

Govt. of Bihar

**MUZAFFARPUR INSTITUTE OF TECHNOLOGY,  
MUZAFFARPUR-842003**

(Under the Department of Science & Technology Govt. of Bihar, Patna)

**Mid-Semester (UG) Examinations, 2018  
Answer Sheet**

**Subject Code- 031713**

**Subject: Protection of Power Apparatus and  
system**

**Semester: 7<sup>th</sup>**

**Department: EE**

**Duration: 2 Hrs.**

**Total marks: 20**

**Instructions:**

- (i) The marks are indicated in the right-hand margin.
- (ii) There are **Six** questions in this paper.
- (iii) Attempt **Four** questions in all.

**Answer the following questions**

1. Define Plug Setting multiplier (PSM). A relay is connected to 400/5 C.T and set at 120% and if the fault current on the primary side is 1440 A. Calculate PSM.

**Answer:**

Plug setting multiplier (PSM) is defined as the ratio of the fault current in secondary Amps to the relay plug setting. The value of PSM tells us about the severity of the current as seen by the relay. A PSM less than 1 means that normal load current is flowing. At  $PSM > 1$ , the relay is supposed to pick up. Higher values of PSM indicate how serious the fault is.

$$PSM = \frac{I_{relay}}{PS}$$

The pick-up setting, or plug setting (PS), 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.

The Primary Current in both relay is 1440 A

$$CT \text{ ratio} = \frac{400}{5} = 80$$

$$\text{Secondary Current} = \frac{\text{Primary Current}}{CT \text{ ratio}}$$

$$= \frac{1440}{80}$$

$$= 18 \text{ A}$$

$$\text{Current setting} = 120\% \text{ of } 5 \text{ A}$$

$$= 1.20 \times 5$$

$$= 6 \text{ A}$$

$$PSM = \frac{\text{Secondary Current}}{\text{Current setting}}$$

$$= \frac{18}{6} = 3$$

2. Explain with diagram for primary protection and Back up protection in details.

**Answer:**

There are times when the primary protection may fail. This could be due to failure of the CT/VT or relay, or failure of the circuit breaker. One of the possible causes of the circuit breaker failure is the failure of the trip-battery due to inadequate maintenance. We must have a second line of

defence in such a situation. Therefore, it is a normal practice to provide another zone of protection which should operate and isolate the faulty element in case the primary protection fails. A little thought will convince the reader that the back-up protection should not have anything in common with the primary protection. It should also preferably be located at a place different from where the primary protection is located. Further, the back-up protection must wait for the primary protection to operate, before issuing the trip command to its associated circuit breakers. In other words, the operating time of the back-up protection must be delayed by an appropriate amount over that of the primary protection. Thus, the operating time of the back-up protection should be equal to the operating time of primary protection plus the operating time of the primary circuit breaker.

Consider the radial system shown in Figure 1. Relay B, in conjunction with circuit breaker CBB, provides primary protection to the line section B-C. Relay A with circuit breaker CBA provides back-up protection to the section B-C. Consider a fault in section B-C as shown in Figure 1.

