

Module 5 : Directional Overcurrent Protection

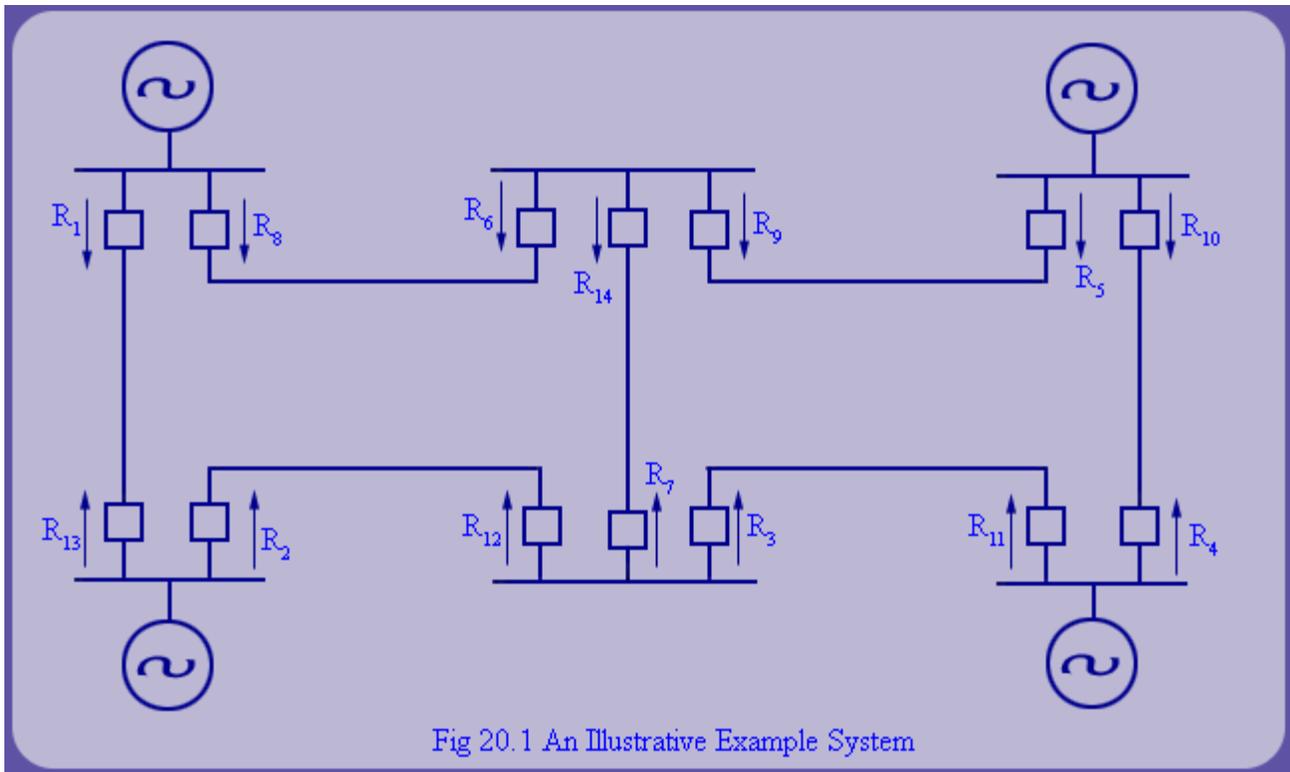
Lecture 20 : Directional Overcurrent Relay Coordination in Multi-loop System

Objectives

In this lecture we will

- Discuss the directional relay coordination problem associated with multiple loop system.
- Identify all possible clockwise and anticlockwise loops for the given systems.
- Define minimum break point relays.

