SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

AN AUTONOMOUS INSTITUTION

Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai

INTERNAL ASSESSMENT EXAMINATION – I ANSWER KEY

VI Semester

B.E – Electrical and Electronics Engineering
19EE605 – Protection and Switchgear

Regulations 2019

PART - A

Q.No	Question
1.	**Give the difference between circuit breaker and switch.**

Aspect	Circuit Breaker	Switch
Function	Protective device, interrupts circuit in case of overload or fault	Control device, manually opens or closes circuit
Operation	Automatic trip mechanism	Manual operation by a person
Types	Thermal-magnetic, magnetic, electronic	Toggle, rocker, push-button, rotary, etc.
Usage	Protects circuits and equipment from damage due to faults	Controls flow of electricity in a circuit, often for lighting, appliances, etc.
Resetting	Can be manually or automatically reset after tripping	No automatic reset feature, stays in the last position set by the user
Application	Found in electrical distribution panels, switchgear, power systems	Used in residential, commercial, and industrial settings for various purposes
Example	Used to protect wiring, appliances, and equipment	Controls the operation of lights, fans, motors, etc.

Q.No	Question
2.	**Compare primary and backup protection.** Primary protection operates with high speed and sensitivity, located close to equipment, for immediate fault clearance. Backup protection serves as a secondary layer, with slightly longer time delays, strategically placed for system reliability in case primary protection fails.
3.	**Prove that** $\frac{1-a}{1+a^2} = 1 - a^2$

	We can multiply both the numerator and denominator by $(1-a)$: $= \frac{(1-a)(1-a)}{(1+a^2)(1-a)}$ Now, expand the numerator: $= \frac{1-2a+a^2}{1-a+a^2-a^3}$ Next, we notice that a^3 is negligible as it will disappear when a tends to zero. So we'll ignore it for the simplification: $= \frac{1-2a+a^2}{1-a+a^2}$ Now, we can see that the numerator and denominator have similar terms but with opposite signs. So, we can cancel out similar terms: $= \frac{1}{1}$ $= 1$
4.	**Write the torque equation of electromagnetic attraction type relay.** $T = k \cdot \frac{\mu_0^2 \cdot A \cdot N \cdot I^2 \cdot r}{2 \cdot g^2 \cdot l}$
5.	**Determine the PSM of a 5 ampere, 3 second overcurrent relay having a current setting of 125% connected to supply circuit through 400/5 current transformer when the circuit carries a fault current of 4000A.** 1. **Calculate Pickup Current (Ip):** • The relay has a current setting of 125%, which means it operates at 125% of its rated current. • Rated current of the relay = 5 Amperes. • Pickup current (Ip) = 125% of rated current = 1.25 * 5 A = 6.25 Amperes. 2. **Determine Secondary Current (Is):** • The current transformer (CT) ratio is 400/5. This means that for every 400 A in the primary circuit, 5 A will flow in the secondary circuit. • Therefore, the secondary current (Is) corresponding to a fault current of 4000 A will be: $Is = \frac{4000A \times 5}{400} = 50A$ 3. **Calculate PSM:** • Plug Setting Multiplier (PSM) is the ratio of pickup current to the secondary current corresponding to the fault current. $PSM = \frac{Ip}{Is}$ • Substituting the values: $PSM = \frac{6.25A}{50A} = 0.125$

PART - B

6.a	**List the essential qualities of protective relay. Explain in detail.**

The basic requirements of a protective system are as follows:

