Distinguish between unit protection and non unit protection. What are the various methods of protecting a transmission line by unit protection? **(Apr 06)**

20. What is meant by 3 Zone protection? Give such schemes of protection for
a. Short length lines b. Medium length lines c. Long lines. **(Apr 06, Jan 03)**

21. i. Discuss the choice between impedance, reactance andMho type relays.
ii. Transformer: 5MVA, Y / , X=6%
The transmission line sections AB and BC are to be protected by Mho distance relays. The system is as shown in the figure. If the C.T. ratio is 300/5 and C.T. ratio is 166000/110V and a 3-; short circuit fault of zero impedance occurs at F, find the impedance seen by the relays and determine the setting
of the relays for high speed protection of line AB and backup protection for line BC, when the relays are located at end A. **(Apr 06)**

22. i. Discuss the time graded over current protection for **(Apr 03)**
a. Radial feeders
b. Ring main system
ii. Explain the carrier system of protection, with a block diagram and neat sketches discuss how the phase comparision scheme can be used for protecting a feeder.

23. i. What are the advantages of distance protection over other type of protection of feeders ? **(Apr 03)**
ii. Describe any type of impedance relay with neat sketches and show how such relays are connected in a transmission line and how they provide discriminating protection.

24. i. What is Translay protection? Give such a scheme of protection for a three phase transmission line.
ii. An IDMT over current relay rated at 5 amp has a current setting of 150% and has a time_multiplier setting of 0.8. The relay is connected in the circuit through a C.T. having a ratio 400/5. Calculate the time of operation of the relay if the circuit carries a fault current of 4800 amps. Assume the relay to have 2.2 sec IDMT characteristic. **(Jan 03)**

25. i. Describe the method of protecting bus bars by differential relaying.
ii. What are the limitations of this method and to what extent these can be overcome. **(Jan 03)**

26. Explain three-zone protection of transmission lines using MHO relays. **(Jan 00)**

27. What is meant by 3-zone protection ? Give such schemes of protection for
i. Short length lines
ii. Medium length lines
iii. Long lines. **(Jan 00)**

28. Consider the problem of relay co-ordination for the distance relays Rl and R2 on adjacent lines of a transmission system (Fig). The Zone 1 and Zone 2 settings for both the relays are indicated on the diagram. Which of the following indicates the correct time setting for the Zone 2 of relays Rl and R2.
i. TZ2R1= 0.6S,TZ2 R2 = 0.3S
ii. TZ2R1= 0.3s, TZ2 R2 = 0.6s
iii. TZ2R1= 0.3S, TZ2 R2 = 0.3S
iv. TZ2R1= o.1s, Tz2 R2 = 0.3s **(GATE 02)**

29. In a 3-step distance protection, the reach of the three zones of the relay at the beginning of the first line typically extends up to
i. 100% of the first line, 50% of the second line and 20% of the third line

ii. 80% of the first line, 50% of the second line and 20% of the third line
iii. 80% of the first line, 20% of the second line and 10% of the third line
iv. 50% of first line, 50% of second line and 20% of the third line. **(GATE 00)**

30. The ratio error of a given 1000/5A current transformer is zero when feeding 5 VA, upf burden at rated current. Estimate the iron loss of the current transformer at this operating condition if the secondary has 198 turns and a winding resistance of 0.02W. Neglect leakage reactance. **(GATE 00)**

31. Describe distance protection scheme for the protection of feeder?

32. Describe the following system of bus-bar protection **(T1-Ch34)**
i. Differential protection.
ii. Fault-bus protection.

33. Discuss the protection of a bus bar as back up from other station apparatus? **(T1-Ch34)**

34. What is the importance of bus-bar protection? **(T1-Ch34)**

35. Compare various systems of feeder protections? **(T1-Ch34)**

36. Explain the necessity of check feature in bus-bar protection? **(T1-Ch34)**

37. Discuss the time-graded O.C.protection for **(R4-Ch14)**
i. Radial feeders.
ii. Parallel feeders.
iii. Ring main system.