20.1 Introduction



In the previous lecture, we discussed the coordination problem associated with single loop system. But the complexity of coordination problem increases in multiple loop system which share some relays. Hence we have to find one common acceptable setting for relays which share multiple loops so that their coordination in individual loops is achievable. The number of such relays should be kept to minimum, so that we make minimum assumptions on relay setting in coordination of loops. Such relays are called Minimum Break Point Relays. For example, it can be verified that R_6 , R_{14} and R_9 are such relays in the fig 20.1. By opening these relays, we are able to break any clockwise or anti clockwise relay loops and it should be checked that no other relay set exists which achieves the above criteria with lesser number of relays. If you open R_1 , R_{13} , R_4 and R_{10} all loops are broken. But we now require four relays. Therefore, the first choice is more acceptable than the second because we have to assume lesser number of TMS to start the coordination process. There can be multiple choices to minimum break point relays. For example an alternative choice is R_{12} , R_7 and R_3 .

Computation of minimum break point set of relays is a involved problem which requires combinatorial optimization techniques.

20.1 Introduction (contd..)

Now let us analyze the system in more detail. There are 3 simple loops in the fig 20.1. So the three clockwise coordination problems are given by,

1. $R_8 \rightarrow R_{14} \rightarrow R_{12} \rightarrow R_{13}$
2. $R_9 \rightarrow R_{10} \rightarrow R_{11} \rightarrow R_7$
3. $R_8 \rightarrow R_9 \rightarrow R_{10} \rightarrow R_{11} \rightarrow R_{12} \rightarrow R_{13}$

Similarly, 3 anti clockwise loop coordination problems are given by,

4. $R_1 \rightarrow R_2 \rightarrow R_7 \rightarrow R_6$
5. $R_{14} \rightarrow R_3 \rightarrow R_4 \rightarrow R_5$
6. $R_1 \rightarrow R_2 \rightarrow R_3 \rightarrow R_4 \rightarrow R_5 \rightarrow R_6$

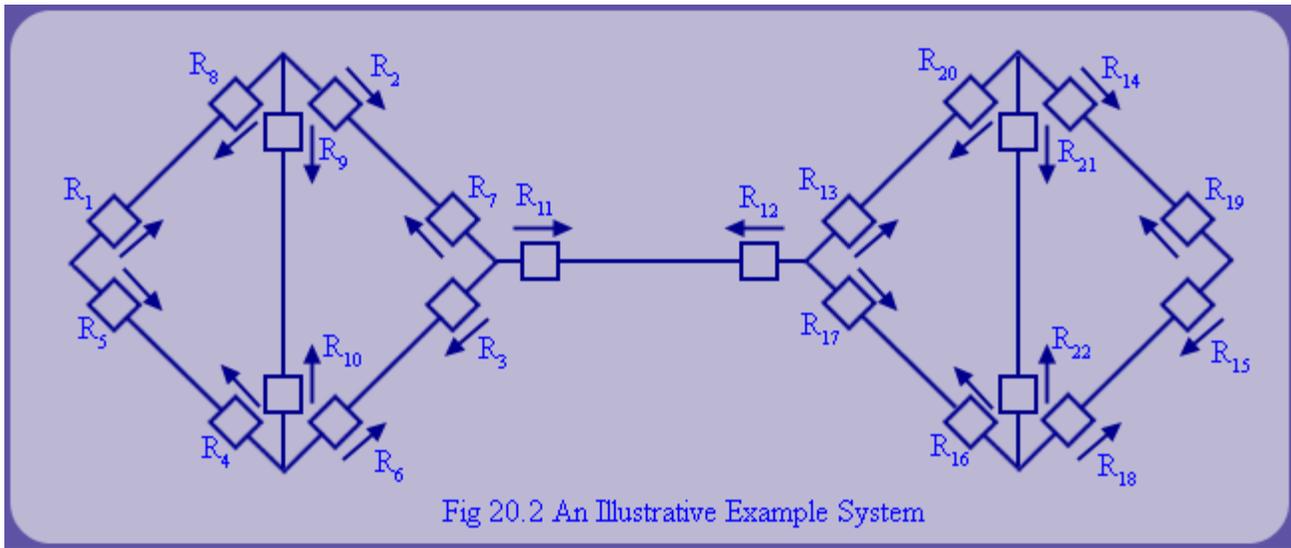
Now these loops are not exclusive and they share relays. For example, loop 1 and loop 3 share R_8 , R_{12} and R_{13} . Therefore, it implies that individual loops cannot be coordinated independently. So the crux of the problem is to find acceptable setting at relays which are shared by multiple loops. Now, take the example of R_6 , R_{14} and R_9 . These relays feature in all loops and by opening them we can open all clockwise and anti clockwise loops. Similar statement can be made for R_3 , R_7 and R_{12} . This set also appears in all loops.

