**Subject Name: SWITCH GEAR AND PROTECTION (SGP)**

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**UNIT – I: INTRODUCTION TO CIRCUIT BREAKERS**

**Important Points / Definitions:**

* A **circuit breaker** is an automatically operated electrical switch designed to protect an electrical **circuit** from damage caused by excess current from an overload or short **circuit**. Its basic function is to interrupt current flow after a fault is detected.
* A circuit breaker is a piece of equipment which can Make or break a circuit either manually or by remote control under normal conditions
* **Arc interruption** is a process where you **interrupt** path of **arc** with the purpose to extinguish it.
* Any abnormal operating state of a power system is known as FAULT
* Recovery voltage : It may be defined as the voltage that appears across the breaker contact after the complete removal of transient oscillations and final extinction of arc has resulted in all the poles.
* Rated Breaking MVA capacity = √3 x KV x KA Where MVA = Breaking capacity of a circuit breaker kV KV = Rated voltage KA = Rated breaking current.
* Rated making current = 1.8 x √2 x Rated short circuit breaking = 2.5 x Rated short circuit breaking current In the above equation the factor √2 convert the r.m.s value to
* peak value. Factor 1.8 takes into account the doubling effect of short circuit current with consideration to slight drop in current during the first quarter cycle .
* Air blast circuit breaker
* increase the arc voltage by cooling the arc plasma. As the temperature of arc plasma is decreased, the mobility of the particle in arc plasma is reduced, hence more voltage gradient is required to maintain the arc.
* Low oil circuit breakers, which use minimum amount of oil. In such circuit breakers oil is used only for arc extinction, the current conducting parts are insulated by air or porcelain or organic insulating material.
* Active recovery voltage : It may be defined as the instantaneous recovery voltage at the instant of arc extinction.
* Arc voltage: It may be defined as the voltage that appears across the contact during the arcing period, when the current flow is maintained in the form of an arc
* RestrikingVoltage : it is the transient voltage that exists during the arcing time. ( natural frequency kHz ).
* Rate of rise of recovery voltage It is the rate of increase of restriking voltage and is abbreviated by R.R.R.V.
* As the length of arc path is increased, the resistance of the path is increased
* Splitting up the arc into a number of series arcs also increases the arc voltage
* Dielectric strength of sf6 gas is 2 to 3 times that of air, such breakers can interrupt much larger currents

**Questions**

**2 Marks**

1. What is a circuit breaker? Explain its functions.
2. What is the function of Auto re closures
3. Why are circuit breakers designed to have a short-time rating?
4. What is switchgear?
5. What are the types of air blast circuit breaker?

**3 Marks**

1. Explain the phenomenon of current chopping
2. Define the following terms as applied to circuit breakers : (i) Arc voltage (ii) Re striking voltage (iii) Recovery voltage
3. What are the major duties that a circuit breaker is required to perform
4. Explain the difference between bulk oil circuit breakers and low-oil circuit breakers
5. Explain the terms (i) symmetrical breaking current (ii) Asymmetrical breaking current(iii) making current.
6. **Marks**
7. a).Derive an expression for restriking voltage in terms of system capacitance and inductance b)Derive the expression for recovery voltage
8. Ina power system the R.M.S voltage is 38.1kv, L is 10mH and C is 0.02µF. determine a) restriking voltage across the circuit breaker b) frequency of restriking voltage transient c) average rate of restriking voltage up to peak restriking voltage and d) maximum RRRV
9. a).Discuss the constructional details and operation of a typical low-oil circuitbreaker? What are its relative merits and demerits? b). Discuss the principle of operation of an air-blast circuit breaker. What are the advantages and disadvantages of using air as the arc quenching medium?
10. a).Describe the construction, principle of operation and application of sf6 circuit breaker. How does this breaker essentially differed from an air blast Breakerb). A circuit breaker is rated at 1500 A, 2000 MVA, 33 kV, 3 sec, 3-phase oil circuit breaker. Determine (*i*)the rated normal current (*ii*) breaking current (*iii*) making current (*iv*) short time