38. Describe the differential pilot wire method of protection of feeders? **(R4-Ch14)**

UNIT-VII

1. What is neutral grounding? What is its necessity? Explain various methods of neutral grounding? **(Jan 13)**

2. i. What are the various methods of neutral grounding? Compare their performance with respect to (i)protective relaying (ii) stability (iii) voltage levels of power system.
ii. Explain the phenomenon of 'Arcing grounds' and suggest the method to minimize the effect of this phenomenon. **(May 12)**

3. What are the various methods for neutral grounding? Explain the in detail. **(Jan 12)**

4. What are the various methods of neutral grounding? Compare their performances with respect to i) protective relaying ii) fault levels iii) stability iv) voltage levels of power systems. **(Jan 12)**

5. i. Discuss about the harmonic suppressors.
ii. How do you select a method for neutral earthing?
iii. Discuss about voltage transformer earthing. **(Jan 11)**

6. i. What are the methods of grounding practice? Explain
ii. What is the equipment used for earthing for safety (**Jan 10)**

7. i. State the advantage of neutral grounding of an electrical system.
ii. Explain reactance grounding with neat sketch. **(Apr 09)**

8. i. Derive an expression for the reactance of the Peterson coil in terms of the capacitance of the protected line.
   ii. Calculate the reactance of a coil suitable for a 33kV, 3-phase transmission system of which the capacitance to earth of each conductor is 0.5 μF. **(Apr 09)**

9. i. Discuss about effectively grounded system and ungrounded system. **(Apr 09, Sep 08)**
   ii. A 132 kV, 3-Phase, 50Hz, 100km long transmission line has a capacitance of 0.012 μF per km per phase. Determine the inductive reactance and kVA rating of the arc suppression coil suitable for this line.

10. i. Discuss ungrounded system and resonant grounded system. **(Apr 09, Sep 08)**
    ii. Write short notes on Protection against arcing grounds.

11. i. Explain the phenomenon of arcing ground. **(Sep 08, Apr 03)**
    ii. Suggest some methods to minimize the effect of this phenomenon with neat sketch.

12. i. Explain the statement in ungrounded system "Healthy line voltage increases by times during an earth fault on the third line".
    ii. Discuss the merits of
    a. Solid grounding
    b. Resistance grounding. **(Sep 08, Apr 05, Nov, Jan 03)**

13. i. Discuss the advantages of grounding the neutral of the system. **(Sep 08)**
    ii. A 33kV, 50 Hz network has a capacitance to neutral of 1.0 μF per phase. Calculate the reactance of an arc suppression coil suitable for the system to avoid adverse effect of arcing ground.

14. i. What are the reasons leading to the general practice of earthing the neutral point of a power system? Explain. **(Apr 08)**
    ii. Explain the phenomenon of arcing grounds and discuss the method to minimize the effect of this phenomenon.

15. i. Describe the various methods of grounding. **(Apr 08)**
    ii. A 132kV, 3 phase, 50Hz overhead line of 100 km length has a capacitance to earth of each line of 0.01 μF per km. Determine inductance and kVA rating of the arc suppression suitable for this line.

16. i. Discuss the advantages of neutral grounding. **(Apr 08)**
    ii. What is tower-footing resistance.

17. i. A 50Hz over head line has the line to ground capacitance of 1.2 μF. It is decided to use a ground fault neutralizer. Determine the reactance to neutralize the capacitance of (i)100% of the length of the wire, and (ii) 80% of the length of the wire **(Apr 08)**
    ii. Write short notes on biased differential protection for transformer.

18. i. Distinguish between neutral earthing and equipment earthing. **(Apr 08)**
    ii. Explain the necessity of reactance grounding.