Another such set is R_1 , R_{13} , R_4 and R_{10} . Now it is better to begin by assuming setting in R_6 , R_{14} and R_9 or R_{12} , R_7 and R_3 , because they involves lesser number of relays than R_1 , R_{13} , R_4 and R_{10} . Thus amount of assumptions are reduced which should reduce the number of iterations in relay coordination. Such a set of minimum number of relays which when opened break all loops in the system are called Minimum Break Point Relay set. There are multiple choices, but each of such sets has same (minimum) number of relays.

So the relay coordination process is as follows.

1. Identify all simple loops and relay sequence to be coordinated.
2. Identify a minimum break point relay sets.
3. Set them as primary relay.
4. Record in the first row of RSM.
5. Find the set of relays which back up the primary relays in above step.
6. Record them in the next row of RSM.
7. All relays exhausted. If yes, RSM is complete else set current back up relays as primary relay and go to 5.
8. From the graph and RSM work out set of sequential primary back up pairs (SSP) for coordination.
9. From the short circuit analysis, find primary back up current pairs.
10. Coordinate the primary back up relays in the order of SSP.
11. Test the primary back up coordination for all relays in the first row of RSM. If any primary back up relay pair does not satisfy the coordination criteria, coordination fails, so select the first primary back up pair from the SSP and return to step 10.

20.2 Example



Consider a transmission network system as shown in fig 20.2. Identify all possible clockwise and anticlockwise loops and also minimum breakpoint relays.
 In the above figure, there are 12 loops, i.e., 6 in the clockwise direction and 6 in the anticlockwise direction.

The clockwise loops are given by

1. $R_1 \rightarrow R_9 \rightarrow R_4$
2. $R_2 \rightarrow R_3 \rightarrow R_{10}$
3. $R_1 \rightarrow R_2 \rightarrow R_3 \rightarrow R_4$
4. $R_{13} \rightarrow R_{21} \rightarrow R_{16}$
5. $R_{14} \rightarrow R_{15} \rightarrow R_{22}$
6. $R_{13} \rightarrow R_{14} \rightarrow R_{15} \rightarrow R_{16}$