**Fill in the blanks:**

1. **High temperature gas** is a conducting medium for electric current.
2. Flash point of dielectric is usually above **140°C**
3. A circuit breaker is **a current interrupting device**
4. Low voltage circuit breakers have rated voltage of less than **1000 V**
5. The fault clearing time of a circuit breaker is usually **few cycles of supply voltage.**
6. The medium employed for extinction of arc in air circuit breaker is **Air**
7. The transient voltage that appears across the contacts at the instant of arc extinction is called **re striking voltage**
8. The normal frequency rms voltage that appears across the breaker poles after final arc extinction has occurred, is **recovery voltage**
9. For high voltage, ac circuit breakers, the rated short circuit current is passed for **3 seconds**
10. The acting contacts for a circuit breakers are made of **Copper tungsten alloy**

**Choose the Best:**

 1. In circuit-breakers the contact space is ionized by **(D)**

(A) thermal ionization of gas

(B) thermal emission from surface of contacts

(C) field emission from the surface of contacts

(D) any of the above.

2. Which of the following are air-break switching devices ? **(D)**

(A) Isolator

(B) Limit switch

(C) Earthing switch

(D) All of the above.

3. In a circuit breaker the active recovery voltage depends upon **(D)**

(A) power factor

(B) armature reaction

(C) circuit conditions

(D) all of the above.

4. If a circuit breaker does not operate on electrical compound, the probable reason could be **(D)**

(A) spring defective

(B) trip circuit open

(C) trip latch defective

(D) any of the above.

5. In a circuit breaker if the insulation resistance between phase terminal and earthed frame is less than the specified limit, the probable cause could be **(D)**

(A) moisture

(B) dirty insulation surface

(C) carbon or copper particles sticking to the internal surface

**(D)** any of the above.

6. The following figure shows the voltage waveform across the pole of a circuit breaker; In this voltage R represents **(B)**



(A) System voltage

(B) Re striking voltage

(C) Recovery voltage

(D) Extinction of arc.

7. In the above figure, D represents **(A)**

**(A)** Recovery voltage

(B) Re striking voltage

(C) System voltage

(D) Extinction of arc.

8. Ionization in a circuit breaker is not facilitated by **(B)**

(A) high temperature of surrounding medium

(B) material of contacts

(C) increase of field strength

(D) increase of mean free path.

9.  In a circuit breaker the current which exists at the instant of contact separation is known as(**C**)

(A) re striking current

(B) surge current

(C) breaking current

(D) recovery current.

10. Breaking capacity of a circuit breaker is usually expressed in terms of (**D**)

(A) Amperes

(B) Volts

(C) MW

(D) MVA.

