EEE4227: POWER SYSTEM PROTECTION

TERM: FINAL-TERM

Topics to be covered in final-term

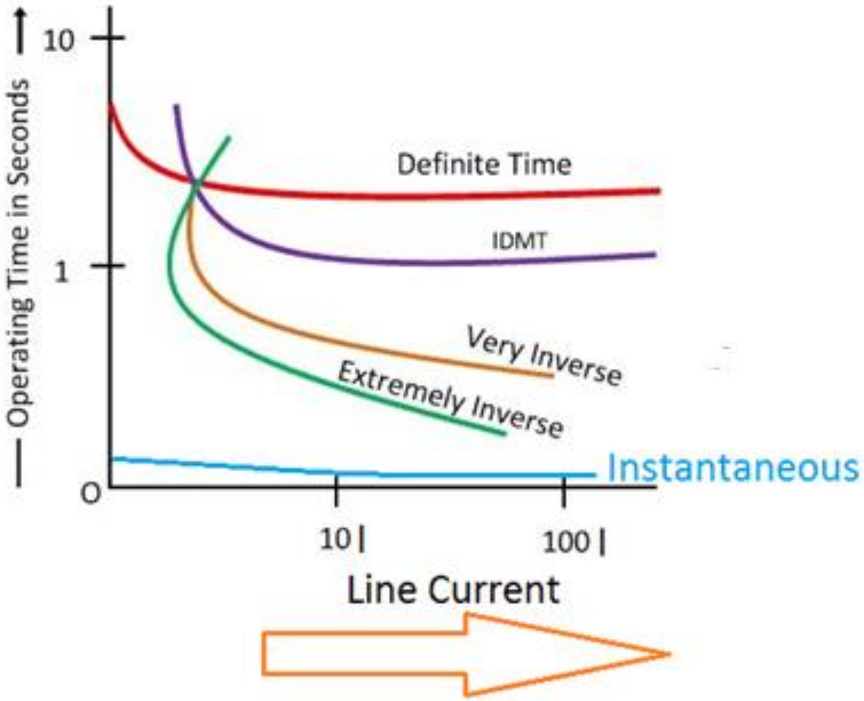
- Over-current relays (Lecture 07)
- Directional protection (Lecture 08)
- Differential protection (Lecture 09)
- Distance protection (Lecture 10)
- Generator protection (Lecture 11)
- Transformer protection (Lecture 12)

Lecture 07
Over-current relays

Different characteristic curves of O/C relays

- By varying the point of saturation, different characteristic curves of O/C relay can be obtained.
- Five different characteristics are available-
  - Definite time
  - Inverse definite minimum time (IDMT) type
  - Very inverse type
  - Extremely inverse type
  - Instantaneous O/C relay

Different characteristic curves of O/C relays



Characteristic of Various Overcurrent Relay

Different characteristic curves of O/C relays

- Definite time
  - $Ik = t$
- Inverse definite minimum time (IDMT) type
  - $t = \frac{0.14}{I^{0.02} - 1}$
- Very inverse type
  - $t = \frac{13.5}{I - 1}$
- Extremely inverse type
  - $t = \frac{80}{I^{2} - 1}$
- Instantaneous O/C relay
  - **No intentional time delay is provided. Operating time of these relays is approximately 0.01sec.**

Here, t= characteristic operating time (tc)
I= plug setting multiplier (PSM)

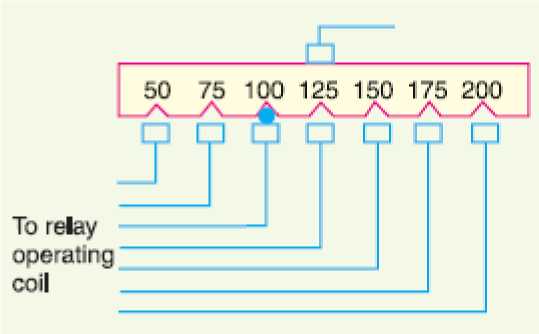
Important terms to be known

- Pick up current, İpickup
    - Minimum current at which relay starts to operate.