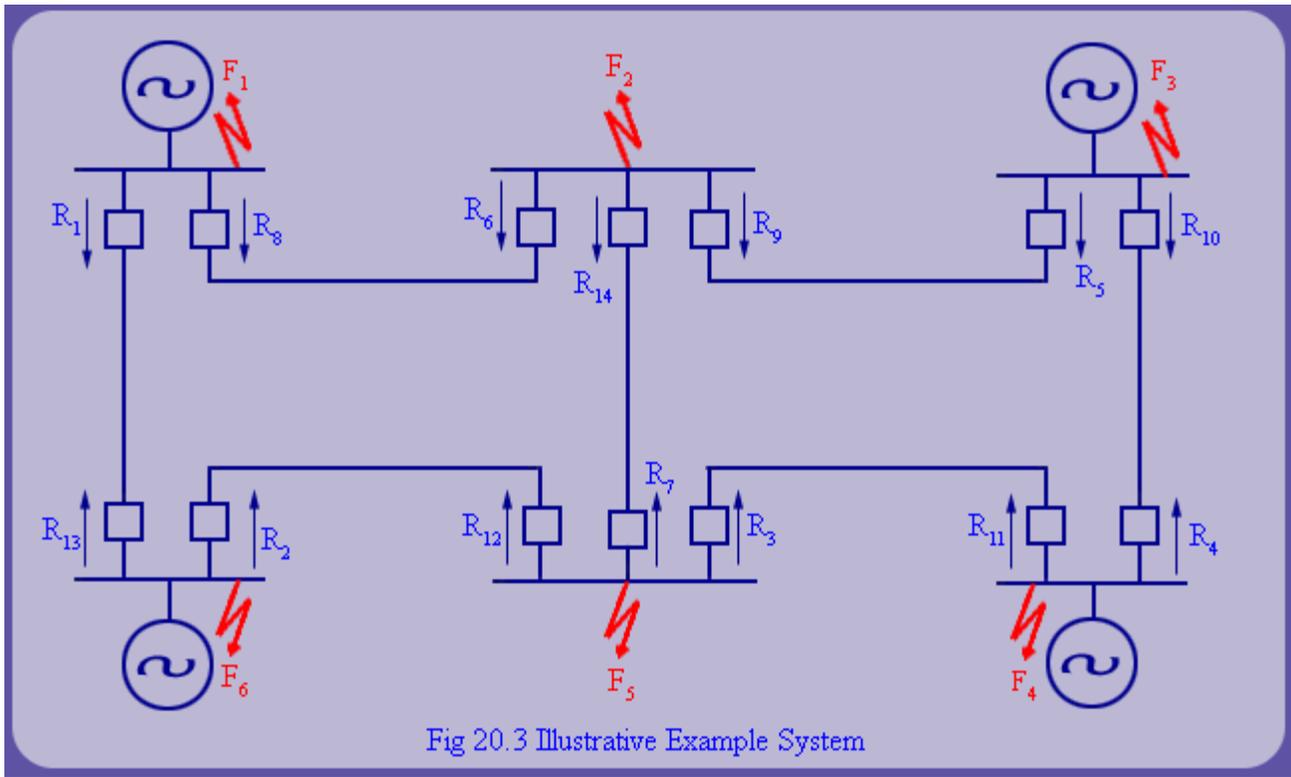
20.2 Example (contd..)

The anticlockwise loops are given by

1. $R_5 \rightarrow R_{10} \rightarrow R_8$
2. $R_6 \rightarrow R_7 \rightarrow R_9$
3. $R_5 \rightarrow R_6 \rightarrow R_7 \rightarrow R_8$
4. $R_{17} \rightarrow R_{22} \rightarrow R_{20}$
5. $R_{18} \rightarrow R_{19} \rightarrow R_{21}$
6. $R_{17} \rightarrow R_{18} \rightarrow R_{19} \rightarrow R_{20}$

Hint: One set of minimum break point relays are given by,

$R_8, R_9, R_2, R_{20}, R_{21}, R_{14}$.



20.2 Example (contd..)

For a transmission system as shown in fig 20.3, the pick up currents and the fault currents seen by the primary and back up relay pairs for remote bus faults at F_1 , F_2 , F_3 , F_4 , F_5 and F_6 are tabulated in table 1 and 2 respectively.

Relay	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆	R ₇	R ₈	R ₉	R ₁₀	R ₁₁	R ₁₂	R ₁₃	R ₁₄
Pick up Current	120	192	80	120	160	80	160	240	80	160	128	128	120	160

Remote Bus Fault at	Clockwise Loop		Anti Clockwise Loop	
	Current seen by Primary Relay	by Back up Relay	Current seen by Primary Relay	by Back up Relay
F ₁	R ₁₃ (861A)	R ₁₂ (0)	R ₆ (977A)	R ₇ (576A)
F ₂	R ₈ (3422A)	R ₁₃ (56A)	R ₇ (1764A)	R ₂ (1477A)
F ₅	R ₁₄ (1483A)	R ₈ (1119A)	R ₂ (4589A)	R ₁ (307A)
F ₆	R ₁₂ (767A)	R ₁₄ (469A)	R ₁ (601A)	R ₆ (0)
F ₂	R ₇ (1764A)	R ₁₁ (287A)	R ₅ (1074A)	R ₄ (0)
F ₃	R ₉ (553A)	R ₇ (157A)	R ₄ (946A)	R ₃ (114A)
F ₄	R ₁₀ (1365A)	R ₉ (0)	R ₃ (639A)	R ₁₄ (152A)
F ₅	R ₁₁ (868A)	R ₁₀ (240A)	R ₁₄ (1483A)	R ₅ (364A)
F ₃	R ₉ (553A)	R ₈ (396)	--	--