19. i. Explain about neutral grounding practice. **(Apr 07)**
    ii. What are the various methods of generator neutral grounding?
    iii. What are the requirements of a ground wire for protecting power conductors against direct lightning stroke ?

20. Explain clearly the meaning of resonant grounding. What are the requirements of the reactor in neutral connections of such a grounding? Draw the connection of arc suppression coil. **(Sep, Apr 06, Nov 03)**

21. Explain the following:
  i. Resistance grounding
  ii. Reactance grounding **(Apr 05)**

22. How do earthing screen and ground wires provide protection against direct lightning strokes?
(Apr 05)

23. i. A 33kV, 3-phase, 50Hz, overhead line 50km long has a capacitance to earth of each line equal to 0.019mf per Km. Determine the inductance and KVA rating of the arc suppression coil.
  ii. Discuss in brief different protective devices against lighting surges. **(Apr 04)**

24. Discuss the advantages of the neutral grounding and explain why there is a trend at present towards effectively earthed systems? **(Nov 03)**

25. Describe the compare the following methods of neutral grounding:
  i. Solid grounding
  ii. Resistance grounding
  iii. Reactance grounding and
  iv. Transformer grounding **(Jan 03)**

26. Discuss the merits of earthing in
  i. Solidly
  ii. Through a resistance. **(Jan 03)**

27. What do you understand by neutral grounding and explain the various methods of neutral grounding in detail ? **(Apr 00)**

28. What are the various methods of neutral grounding ? Compare their performance with respect to (i) protective relaying, (ii) fault levels, (iii) stability, (iv) voltage levels of power systems. **(T3-Ch11)**

29. A transmission line has a capacitance of 0.1 mF per phase. Determine the inductance of Peterson coil to neutralize the effect of capacitance of (i) complete length of line, (ii) 97% of the line, (iii) 90% length of the line. The supply frequency is 50 Hz. **(T3-Ch11)**

30. A 132 kV, 50 Hz, 3-phase, 100 km long transmission line has a capacitance of 0.012 mF per km per phase. Determine the inductive reactance and kVA rating of the arc suppression coil suitable for the line to eliminate arcing ground phenomenon. **(T3-Ch11)**

31. What is arcing ground ? Explain its effect on the performance of a power system.
(T3-Ch11)

32. Discuss the advantages of (i) grounding the neutral of the system, (ii) keeping the neutral isolated.
(T3-Ch11)

UNIT-VIII

1. i. Explain the construction and working of valve type lightning arresters.
  ii. Discuss about lightning arrester ratings.
(Jan 13)

2. Write short notes on:
  i. Insulation Coordination
  ii. Valve type and Zink oxide lighting arrestors. **(Jan 12)**

3. i. What protective measures are taken against lightning over voltages.
   ii. Describe the construction and operation of metal oxide surge arrester. **(Apr 09)**

4. Describe the construction and principle of operation of valve type and Zinc oxide lightning arrester. **(Apr 09)**

5. i. What are the basic requirements of a lightning arrester? Differentiate between
   a. A lightning arrester and a lightning conductor
   b. Surge diverter and surge absorber.
   ii. An overhead transmission line with surge impedance 400 ohms is 300km long. One end of this line is short circuited and at the other end a source of 11kV is suddenly switched in, calculate the current at the source end 0.005 sec after the voltage is applied. **(Apr 09)**

6. Explain the working lightning arrests.
   i. Rod gap
   ii. Horn gap
   iii. Multi gap
   iv. Expulsion type. **(Apr 09)**

7. i. How over head transmission lines are protected from lightning strokes. **(Sep, Apr 08)**
   ii. Why ground wire is provided as the top lost conductor in high voltage transmission lines.

8. i. What are volt time curves. **(Sep, Apr 08)**
   ii. What is their significance in power system studies.

9. i. Explain clearly why lightning arresters are used. **(Sep 08)**
   ii. Explain about lightning absorbers and diverters.