(a) Selectivity or discrimination

(b) Reliability

(c) Sensitivity

(d) Stability

(e) Fast operation

(a) Selectivity or Discrimination

Selectivity, is the quality of protective relay by which it is able to discriminate between a fault in the protected section and the normal condition. Also, it should be able to distinguish whether a fault lies within its zone of protection or outside the zone. Sometimes, this quality of the relay is also called discrimination. When a fault occurs on a power system, only the faulty part of the system should be isolated. No healthy part of the system should be deprived of electric supply and hence should be left intact. The relay should also be able to discriminate between a fault and transient conditions like power surges or inrush of a transformer's magnetising current. The magnetising current of a large transformer is comparable to a fault current, which may be 5 to 7 times the full load current. When generators of two interconnected power plants lose synchronism because of disturbances, heavy currents flow through the equipment and lines. This condition is like a short circuit. The flow of heavy currents is known as a power surge. The protective relay should be able to distinguish between a fault or power surge either by its inherent characteristic or with the help of an auxiliary relay. Thus, we see that a protective relay must be able to discriminate between those conditions for which instantaneous tripping is required and those for which no operation or a time-delay operation is required.

(b) Reliability

A protective system must operate reliably when a fault occurs in its zone of protection. The failure of a protective system may be due to the failure of any one or more elements of the protective system. Its important elements are the protective relay, circuit breaker, VT, CT, wiring, battery, etc. To achieve a high degree of reliability, greater attention should be given to the design, installation, maintenance and testing of the various elements of the protective system. Robustness and simplicity of the relaying equipment also contribute to reliability. The contact pressure, the contact material of the relay, and the prevention of contact contamination are also very important from the reliability point of view. A typical value of reliability of a protective scheme is 95%.

(c) Sensitivity

A protective relay should operate when the magnitude of the current exceeds the preset value. This value is called the pick-up current. The relay should not operate when the current is below its pick-up value. A relay should be sufficiently sensitive to operate when the operating current just exceeds its pick-up value.

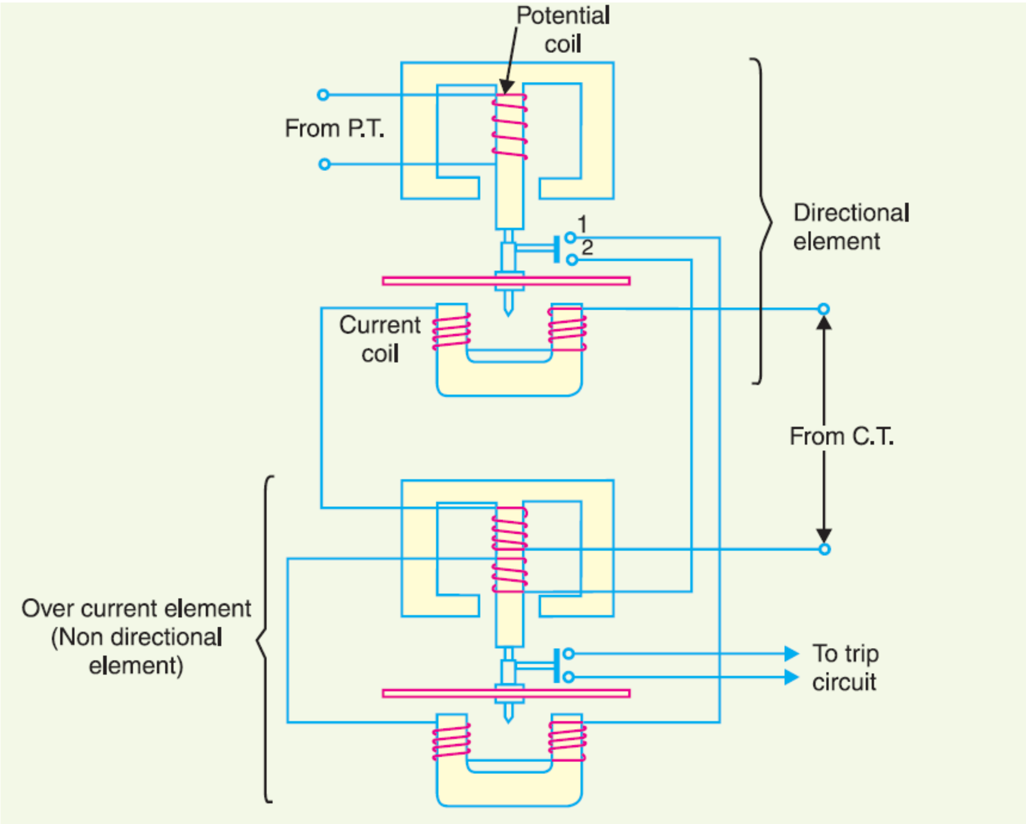
(d) Stability

A protective system should remain stable even when a large current is flowing through its protective zone due to an external fault, which does not lie in its zone. The concerned circuit breaker is supposed to clear the fault. But the protective system will not wait indefinitely if the protective scheme of the zone in which fault has occurred fails to operate. After a preset delay the relay will operate to trip the circuit breaker.