$$I_{pickup} = Primary\ current\ of\ CT(I_{CTprimary}) \times Plug\ setting(PS)$$

- Current setting(CS) or plus setting(PS)
    - Plug setting usually range from 50% to 200% in the steps of 25% for O/C relays.

$$PS = \frac{I_{pickup}}{I_{CTprimary}}$$

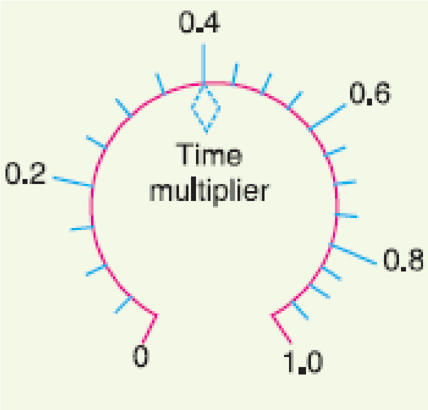


Important terms to be known

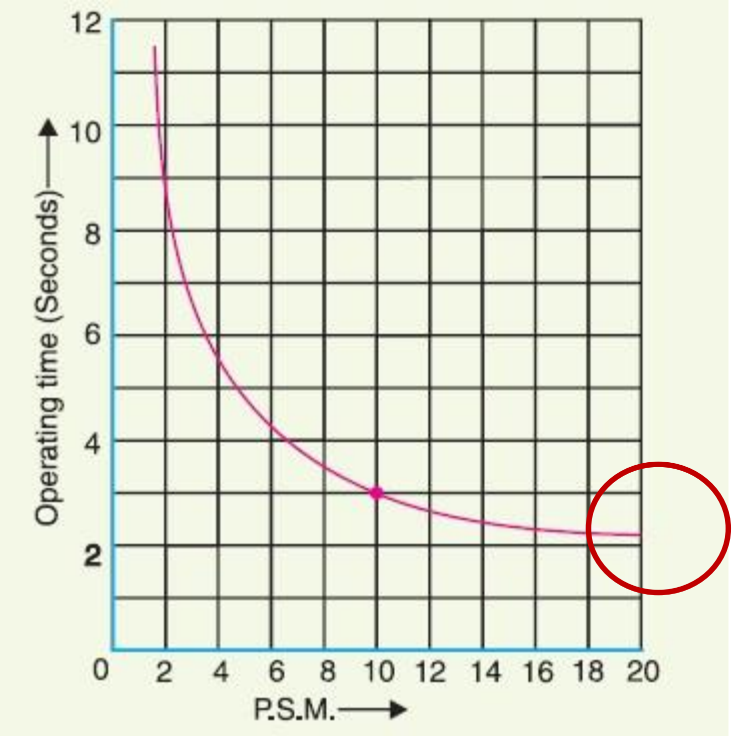
- Plug setting multiplier (PSM)

$$PSM = \frac{I_{fault}}{I_{pickup}}$$

- Time setting multiplier (TSM)
  - It is adjustment to control the relay time of operation. The time setting dial is calibrated from 0 to 1 in steps of 0.05 sec.



Time vs PSM curve of IDMT relay



Practice problem- 21.1

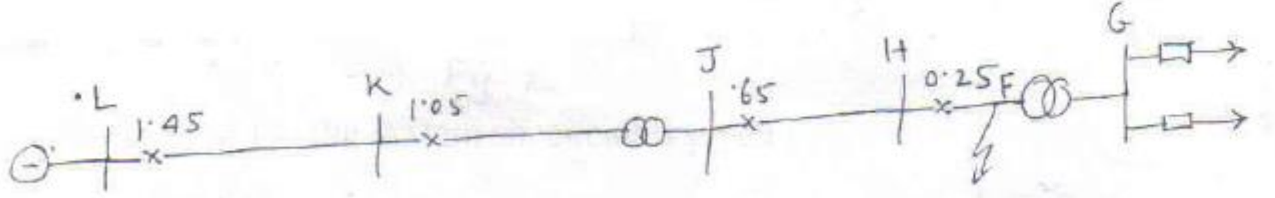
Grading schemes

- For providing proper coordination following grading schemes are used-
  - Time graded scheme
  - Current graded scheme
  - Combination of time and current graded scheme

Aim of all the grading schemes is to provide proper discrimination between relays.