10. i. Explain the coordination of insuation in EHV system. **(Sep 08)**
    ii. Explain with a neat sketch value type lightning arrester.

11. Describe the construction and working principle of a zinc oxide gapless arrester with a neat sketch. **(Sep 08, Apr 07, 05, 04)**

12. Explain why the surge diverters are located very close to the equipments to be protected and mention the application of surge absorbers. **(Apr 08, 05)**

13. i. What are various methods of over voltage protection of overhead transmission lines. **(Apr 08)**
    ii. Explain clearly how the rating of a lightning arrester is selected. What is the best location of a lightning arrester and why?

14. Write short notes of the following: **(Apr 08)**
    i. Causes of over voltages in a power system.
    ii. Switching surges.
    iii. Protection against over voltages.

15. i. Explain about surge absorbers.
    ii. What are the types of surge arresters?
    iii. What is the relation between neutral earthing and selection of voltage rating of the lightning arrester? **(Sep 06, Jan 03)**

16. Define the following terms:-
    i. Dry flash over voltage
    ii. Wet flash over voltage
    iii. Impulse flash over voltage
    iv. Impulse spark over volt-time characteristics **(Sep 06)**

17. i. Explain station type surge arrester with a neat sketch.
ii. Explain the tests conducted on surge arresters. **(Apr 06)**

18. i. Discuss the causes of switching surges .
ii. Explain the selection of surge arresters with reference to switching surges . **(Apr 06, Apr 03)**

19. i. What are the requisites of a good lightning arrester?
ii. Discuss the relative merits and demerits of
a. rod gap b. expulsion arresters c. valve arresters **(Apr 06, Jan 03, Nov 01)**

20. Write short notes on the following :
i. Rod gap
ii. Horn gap
iii. Expulsion gap **(Apr 04)**

21. Define the terms :
i. rated voltage of lightning arrester
ii. normal discharge current
iii. spark over voltage - power frequency impulse
iv. non linear resistance
v. protective ratio
vi. residual voltage. **(Apr 04)**

22. i. Describe the protection of power stations and substations against direct lightning strokes.
ii. Discuss about insulation coordination in power systems. **(Jan 03)**

23. i. Explain the various arrester rating.
ii. Differentiate from the view point of the principle of working between a surge diverter and surge absorber. **(Jan 03)**

24. i. Draw the expulsion type lightning arrester and explain its operation. To what voltage loads can this be used on power system.
ii. What are horn gaps ? How are they useful in protecting equipment on a power system against over voltages? **(Jan 03)**

25. i. Differentiate from the view-point of the principle of working between a surge diverter and surge absorber. Why are lightning arresters and sure absorbers used together in important substations.
ii. What are the requisites of a good lightning arrester ?
Discuss the relative merits and demerits of :
a. Rod gaps b. Expulsion arrestors and c. Valve arresters **(Nov 01)**

26. Describe the lighting phenomenon and what are the methods of protection of transmission lines against lightning? Explain. **(Apr 00)**

27. What are volt-time curves? What is their significance in power system studies? **(T1-Ch18A)**

28. What are BILS? Explain their significance in power system studies? **(T1-Ch18A)**

29. How over voltage are generated in power system? **(T1-Ch18A)**

30. Suggest a suitable insulation co-ordination scheme for a 400KV substation? **(T1-Ch18A)**

31. What do you mean by standard impulse test wave? **(T1-Ch18A)**

32. Explain the protective characteristic of a surge arrester against the withstand characteristics of equipment on a voltage/time curve? **(T1-Ch18A)**

33. Write short notes of impulse ratio? **(T1-Ch18A)**

34. Explain with neat sketches the mechanism of lightning discharge. **(T3-Ch11)**

35. What is a voltage surge? Draw a typical lightning voltage surge? **(R4-Ch16)**

36. Explain the various arrester ratings? **(R4-Ch16)**

37. What is lightning? Describe the mechanism of lightning discharge? **(R4-Ch16)**

38. What are the main causes of voltage surges on overhead transmission lines? Explain hoe the waveform of a surge is specified. Discuss the protection of terminal equipment of a line from surge and describe one method of protection? **(R4-Ch16)**