(e) Fast Operation

	A protective system should be fast enough to isolate the faulty element of the system as quickly as possible to minimise damage to the equipment and to maintain the system stability. For a modern power system, the stability criterion is very important and hence, the operating time of the protective system should not exceed the critical clearing time to avoid the loss of synchronism. Other points under consideration for quick operation are protection of the equipment from burning due to heavy fault currents, interruption of supply to consumers and the fall in system voltage which may result in the loss of industrial loads. The operating time of a protective relay is usually one cycle. Half-cycle relays are also available. For distribution systems the operating time may be more than one cycle.
6.b	**Justify why neutral grounding is provided and compare different types of neutral grounding.** 1. **Safety**: Grounding the neutral helps to limit the voltage levels on ungrounded phases during faults, reducing the risk of electric shock to personnel and damage to equipment. 2. **System Stability**: Neutral grounding assists in stabilizing the system voltage during unbalanced or asymmetrical fault conditions. It helps to limit the magnitude of fault currents and reduces the likelihood of cascading failures and system-wide voltage instability. 3. **Equipment Protection**: Grounding the neutral provides a path for fault currents to flow, allowing protective devices such as circuit breakers and fuses to detect and clear faults promptly. This helps to protect equipment from damage due to overcurrent conditions. Now, let's compare different types of neutral grounding: **Types of Neutral Grounding:** 1. **Solid Grounding**: o In solid grounding, the neutral is directly connected to the earth or ground, typically through a grounding resistor or reactor. o Provides a low-impedance path for fault currents, allowing for rapid fault detection and clearing. o Offers high fault current levels, which can lead to high mechanical and thermal stresses on equipment during faults. 2. **Resistance Grounding**: o In resistance grounding, a resistor is connected between the neutral and ground, limiting the fault current magnitude. o Provides some level of fault current protection while reducing mechanical and thermal stresses on equipment compared to solid grounding. o Allows for selective coordination of protective devices and reduces the likelihood of system-wide voltage disturbances during faults. 3. **Reactance Grounding**: o Reactance grounding involves connecting a reactor between the neutral and ground, providing impedance to limit fault currents. o Offers better system stability compared to resistance grounding by limiting fault current magnitudes while still providing some fault current protection. o Helps to reduce the effects of transient overvoltages and minimizes the risk of ferroresonance. 4. **Ungrounded (Isolated) System**: o In an ungrounded system, the neutral is not connected to ground, and fault currents are limited by the system capacitance and inductance. o Provides high system reliability and reduces the risk of ground faults causing system-wide outages. o However, fault detection can be challenging, and prolonged faults can lead to insulation degradation and equipment damage.
7.a	**Describe the operating principles, constructional features and area of applications of directional relay. How do you implement directional feature in the over-current realy.** The directional power relay discussed above is unsuitable for use as a directional protective relay under

short-circuit conditions. When a short-circuit occurs, the system voltage falls to a low value and there may be insufficient torque developed in the relay to cause its operation. This difficulty is overcome in the directional overcurrent relay which is designed to be almost independent of system voltage and power factor.



Constructional details. Fig. 21.19 shows the constructional details of a typical induction type directional ovecurrent relay. It consists of two relay elements mounted on a common case viz. (i) directional element and (ii) non-directional element.

(i) Directional element. It is essentially a directional power relay which operates when power flows in a specific direction. The potential coil of this element is connected through a potential transformer (P.T.) to the system voltage. The current coil of the element is energised through a C.T. by the circuit current. This winding is carried over the upper magnet of the non-directional element.