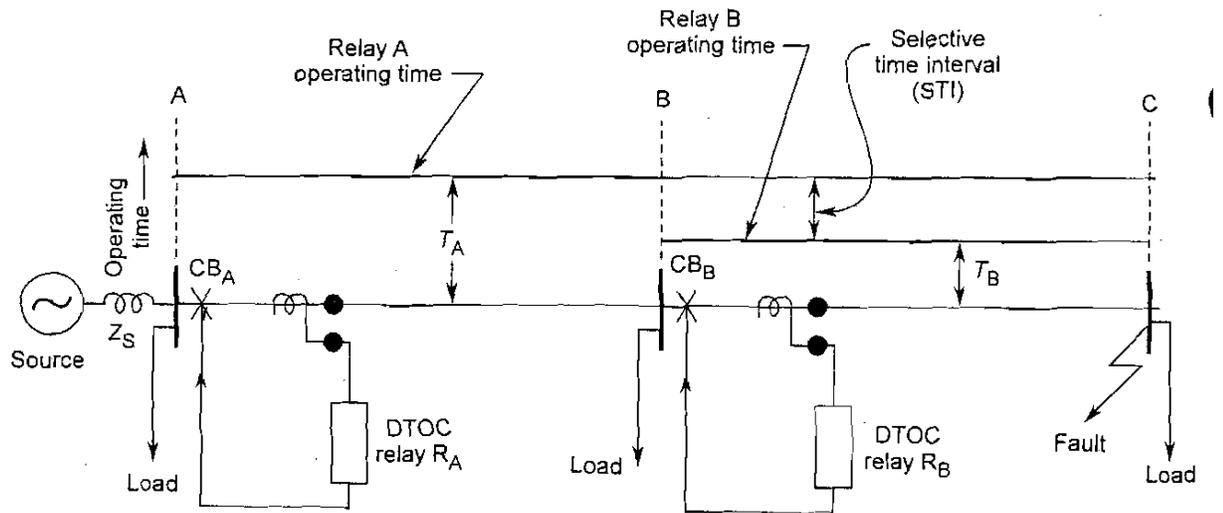


Figure 1. primary and back-up protection

When a fault takes place, both the primary relay  $R_B$  and the back-up relay  $R_A$  start operating simultaneously. In case the primary protection (provided by  $R_B + CB_B$ ) operates successfully, the line B-C gets de-energized but the loads on buses A and B remain unaffected. Therefore, the back-up protection (provided by  $R_A + CB_A$ ) resets without issuing a trip command. The sequence of events in such a case is depicted in Figure 2. However, in case the primary protection fails to operate, the back-up which is already monitoring the fault, waits for the time in which the primary would have cleared the fault and then issues the trip command to its allied circuit breakers. When the back-up operates, the time for which the fault persists is longer and disruption to the loads also lasts longer.

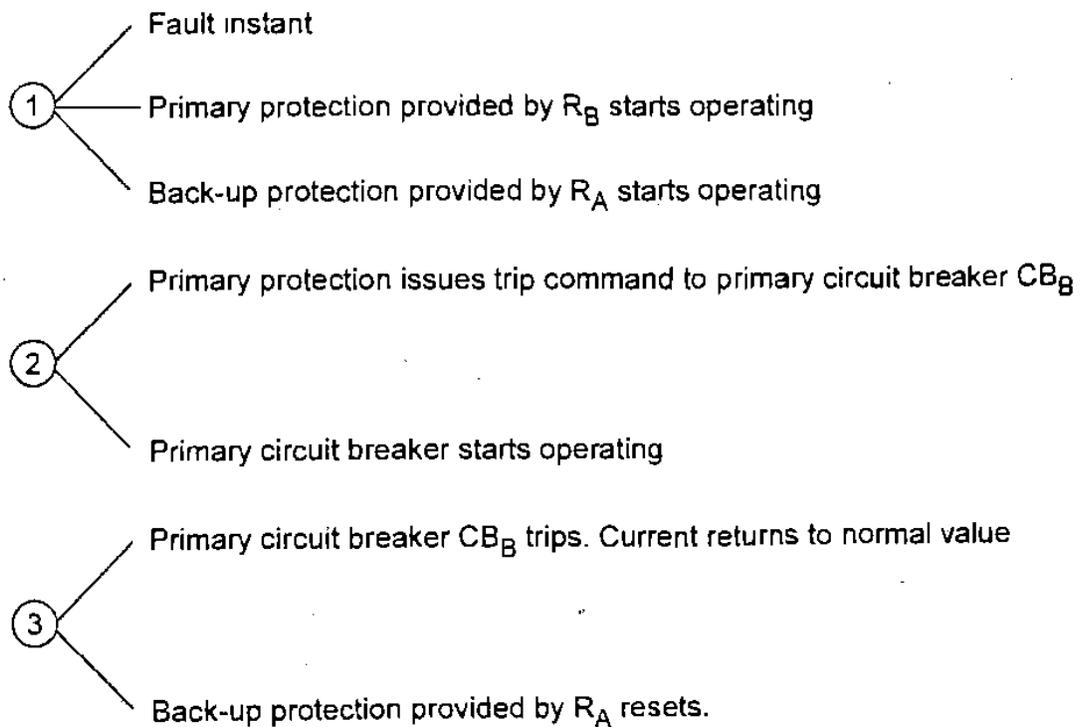
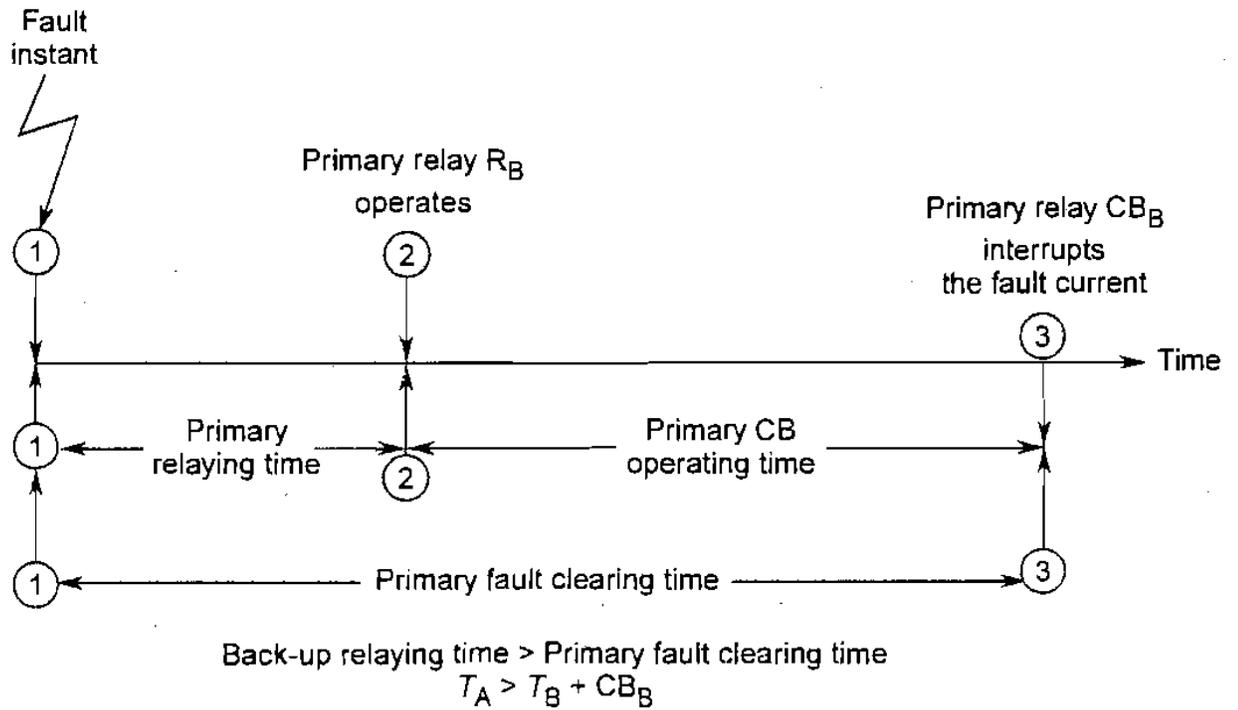