Time graded scheme

- In this method an approximate time interval is given by each of the relays controlling the circuit breaker in a power system to ensure that the breaker nearest to the fault opens first.

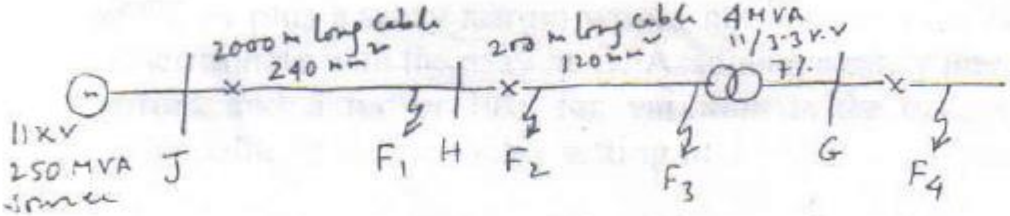


Radial system with time discrimination.

- Disadvantage:
  - Longest fault clearance time occurs for fault in the section closest to the power source, where the fault level is highest.

Current graded scheme

❖ Relies on the fact that fault current varies with the position of the fault because of difference in impedance values between source and the fault.



For fault. at F1 the system sh. circuit is given by-

$$I = \frac{11000/\sqrt{3}}{Z_s + Z_c} \qquad \text{where } Z_s = \text{source impedance} = \frac{(11)^2}{250} = .485\ \Omega$$

$$Z_c = \text{Cable impedance between J and H} = 0.24\ \Omega \text{ (say)}$$

$$I = \frac{6350}{.725} = 8800\ A$$

Current graded scheme

- A relay, which controls CB at J, is required to set to operate at 8800Amp.Infact, relay J would protect the cable section between J and H.
- Two important points to be noted-
  - Not possible to distinguish fault between point F1 and F2 because of very small distance between the points.
  - In practice, there would be variation in source fault level, typically from 250MVA to 130MVA. At the lower fault level, fault current would not exceed 6800Amp, even for a cable fault close to J. so, the relay set at 8800Amp would not protect any of the cable section concerned.

Combination of time and current graded scheme

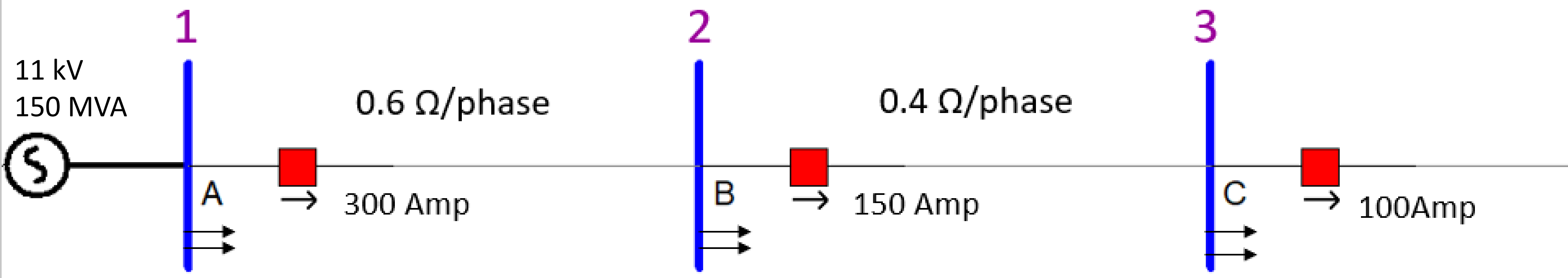
- It is because of these limitations imposed by the independent use of either time or current coordination, the inverse time O/C characteristic in evolved.
- With this characteristic, the time of operation is inversely proportional to the fault current level and the actual characteristic is a function of both time and current settings.