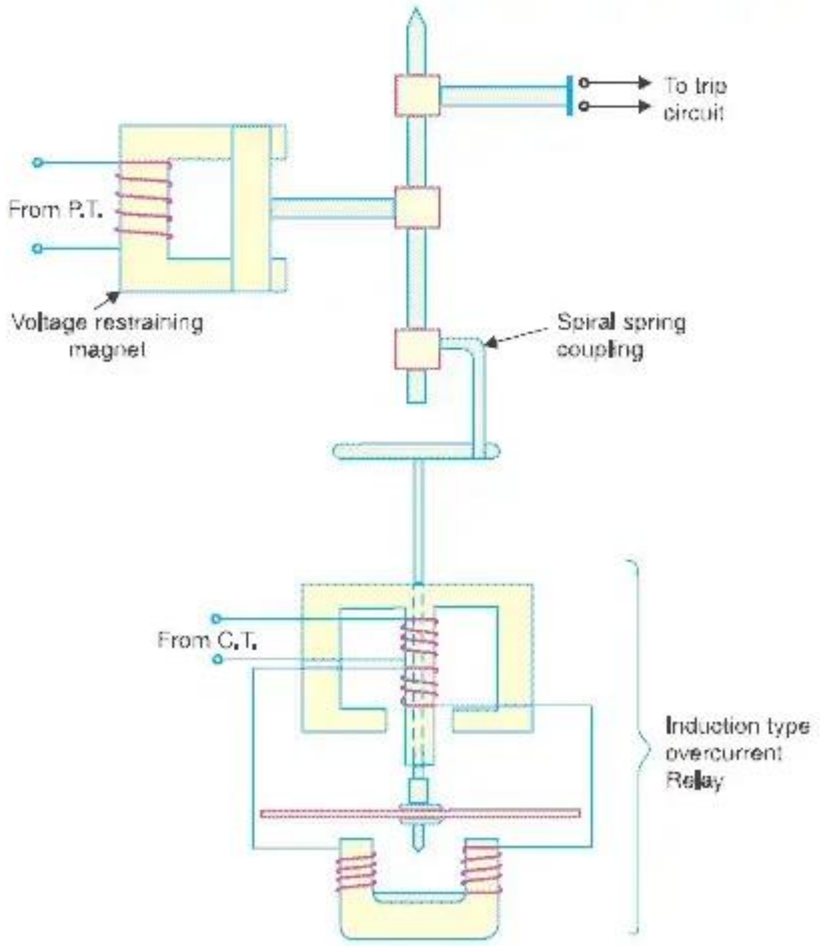
The trip contacts (1 and 2) of the directional element are connected in series with the secondary circuit of the overcurrent element. Therefore, the latter element cannot start to operate until its secondary circuit is completed. In other words, the directional element must operate first (i.e. contacts 1 and 2 should close) in order to operate the overcurrent element.

(ii) Non-directional element. It is an overcurrent element similar in all respects to a non-directional overcurrent relay described in Art. 21.11. The spindle of the disc of this element carries a moving contact which closes the fixed contacts (trip circuit contacts) after the operation of directional element.