Figure 2. Primary and back-up protection: sequence of events: normal operation

3. Describe the principle and need for protective system.

**Answer:**

**Principle-**

- A protective system includes circuit breakers, transducers (CTs & VTs) and protective relays to isolate the faulty section of power system from the healthy section
- A circuit breaker can disconnect faulty element of the system when it is called upon to do so by the protective relay.
- Transducers are used to reduce currents and voltages to lower values and to isolate protective relays from the high voltages of the power system.
- The function of protective relay is to detect and locate a fault and issue a command to the circuit breaker to disconnect the faulty element.

#### Need for Protective Relays

- An electrical power system consists of generators, transformers, transmission and distribution etc.
- If a fault occurs in a element of power system, an an automatic protective device is needed to isolate faulty element as quickly as possible to keep the healthy section of the system in normal operation.
- A heavy short circuit may cause a fire.
- Due to low level of voltage, different power stations may lose synchronism.
- Protection is needed not against any other abnormal conditions which may arise on a power system. Abnormal conditions are overspeed of generators & motors, overvoltage, under frequency, loss of excitation, overheating of stator & rotor of an alternator.

4. Explain the operation of electromechanical reactance relay with proper diagram and supporting equations.

**Answer:**

Again consider the universal torque equation:

$$T = k_1 |I_R|^2 + k_2 |V_R|^2 + k_3 |V_R| |I_R| \cos(\theta - \tau) + k_4$$

If we set  $k_2$  equal to zero, make  $k_1$  positive (i.e. cause the current to provide tripping torque) and make  $k_3$  negative (i.e. cause the directional torque to oppose tripping), noting that  $k_4$  can be neglected when the relay is on the verge of operation, we get the following trip law:

If $k_1  I_R ^2 > k_3  V_R   I_R  \cos(\theta - \tau)$ then trip; else restrain
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which can be written as:

$$k_3 |V_R| |I_R| \cos(\theta - \tau) < k_1 |I_R|^2$$

and can be simplified as:

$$\frac{|V_R||I_R|}{|I_R|^2} \cos(\theta - \tau) < \frac{k_1}{k_3}$$

or

$$\frac{|V_R|}{|I_R|} \cos(\theta - \tau) < \frac{k_1}{k_3}$$

However,  $|V_R|/|I_R| = |Z_{seen}|$ , the apparent impedance seen by the relay.  
Therefore,

$$|Z_{seen}| \cos(\theta - \tau) < \frac{k_1}{k_3}$$

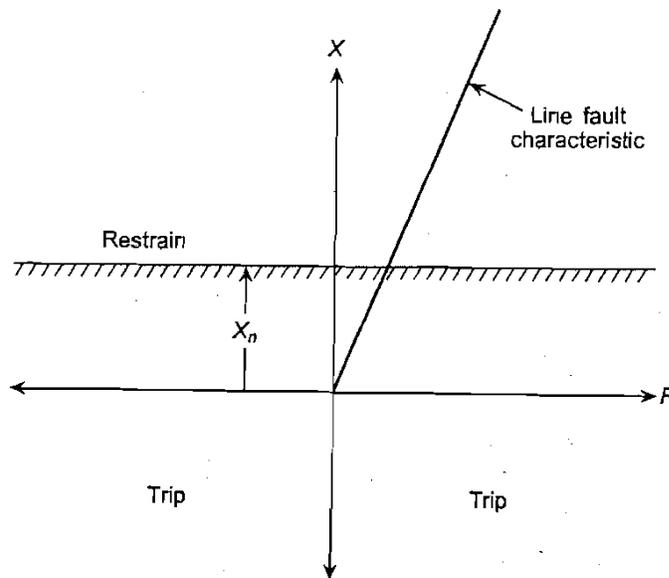
If we set the MTA of the directional element to be  $90^\circ$ , and let  $(k_1/k_3) = X_n$ , we get

$$|Z_{seen}| \cos(\theta - 90^\circ) < X_n$$

Since  $|Z_{seen}| \cos(\theta - 90^\circ) = |Z_{seen}| \sin \theta = |X_{seen}|$ , which is the reactive part of the impedance seen by the relay, we finally get the trip law as:

$$\boxed{\text{If } |X_{seen}| < |X_n| \text{ then trip; else restrain}}$$

The relay is thus sensitive only to the reactive part of the impedance seen, and trips if the reactive part is less than a particular set value  $X_n$ . Hence, such a relay is called a *reactance relay*. The operating characteristic of the relay on the  $R$ - $X$  plane is a straight line with intercept of  $X_n$  on the reactance axis. The entire area below this straight line represents the trip region. Thus, the area occupied is too large. This is shown in Figure 6.12.



**Figure 6.12** Characteristic of reactance relay.

5. In what way is distance protection superior to over-current protection of transmission lines?

**Answer:**

Overcurrent protection scheme is essentially a simple protection scheme. Consequently, its accuracy is not very high. It is comparatively cheap as non-directional protection does not require VT. However, it is not suitable for protection of meshed transmission systems where selectivity

and sensitivity requirements are more stringent. Overcurrent protection is also not a feasible option, if fault current and load currents are comparable. We now discuss about distance protection scheme which provides both 'higher' sensitivity and selectivity.

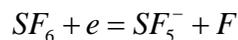
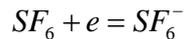
Distance protection provides the following features:

- More accurate as more information is used for taking decision.
- Directional, i.e. it responds to the phase angle of current with respect to voltage phasor.
- Fast and accurate.
- Back-up protection.
- Primarily used in transmission line protection.
- It can be applied to generator backup, loss of field and transformer backup protection.