Mathematical problem

Problem 01-

(a) Evaluate the time-current grading system for the following system.

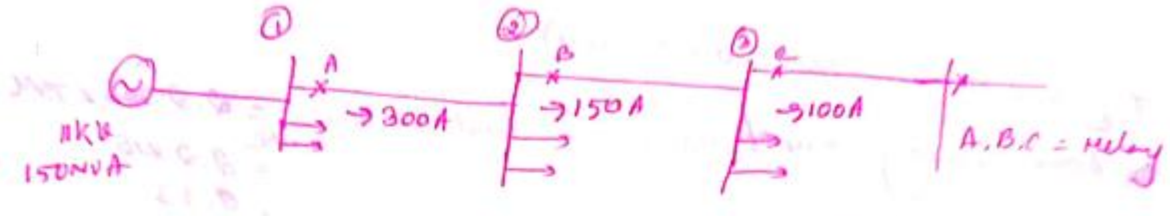
(b) Illustrate the time current characteristic curve of relay C.



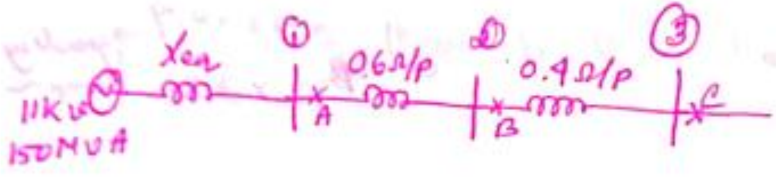
Mathematical problem

<u>Solution:</u>

(a) Single line diagram of the system is given as-



So, impedance diagram of the system would be-



$$X_{eq} = \frac{(11)^2}{150}$$

$$= 0.806\ \Omega$$

$$Z_s = 0.806\Omega$$

$$Z_{l2} = 0.6\Omega$$

$$Z_{l3} = 0.4\Omega$$

Mathematical problem

$$I_{f3} = \frac{11000/\sqrt{3}}{Z_s + Z_{12} + Z_{23}} = 3516.5(A)$$

$$I_{f2} = \frac{11000/\sqrt{3}}{Z_3 + Z_{12}} = 4516(A)$$

$$I_{f1} = \frac{11000/\sqrt{3}}{Z_3} = 7879(A)$$

Relay C

If fault occurs at bus 3, Fault current = 3516 (A)

Nominal current = 100 (A)

Load margin = 30%

$\therefore$ Overload current = $100 \times 1.3 = 130$ (A)

Assume CT rating = 200/5

PS should be chosen such as pickup current must be greater than overload rating, 130 A.

Assume, PS = 75%

$$\therefore I_{pickup\,primary} = I_{CT\,primary} \times PS$$

$$= 200 \times 0.75$$

$$= 150\ (A)$$

Mathematical problem

$$PSM = \frac{I_{fault} \text{ at bus } 3}{I_{pickup} \text{ primary}}$$

$$= \frac{3516}{150} = 23.44 > 20$$

$\therefore t_{c_c} = 2.2 \text{ sec}$, $TSM = 0.15$ (say)

Actual operating time of relay C for fault at bus 3 $= 2.2 \text{ sec} \times TSM$
$= 2.2 \times .15$
$= 0.33$

Relay B → if relay C fails.

Actual operating time of relay B for fault at bus 3 at B $= 0.33 + 0.4$ → grading margin
$= 0.73 \text{ Sec}$

Nominal current at $B = 150A$

Load margin $= 30\%$

Mathematical problem

$\therefore$ O/L rating = $150 \times 1.3 = 195$ (A)

CT rating = $200/5$ (A) (say)

PS should be chosen as I_{pickup} must be greater than O/L rating.