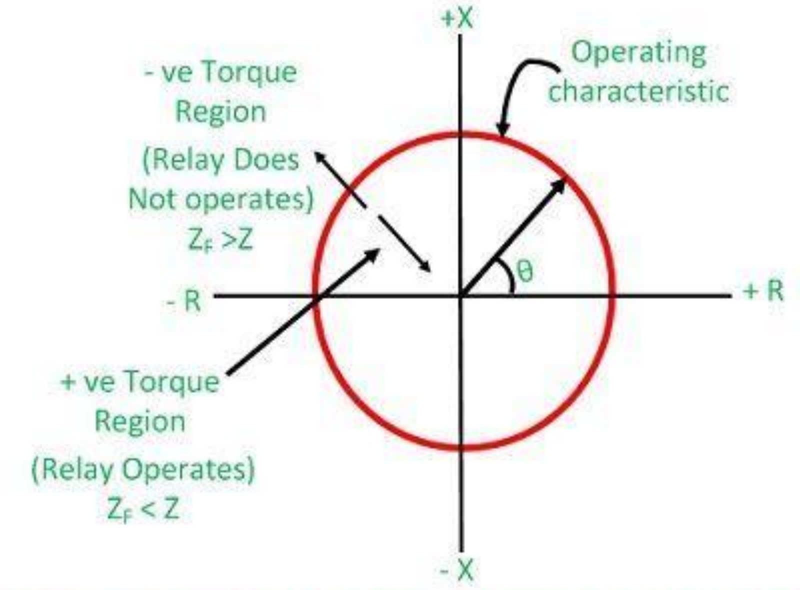
It may be noted that plug-setting bridge is also provided in the relay for current setting but has been omitted in the figure for clarity and simplicity. The tappings are provided on the upper magnet of overcurrent element and are connected to the bridge.

Operation. Under normal operating conditions, power flows in the normal direction in the circuit protected by the relay. Therefore, directional power relay (upper element) does not operate, thereby keeping the overcurrent element (lower element) unenergised. However, when a short-circuit occurs, there is a tendency for the current or power to flow in the reverse direction. Should this happen, the disc of the *upper element rotates to bridge the fixed contacts 1 and 2. This completes the circuit for overcurrent element. The disc of this element rotates and the moving contact attached to it closes the trip circuit. This operates the circuit breaker which isolates the faulty section. The two relay elements are so arranged that final tripping of the current controlled by them is not made till the following conditions are satisfied:

	(i) current flows in a direction such as to operate the directional element. **(ii)** current in the reverse direction exceeds the pre-set value. **(iii)** excessive current persists for a period corresponding to the time setting of overcurrent element.
7.b	**Illustrate the construction and operating principle of impedance type distance relay with R-X diagram.** There is one type of relay which functions depending upon the distance of fault in the line. More specifically, the relay operates depending upon the impedance between the point of fault and the point where relay is installed. These relays are known as distance relay or impedance relay. **Working Principle of Distance or Impedance Relay** Working Principle of Distance or Impedance Relay: The operation of an impedance relay is straightforward. It uses a voltage element from a potential transformer and a current element from a current transformer. The relay's action depends on the balance between the restoring torque (from voltage) and the deflecting torque (from current). Normal vs. Fault Conditions: Under normal conditions, the restoring torque (from voltage) exceeds the deflecting torque (from current), keeping the relay inactive. During a fault, increased current and reduced voltage shift this balance, activating the relay by closing its contacts. Thus, the relay's function is determined by the impedance, or the voltage to current ratio. Activation Threshold: The impedance relay activates when the voltage to current ratio, or impedance, falls below a predefined value. This typically indicates a fault within a specific, predetermined distance along the transmission line, as line impedance is proportionate to its length. **Definite Distance Relay** This is simply a variety of balance beam relay. Here one beam is placed horizontally and supported by hinge on the middle. One end of the beam is pulled downward by the magnetic force of voltage coil, fed from potential transformer attached to the line. Other end of the beam is pulled downward by the magnetic force of current coil fed from current transformer connected in series with line. Due to torque produced by these two downward forces, the beam stays at an equilibrium position. The torque due to voltage coil, serves as restraining torque and torque due to current coil, serves as deflecting torque. **Time Distance Impedance Relay** This delay automatically adjusts its operating time according to the distance of the relay from the fault point. The time distance impedance relay will not only be operated depending upon voltage to current ratio, its operating time also depends upon the value of this ratio. That means, $$Operating\ time\ T \propto \frac{Voltage}{Current} \propto Impedance \propto Distance\ along\ transmission\ line$$



The R-X Diagram is



Operating Characteristic of an Impedance Relay on an R-X Diagram

PART - C

8.a **A 230 kV, 3-phase, 50 Hz, 200 km transmission line has a capacitance to earth of 0.02 µF/km per phase. Calculate the inductance and kVA rating of the Peterson coil used for earthing the above system.**