**Unit –II: Electromagnetic and Static Relays**

**Important Points / Definitions:**

* The primary protection scheme ensures fast and selective clearing of any fault within the boundaries of the circuit element, that the zone is required to protect. Primary Protection as a rule is provided for each section of an electrical installation
* Back-up protection is the name given to a protection which backs the primary protection whenever the later fails in operation. The back-up protection by definition is slower than the primary protection system
* Reliability: It is the ability of the protection system to operate correctly
* The Relay Time : This is the time between the instant of occurrence of the fault to the instant at which the relay contacts open
* The Breaker Time: This is the time between the instant of closing of relay contacts to the instant of final arc extinction inside the medium and removal of the fault.
* Selectivity: This feature aims at maintaining the continuity of supply system by disconnecting the minimum section of the network necessary to isolate the fault
* Sensitivity: The sensitivity of a relay refers to the smallest value of the actuating quantity at which the relay operates detecting any abnormal condition.
* Stability: It is the quality of any protection system to remain stable within a set of defined operating scenarios and procedures
* Adequacy: It is economically unviable to have a 100% protection of the entire system in concern
* Pick-up setting The pick-up setting, or plug setting, is used to define the pick-up current of the relay, and fault currents seen by the relay are expressed as multiples of plug setting
* Plug setting multiplier (PSM) is defined as the ratio of the fault current in secondary Amps to the relay plug setting.
* Pick-up setting = (OLF x Inom) / CTR
* Induction cup type relay is practically suited as directional or phase comparison units.
* Relays are electrical switches that open or close another circuit under certain conditions.
* Primary Relay: relay connected directly in the circuit ′
* Secondary Relay: relay connected to the protected circuit through CT & VT.
* Auxiliary Relay: relay operate in response to opening or closing of another relay.
* Measuring Relay: It performs the measurement of normal & abnormal conditions in the power system. ′ Electro Magnetic Relay: It operates on the principle of Electromagnetic induction. ′ Static Relay(Solid-state relay): They use diodes , transistors , SCRs , Logic gates etc. (Static circuit is the measuring circuit & no moving parts) ′ Microprocessor Based Relay: All functions of a relay can done by using microprocessor . Relays are programmable. µP can compare , compute and send trip signals
* Thermal Relay: It operates on the principle of Electrothermal effect. ′ Distance Relay: relay measures the impedance or reactance or admittance. ′ Impedance Relay: relay measures the impedance of the transmission line. ′ Reactance Relay: relay measures the reactance of the transmission line. ′ Over-current Relay: relay operates when the current exceeds a pre-set value. ′ Under-voltage Relay: relay operates when the voltage falls a pre-set value. ′ Directional Relay: relay able to sense whether fault lies in forward or reverse direction. ′ Polarized Relay: relay depends on the direction of the current
* non directional relays are activated by only current flowing in the circuit to be protected.
* directional relays are activated by power flowing in the specific direction. Hence it requires both current and voltage of the circuit to be protected.
* IMPEDANCE RELAY Also called voltage restrained over current relay
* +ve (operative)Torque by current element
* -ve(restraining)Torque by voltage element
* At normal condition operative torque = restraining torque
* At fault operative torque > restraining torque
* Reactance relay :-
* Operative Torque by current
* Restraining Torque by Current-Voltage
* Directional relay
* +ve torque by over current element
* -ve torque by directional unit
* Directional element designed for maxi. Torque angle = 90 degree
* Mho relay :- ¬Induction cup type structure. oOperative Torque produced by V & I element. o Restraining Torque by Voltage element. ¬Also called Admittance relay.

**Questions**

**2 Mark Questions**

1. What are the functions of protective relay
2. What is meant by primary and back up protection
3. What is the difference between a fuse and a relay?
4. Why are differential relays more sensitive than over current relays?
5. What is protective relay?

**3 Mark Questions**

1. Define following terms a) Current setting b) time setting
2. What is the difference between an over current relay and current differential relay ?
3. What is the difference between a balanced voltage relay and a Translay relay?
4. Drive universal torque equation for distance relay
5. How the relays are basically classified

**5 Mark Questions**

1. With the help of neat sketch explain the principle of operation of Differential relays
2. Describe the operating principle, constructional features and area of applications of reverse power or directional relay
3. Explain the working principle of distance relays
4. What are the different inverse time characteristics of over current Relays? Mention how characteristics can be achieved practice for an electromagnetic relay.

**Fill in the blanks:**

1. A relay used for protection of motors against overload is **Thermal relay**
2. Thermal relays are often used in **motor starters**
3. Which of the following is not a relay using electromagnetic force **Buchholz relay**
4. MHO relay is used for **transmission lines**
5. Relay contacts are normally made up of **Silver contacts**
6. The most efficient torque-producing actuating structure for induction type relays is **Induction cup structure**
7. Impedance relays can be used for **Both earth and phase faults**
8. Sparking between the contacts can be reduced by inserting **A capacitor in parallel with the contacts**
9. The contact resistance is least affected by: **Ambient temperature**
10. Over-current protection for motor is provided by **over-current relay**

**Choose the Best:**

1. Electro-magnetic relays may be operated by **(D)**

(A) electro-magnetic attraction

(B) electro-magnetic induction

(C) thermal effect

(D) any of the above.

2. The actuating quantity for the relays can be **(D)**

(A) magnitude

(B) phase angle

(C) frequency

(D) any of the above.

3. Match the following : **(B)**

|  |  |
| --- | --- |
| Relay | Operation |
| (a) Static relay | (i) Responds to vector difference between two electrical quantities |
| (b) Over current relay | (ii) Quick operation |
| (c) Differential relay | (iii) Responds to increase in current |
| (d) Instantaneous | (iv) No moving parts relay |

(A) a - (i), b- (ii), c - (iii), d - (iv)

(B) a - (iv), b - (iii), c - (i), d- (ii)

(C) a - (ii), b - (i) c- (iii), d - (iv)

(D) a - (iii), b - (ii), c - (i), d - (iv).