F ₆	R ₁₂ (767A)	R ₁₁ (298A)	--	--
F ₁	--	--	R ₆ (977A)	R ₅ (401A)
F ₄	--	--	R ₃ (639A)	R ₂ (487A)

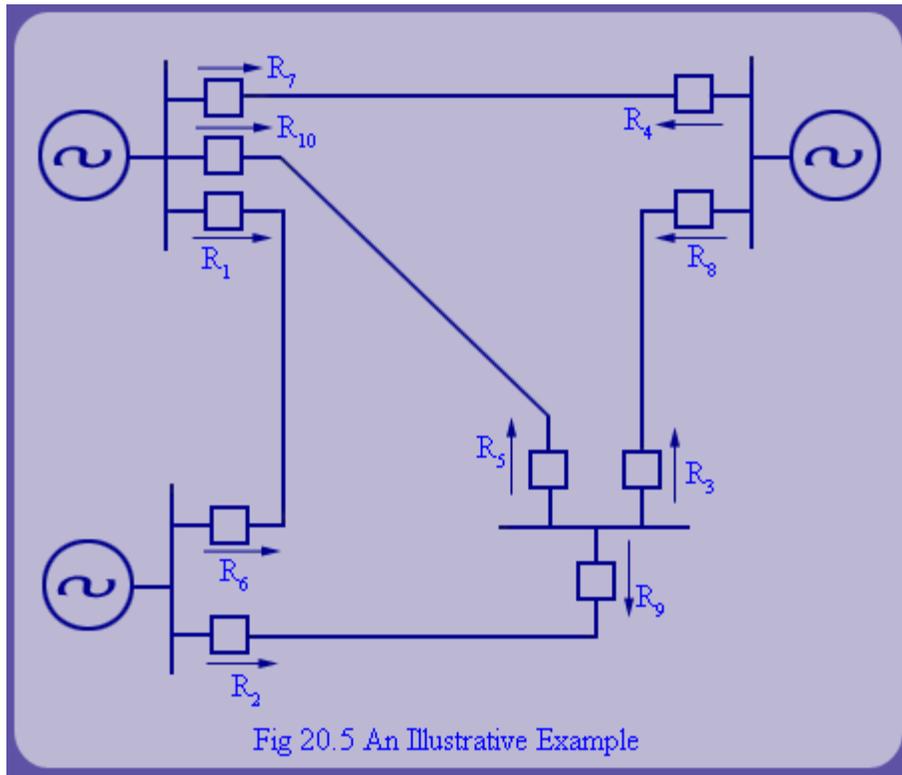
The inverse characteristic of the relays is modelled by the following equation.

$$t = b_0 + b_1(TMS) + \frac{b_2(TMS)}{(PSM-1)^2} + \frac{b_3(TMS)^2}{(PSM-1)} + \frac{b_4(TMS)}{(PSM-1)^3} + \frac{b_5(TMS)^2}{(PSM-1)^2} + \frac{b_6(TMS)^2}{(PSM-1)^4}$$

where $b_0 = 0.03443$, $b_1 = 0.08071$, $b_2 = 1.95010$, $b_3 = 0.05773$, $b_4 = -0.69961$, $b_5 = -0.06793$ and $b_6 = 0.01989$

Write a program to coordinate the relays. Identify the minimum break point relays. There may be some relays whose coordination is not possible. Identify such relays. This equation corresponds to CO-8 Westinghouse relay characteristic as shown in fig 20.4.

Review Questions



1. What is meant by break point relays?
2. Define minimum break point relays.
3. For the transmission system as shown in fig 20.4, identify all possible clockwise and anticlockwise loops and minimum break point relays.
4. Develop an algorithm for computing SSP from RSM.
5. Develop an algorithm for coordination of sequential primary back up current pair. It should account for limits of the setting (TMS, PSM) of relays and also identify current pairs which cannot be coordinated

Recap

In this lecture we have learnt the following:

- Break point relays and minimum break point relays.
- Directional relay coordination in a multiple loop system.

- Clockwise and anticlockwise loops coordination problems for the given systems.