	Solution. Supply frequency, $f = 50$ Hz Capacitance of each line to earth, $C = 200 \times 0{\cdot}02 = 4 \times 10^{-6}$ F Required inductance of Peterson coil is $L = \frac{1}{3\omega^2 C}$ $= \frac{1}{3\times(2\pi\times 50)^2\times 4\times 10^{-6}} =$ **0·85 H** Current through Peterson coil is $I_F = \frac{V_{ph}}{X_L} = \frac{230\times 10^3/\sqrt{3}}{2\pi\times 50\times 0{\cdot}85} = 500\ A$ Voltage across Peterson coil is $V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{230\times 1000}{\sqrt{3}}\ V$ ∴ Rating of Peterson coil $= V_{ph}\times I_F = \frac{230\times 1000}{\sqrt{3}} \times 500 \times \frac{1}{1000}$ **kVA = 66397 kVA**
8.b	**In a 3-phase, 4-wire system, the currents in R, Y and B lines under abnormal conditions of loading are as under:** $\vec{I_R} = 100\angle 30^\circ\ A;\ \vec{I_Y} = 50\angle 300^\circ\ A;\ \vec{I_B} = 30\angle 180^\circ\ A$ **Calculate the positive, negative and zero sequence currents in the R-line and return current in the neutral wire.** $\vec{I_0} = \frac{1}{3}\left[\vec{I_R} + \vec{I_Y} + \vec{I_B}\right]$ $= \frac{1}{3}[100\angle 30^\circ + 50\angle 300^\circ + 30\angle 180^\circ]$ $= \frac{1}{3} * [(86{\cdot}60 + j\,50) + (25 - j\,43{\cdot}3) + (-30 + j0)]$ $= \frac{1}{3}[81{\cdot}6 + j\,6{\cdot}7]$ $= (27{\cdot}2 + j\,2{\cdot}23) =$ **27·29 ∠4·68° A** $\vec{I_1} = \frac{1}{3}\left[\vec{I_R} + a\,\vec{I_Y} + a^2\,\vec{I_B}\right]$ $= \frac{1}{3}[100\angle 30^\circ + 1\angle 120^\circ \times 50\angle 300^\circ + 1\angle -120^\circ \times 30\angle 180^\circ]$ $= \frac{1}{3}[100\angle 30^\circ + 50\angle 60^\circ + 30\angle 60^\circ]$ $= \frac{1}{3}[(86{\cdot}6 + j\,50) + (25 + j\,43{\cdot}3) + (15 + j\,25{\cdot}98)]$ $= \frac{1}{3}[126{\cdot}6 + j\,119{\cdot}28]$ $= (42{\cdot}2 + j\,39{\cdot}76) =$ **57·98 ∠43·3° A**

	$\vec{I_2}$	$= \frac{1}{3}[\vec{I_R} + a^2\,\vec{I_Y} + a\,\vec{I_B}]$
		$= \frac{1}{3}[100\,\angle 30^\circ + 1\,\angle{-120^\circ} \times 50\,\angle 300^\circ + 1\,\angle 120^\circ \times 30\,\angle 180^\circ]$
		$= \frac{1}{3}[100\,\angle 30^\circ + 50\,\angle 180^\circ + 30\,\angle 300^\circ]$
		$= \frac{1}{3}[(86{\cdot}6 + j\,50) + (-50 + j\,0) + (15 - j\,25{\cdot}98)]$
		$= \frac{1}{3}[51{\cdot}6 + j\,24{\cdot}02]$
		$= (17{\cdot}2 + j\,8) =$ **$18{\cdot}96\,\angle 24{\cdot}9^\circ$ A**
	Current in the neutral wire	$= \vec{I_R} + \vec{I_Y} + \vec{I_B} = (81{\cdot}6 + j\,6{\cdot}7) =$ **$81{\cdot}87\,\angle 4{\cdot}7^\circ$ A**