4). Plug setting of a relay can be altered by varying

 air gap of magnetic path.

  no. of ampere-turns.

 adjustable back up stop.

 none of these.

5). For extra high voltage lines which circuit breaker is preferred

(A) Bulk oil circuit breaker

(B) Vacuum circuit breaker

(C) SF6 gas circuit breaker

(D) Minimum oil circuit breaker.

6). The number of cycles in which a high speed circuit breaker can complete its operation is

(A) 3 to 8

(B) 10 to 18

(C) 20 to 30

(D) 40 to 50.

8). Which circuit breaker is generally used in railway traction ?

(A) SF6 gas circuit breaker

(B) Air break circuit breaker

(C) Vacuum circuit breaker

(D) Minimum oil circuit breaker.

9). Which relay is used for feeders ?

(A) MHO relay

(B) Translay relay

(C) Merz price protection

(D) Buchholz relay.

10). Which of the following relays is used on transformers ?

(A) Buchholz relay

(B) MHO relay

(C) Merz price relay

(D) None of the above.

**Unit – III PROTECTION OF POWER EQUIPMENT**

**Important Points / Definitions:**

* Buchholz Protection Also known as gas accumulator relay, commonly used on all oil-immersed transformer provided with conservator.
* The core-balance protection cannot provide protection against overload. It is usual practice to provide combined leakage and overload protection for transformer. The earth relay has low current setting and operates under earth faults only. The overload relays have high current setting and are arrange to operate against faults between the phases
* CLASS – A: Protection where electrical isolation is an emergency.( Insulation failure, ,S.C. etc.). Trip the GCB/Turbine/Boiler without time delay or Generator automatic trips. ν .Class – A follows; ν Gen. Differential Prot. ν Gen. 100% E/F ν Gen. SB E/F ν Gen. NVD ν Gen. O/C ν Rotor 2nd stage E/F ν Gen. Brg. Temp. high
* CLASS – B: Protection where external abnormalities come into picture, such as temp. rise. Generator trips through LFP relay.
* The following types of transformer faults can be protected by the Buchholz relay and are indicated by alarm: 1. Local overheating 2. Entrance of air bubbles in oil 3. Core bolt insulation failure 4. Short circuited laminations 5. Loss of oil and reduction in oil level due to leakage
* Biased Differential scheme (Merz-Price Scheme) for protection of Generators. This is most commonly used protection scheme for the alternator stator windings. The scheme is also called biased differential protection and percentage differential protection
* Pilot wire schemes for feeder protection
* 1. Merz-Price Voltage Balance System 2. Translay Scheme
* Biased Differential scheme (Merz-Price Scheme) for protection of Generators. This is most commonly used protection scheme for the alternator stator windings. The scheme is also called biased differential protection and percentage differential protection
* EARTH FAULT PROTECTION • Earth fault protection can be obtained by applying a relay to measure the transformer secondary current by connecting a voltage measuring relay in parallel with the load resistor
* INTERNAL FAULTS The primary protection of a power transformer is intended for conditions which arises as a result of faults inside the protection zone. 1. Phase-to-earth fault or phase- to- phase fault on HV and LV external terminals 2. Phase-to-earth fault or phase-to- phase fault on HV and LV windings. 3. Interturn faults of HV and LV windings. 4. Earth fault on tertiary winding, or short circuit between turns of a tertiary windings.
* BUSBAR FAULTS • Majority of bus faults involve one phase and earth, but faults arise from many causes and a significant number are inter-phase clear of earth. • With fully phase-segregated metal clad gear, only earth faults are possible ,and a protective scheme need have earth fault sensitivity only. • For outdoor busbars , protection schemes ability to respond to inter-phase faults clear of earth is an advantage
* A system protection that includes over current or distance systems will inherently give protection cover to the bus bars. • Over current protection will only be applied to relatively simple distribution systems, or as a back-up protection set to give considerable time delay. Distance protection will provide cover with its second zone. • In both cases, therefore ,the bus bar protection so obtained is slow