$\therefore$ PS = 100%

$\therefore I_{pickup\ primary} = 200 \times 100\% = 200$ (A)

$$PSM = \frac{I_{f\ at\ bus\ 3}}{I_{pickup\ primary}} = \frac{3516}{200} = 17.58 < 20$$

$$t_{CB} = \frac{0.14}{(PSM)^{0.02} - 1} = \frac{0.14}{17.58^{0.02} - 1} = 2.372$$ [If fault is on bus 3]

$$TSM_B = \frac{t_{AB}}{t_{CB}} = \frac{0.73}{2.372} = 0.307$$ [If fault is on bus 3 & relay C fails]

TSM should be within 0-1 with steps of 0.05 $\therefore TSM_B = 0.3$

Mathematical problem

fault is on bus 2

$PSM = \frac{I_f \text{ at bus } 2}{I_{pickup\ primary}} = \frac{4516}{200} = 22.58 > 20.$

$\therefore t_{cB} = 2.2 \text{ sec}$

$= t_{cB} \times TSM_B$

$\therefore t_{aB} = 2.2 \times 0.3\cancel{07} = 0.675 \text{ sec}$

Relay A

If fault is on bus 2 but relay B fails

Actual operating time of relay A for fault at bus 2 $t_{aA} = 0.675 + 0.4$

$= 1.07 \text{ (Sec)}$

Nominal current $= 300(A)$

Load margin $= 30\%$

O/L rating $= 300 \times 1.3 = 390(A).$

Mathematical problem

Say, CT rating = 400/5

∴ PS should be such that I_{pickup} should be greater than 390 A.

Say PS = 100%

$$I_{pickup\ primary} = 400 \times 100\% = 400\ (A)$$

$$PSM = \frac{I_f \text{ at Bus } 2}{I_{pickup\ primary}} = \frac{4516}{400} = 11.29 < 20$$

$$\therefore t_{CA} = \frac{0.14}{(11.29)^{0.02} - 1} = 2.818\ (Sec)$$

$$\therefore TSM_A = \frac{t_{aA}}{t_{cA}} = \frac{1.07}{2.818} = 0.379$$

But TSM should be within 0−1 with steps of 0.05

$$\therefore TSM_A = 0.4$$

If fault is on bus A

$$PSM = \frac{I_f \text{ at bus } 1}{I_{pickup\ primary}} = \frac{7879}{400} = 19.69 < 20$$

$$t_c = \frac{0.14}{(19.69)^{0.02} - 1} = 2.279$$

$$\therefore t_{aA} = t_c \times TSM_A = 2.279 \times 0.4 = 0.911 \text{ sec.}$$

Mathematical problem

(b) Determination of TCC curve of relay C-

current	operating time
3516	— $.33$ sec.
3000	— $PSM = \frac{3000}{150\,(I_R)} = 20$; $t_c = 2.2$ sec. ; $t_a = 2.2 \times .15 = .33$ sec
2500	— $PSM = \frac{2500}{150} = 16.66$; $t_c = \frac{.14}{(16.66)^{.02} - 1} = 2.42$; $t_a = 2.42 \times .15 = .36$ sec
2000	— $PSM = \frac{2000}{150} = 13.33$; $t_c = \frac{.14}{(13.23)^{.02} - 1} = 2.63$; $t_a = 2.63 \times .15 = .39$ sec.
1500	— $PSM = \frac{1500}{150} = 10$; $t_c = 2.97$; $t_a = 2.97 \times .15 = .45$ sec.
1000	— $PSM = \frac{1000}{150} = 6.66$, $t_c = 3.62$; $t_a = 3.62 \times .15 = .54$ sec.
500	— $PSM = \frac{500}{150} = 3.333$, $t_c = 5.74$, $t_a = 5.74 \times .15 = .86$ sec.

- Reference-
- Topic 21.7-21.9/ Chapter 21/ Principles of power systems/V.K.Mehta & Rohit Mehta

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