39. Explain clearly how the rating of a lightning arrester is selected. What is the best location of a lighting arrester and why? **(R4-Ch16)**

40. Write short notes on insulation co-ordination? **(R4-Ch16)**

LIST OF ASSIGNMENT QUESTIONS

UNIT-1

1. i. Explain how the arc is initiated and sustained in a circuit breaker when the circuit breaker contacts separated

   ii In a short circuit test on a 132 kV three phase system the breaker gave the following results: p.f of the fault: 0.4, recovery voltage 0.90 of full line value. The breaking current is symmetrical and the re-striking transient had a natural frequency of 20 kHz. Determine the average rate of rise of re-striking voltage. Assume that the fault is grounded.

2. i. Define the terms:
   a. restriking voltage
   b. recovery voltage
   c. RRRV

   ii. Derive an expression for the restriking voltage in terms of system voltage, inductance and capacitance across a C.B. contact when a 3-phase fault takes place. Assume the neutral of the system to be solidly grounded.

   iii. Discuss the principle of arc interruption in an oil circuit breaker.

3. i. Explain how the arc is initiated and sustained in a circuit breaker when the circuit breaker contacts separated.

   ii. In a short circuit test on a 132 kV three phase system the breaker gave the following results:

   p.f of the fault : 0.4 , recovery voltage 0.95 of full line value. The breaking current is symmetrical and the re-striking transient had a natural frequency of 16kHz.Determine the rate of rise of re-striking voltage. Assume that the fault is grounded.

4. i. What is arc quenching? Explain different arc quenching theories.

   ii. What is current chopping? Explain.

5. A Circuit Breaker is rated as 2500A, 1500MVA, 33kV, 3 secs, 3-phase oil circuit breaker.

   Determine the rated symmetrical breaking current, rated making current, short time rating and rated service voltage.

UNIT-2

3. Explain the construction and operation of SF6 circuit breaker with a neat sketch.
   What are the advantages of SF6 circuit breaker over other circuit breakers?

4. Explain the construction and operation of minimum oil circuit breaker with a neat sketch. Discuss its performance characteristics

3. Explain the construction and operation of Vacuum circuit breaker with a neat sketch

4. Explain the construction and operation of air blast circuit breaker with a neat sketch.

5. Distinguish between oil circuit breakers and SF_6 circuit breakers?

UNIT-3

1. Explain the principle and operation of Directional over current relay. Discuss its various characteristics.
2. Discuss with a neat sketch the general principle of operation of a distance protection scheme.
3. What is the effect of 'arc-resistance' on the performance of impedance relay? and explain how it is Overcome in case of reactance relay?
4. i. Write the comparison between static relays and electromagnetic relays.
   ii. What is Universal torque equation? Using this equation derive the characteristics of reactance relay.
   iii. Write the applications of
      a. impedance relay b. mho relay c. over current relay
      d. under voltage relay and e. percentage differential relay.
5. A 6.6 kV, 4000 kVA star connected alternator with a transient reactance of 2 ohm/phase and negligible resistance, is protected by a circulating current protective system. The alternator neutral is earthed through a resistor of 7.5 ohm. The relays are set to operate when there is an out of balance current of 1A in the secondary windings of the 500/5 A current transformer. What percentage of each phase winding is protected against an earth fault?

UNIT-4

1. Why generators are to be protected? Explain the protection schemes for the following Faults
   i. Unbalanced loading
   ii. Failure of prime mover
   iii. Restricted earth fault
   iv. Over speed protection

2. i.What is restricted earth fault protection for alternators? Why is this form of protection used for alternators even though it does not provide protection for the complete winding?
   ii.With a neat sketch explain the protection of alternator against stator faults and rotor faults.