**2 Mark Questions**

1. Why is overload protection not necessary for alternators?
2. What are the types of stator winding faults in alternator?
3. What are the rotor faults in alternator
4. What is field suppression?
5. How many faults develop in a power transformer?
6. What are the advantages in operating choppers at high frequency

**3 Mark Questions**

1. What do you understand by field suppression of an alternator? (b) How is it achieved?
2. Explain biased differential Protection?
3. Discuss the protection employed against loss of excitation of an alternator
4. Mention the most commonly used protection scheme for alternators
5. What is the principle of harmonic restraint relay
6. What is magnetic inrush current?
7. **Mark Questions**
8. a). Explain with a neat diagram the application of Merz-Price circulating current principle for the protection of alternator.b).A star-connected, 3-phase, 10 MVA, 6·6 kV alternator is protected by Merz-Price circulating-current principle using 1000/5 amperes current transformers. The star point of the alternator is earthed through a resistance of 7·5 Ω. If the minimum operating current for the relay is 0·5 A, calculate the percentage of each phase of the stator winding which is unprotected against earth-faults when the machine is operating at normal voltage
9. a).What type of a protective device is used for the protection of an alternator against overheating of its (i) stator (ii) rotor? Discuss them in briefb). Describe protection scheme of an alternator against inter-turn fault
10. a). Explain with a neat circuit diagram the differential protection scheme used to protect star/delta transformers.b). Describe with a neat sketch the operation of Buchholz relay
11. What is the principle of harmonic restraint relay? Explain its applications
12. A 3-phase transformer having a line voltage ratio of 400/33,000V is star-delta connected. The CTs on the 400v side have a ratio of 800/5A.What must be the ratio of CTs on 33,000V side?

 **Fill in the blanks:**

1. Differential protection principle is used in the protection of **generators transformers feeders**
2. The material used for bus bars should have **low resistivity higher softening temperature low cost**
3. The main factor in favour of the use of aluminium as bus bar material is **its low cost**
4. **Translay relay**  relay is used for feeders
5. MHO relay is used for **transmission lines**
6. Buchholz relay is operated by **Gas pressure**
7. **Overhead lines** portion of the transmission system faults occur most frequently
8. **Buchholz relay** relays is used on transformers.
9. 9) . Under-voltage relay is mostly used for: **Motor protection**
10. 10).Differential relays are used for the protection of equipments against: **Internal faults**

1). Merze price [electric current](http://electricalstudy.sarutech.com/electric-current-and-theory-of-electricity/index.html) scheme protection is used in

 transformer.

 alternator.

 both a and b.

 bus bars.

2). The ohmic value of impedance to be connected in the neutral to ground circuit of a 2000 kVA transformer with earth fault relay set to 40%, with respect to 400 V side will be

(A) 0.2 ohm

(B) 2.0 ohms

(C) 20 ohms

(D) 200 ohms.

3).  Buchholz relay is operated by

(A) Eddy currents

(B) Gas pressure

(C) Electro-magnetic induction

(D) Electro-static induction.

4). Thermal relays are often used in

(A) generator protection

(B) transformer protection

(C) motor starters

(D) none of the above.

5). Over-current protection for motor is provided by

(A) cartridge fuses

(B) high resistance fuses

(C) over-current relay

(D) all of the above.

6). In which method of starting a motor, the starting current is the maximum ?

(A) Auto-transformer

(B) Star-delta starter

(C) Stator rotor starter

(D) Direct-on-line.

8. Which of the following circuit breakers is preferred for EHT application

(A) Air blast circuit breakers

(B) Minimum oil circuit breakers

(C) Bulk oil circuit breakers

(D) SF6 oil circuit breakers.

9.While selecting a gas for circuit breaker, the property of gas that should be considered is

(A) high dielectric strength

(B) non-inflammability

(C) non-toxicity

10. Ionization in a circuit breaker is not facilitated by **(B)**

(A) high temperature of surrounding medium

(B) material of contacts

(C) increase of field strength

(D) increase of mean free path.