6 Explain, with proper diagram, the working of SF<sub>6</sub> Circuit breakers.

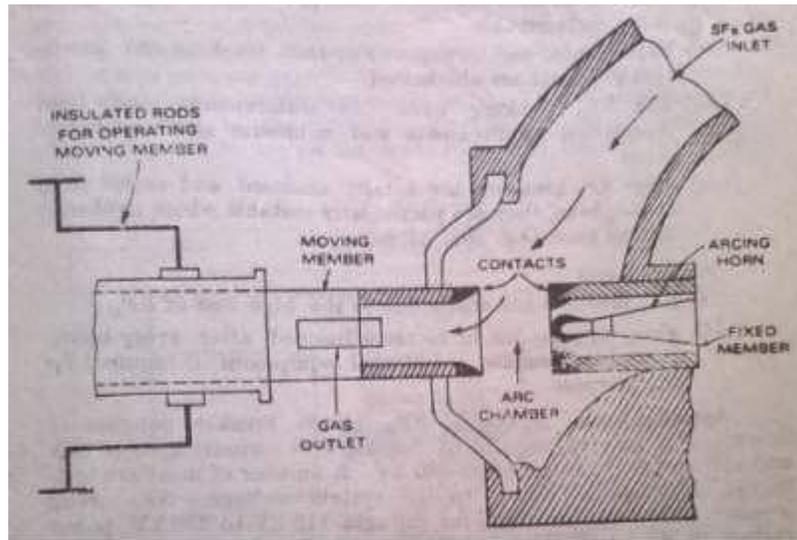
**Answer:**

A circuit breaker in which the current carrying contacts operate in Sulphur hexafluoride or SF<sub>6</sub> gas is known as an SF<sub>6</sub> *circuit breaker*. SF<sub>6</sub> has excellent insulating property and it has a high electro-negativity. Therefore, it has high affinity of absorbing free electrons. Whenever a free electron collides with the SF<sub>6</sub> gas molecule, it is absorbed by that gas molecule and forms a negative ion with the following processes.



These negative ions are much heavier than a free electron and therefore the overall mobility of the negatively charged particle in the medium is considerably reduced compared to other gases. As the mobility of charged particle is reduced, therefore the severity of arcing shall also be affected and reduced. Hence, for heavier and less mobile charged particles in SF<sub>6</sub> gas, it acquires very high dielectric strength. Not only the gas has a good dielectric strength but also it has the unique property of fast recombination after the process of arcing is completed. The gas also has a very good heat transfer property. Due to its low gaseous viscosity (because of less molecular mobility) SF<sub>6</sub> gas can efficiently transfer heat by convection. So due to its high dielectric strength and high cooling effect SF<sub>6</sub> gas is approximately 100 times more effective arc quenching medium compared to air. Due to these unique properties of this gas, SF<sub>6</sub> circuit breaker is used in complete range of medium voltage and high voltage electrical power system. These circuit breakers are available for the voltage ranges from 33KV to 800KV and even more.

**DIAGRAM: -**



### WORKING OF SF<sub>6</sub> CIRCUIT BREAKER: -

The working of SF<sub>6</sub> CB of first generation was quite simple it is some extent similar to air blast circuit breaker. Here SF<sub>6</sub> gas was compressed and stored in a high-pressure reservoir. During operation of SF<sub>6</sub> circuit breaker this highly compressed gas is released through the arc in breaker and collected to relatively low-pressure reservoir and then it pumped back to the high-pressure reservoir for re utilize. The working of SF<sub>6</sub> circuit breaker is little bit different in modern time. Innovation of *Puffer* type design makes operation of SF<sub>6</sub> CB much easier. In *Puffer* type design, the arc energy is utilized to develop pressure in the arcing chamber for arc quenching. Here the breaker is filled with SF<sub>6</sub> gas at rated pressure. There are two fixed contact fitted with a specific contact gap. A sliding cylinder bridges these to fixed contacts. The cylinder can axially slide upward and downward along the contacts. There is one stationary piston inside the cylinder which is fixed with other stationary parts of the SF<sub>6</sub> circuit breaker, in such a way that it cannot change its position during the movement of the cylinder. As the piston is fixed and cylinder is movable or sliding, the internal volume of the cylinder changes when the cylinder slides. During opening of the breaker, the cylinder moves downwards against position of the fixed piston hence the volume inside the cylinder is reduced which produces compressed SF<sub>6</sub> gas inside the cylinder. The cylinder has numbers of side vents which were blocked by upper fixed contact body during closed position. As the cylinder move further downwards, these vent openings cross the upper fixed contact, and become unblocked and then compressed SF<sub>6</sub> gas inside the cylinder will come out through this vent in high speed towards the arc and passes through the axial hole of the both fixed contacts. The arc is quenched during this flow of SF<sub>6</sub> gas. During closing of the circuit breaker, the sliding cylinder moves upwards and as the position of piston remains at fixed height, the volume of the cylinder increases which introduces low pressure inside the cylinder compared to the surrounding. Due to this pressure difference SF<sub>6</sub> gas from surrounding will try to enter in the cylinder. The higher-pressure gas will come through the axial hole of both fixed contact and enters into cylinder via vent and during this flow; the gas will quench the arc.