3. Explain the following protection mechanism for generators.
   i.Stator protection
   ii.Inter-turn fault protection
   iii.Rotor protection
   iv.Failure of prime mover.

4. A 6.6 kV, 5 MVA star connected generator has a reactance of 1.5 ohm per phase and negligible resistance. Merz-Price protection scheme is used which operates when the out of balance of the current exceeds 25% of the full load current. The neutral of the generator is grounded through a resistance of 8 ohms. Determine the proportion of the winding which remains unprotected against earth fault. Show that the effects of alternator reactance can be ignored.

5. An 11 kV, 100MVA generator is grounded through a resistance of 6 ohms The C.T.s have a ratio 1000/5.The relay is set to operate when there is an out of balance current of 1 A. What percentage of the generator winding will be protected by the percentage differential scheme of protection

UNIT-5

1.Describe the construction, principle of operation with a neat sketch and applications of Buchholz's Relay. Why this form of protection is ideal for transformer?

2.Explain the principle of Merz-piece protection scheme used for power transformers. What are the limitations of this scheme? How they are overcome?

3.Explain the construction and operation of Bucchholz's relay.

4. i. .Discuss about differential protection scheme for transformers.
   ii. A 3-phase transformer rated for 33kV/6.6kV is connected star/delta and the protecting current transformer on the low voltage side have a ratio of 400/5. Determine the ratio of the current transformer on the HV side.

5. For protecting a 132/33kV, 50 MVA power transformer from internal faults, what are the different protection schemes normally used? Discuss one of the them in brief, with sketch.

UNIT-6

1. i. Explain three zone protection scheme using impedance relays.
   ii. Explain carrier current protection scheme with neat diagrams.

2. i. What is meant by 3- zone protection ? With a neat diagram Explain such scheme of protection for long lines.
   ii. Explain Translay protectin scheme of busbars.

3. i. Explain the carrier current protection scheme for transmission lines.
   ii. Discuss about the settings of the distance relay.

4. i. Explain over current protection of feeder.
   ii. Explain a scheme of protection for a ring mains.

5. i. Explain how the selection of current and time settings is done in a time current graded system.
   ii. Give schemes of protection for a parallel feeder fed from
      a. one end
      b. both the ends

UNIT-7

1. What is neutral grounding? What is its necessity? Explain various methods of neutral grounding?

2. i. Discuss about the harmonic suppressors.
   ii. How do you select a method for neutral earthing?
   iii. Discuss about voltage transformer earthing.

3.. i. State the advantage of neutral grounding of an electrical system.
ii. Explain reactance grounding with neat sketch.

4. i. Derive an expression for the reactance of the Peterson coil in terms of the capacitance of the protected line.
ii. Calculate the reactance of a coil suitable for a 33kV, 3-phase transmission system of which the capacitance to earth of each conductor is 0.5μF.

5. i. Discuss ungrounded system and resonant grounded system.
ii. Write short notes on Protection against arcing grounds.

UNIT-8

1. i. Explain the construction and working of valve type lightning arresters.
ii. Discuss about lightning arrester ratings.

2. i. What protective measures are taken against lightning over voltages.
ii. Describe the construction and operation of metal oxide surge arrester.

3. i. What are the basic requirements of a lightning arrester? Differentiate between
a. A lightning arrester and a lightning conductor
b. Surge diverter and surge absorber.
ii. An overhead transmission line with surge impedance 400 ohms is 300km long. One end of this line is short circuited and at the other end a source of 11kV is suddenly switched in, calculate the current at the source end 0.005 sec after the voltage is applied.

4. Explain the working lightning arrests.
i. Rod gap
ii. Horn gap
iii. Multi gap
iv. Expulsion type.

5. i. How over head transmission lines are protected from lightning strokes.
ii. Why ground wire is provided as the top lost conductor in high voltage transmission lines.