BIRZEIT UNIVERSITY
FACULTY OF ENGINEERING
AND TECHNOLOGY

PROTECTION AND AUTOMATION IN ELECTRICAL POWER SYSTEMS

DIRECTIONAL RELAYS

By

Dr. Jaser Sa'ed

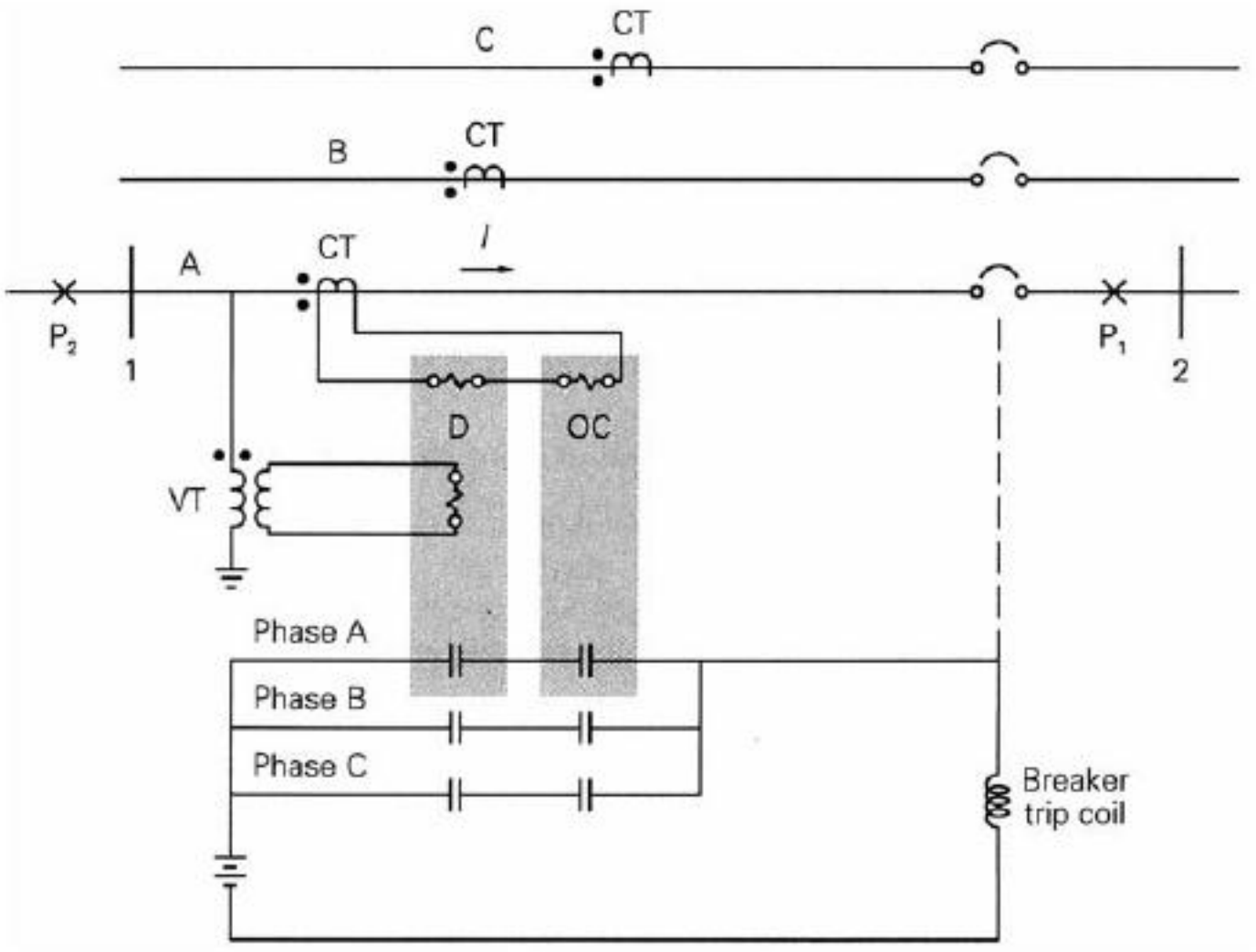
Department of Electrical and Computer Engineering

DIRECTIONAL RELAYS

Directional relay: A relay that responds to the relative phase position of a current with respect to another current or voltage reference, (Directional relays are designed to operate for fault currents in only one direction)

Consider the directional relay D in the next Figure, which is required to operate only for faults to the right of the CT. Since the line impedance is mostly reactive, a fault at P1 to the right of the CT will have a fault current I from bus 1 to bus 2 that lags the bus voltage V by an angle of almost 90. This fault current is said to be in the forward direction. On the other hand, a fault at P2, to the left of the CT, will have a fault current I that leads V by almost 90. This fault current is said to be in the reverse direction.

DIRECTIONAL RELAYS



DIRECTIONAL RELAYS

The directional relay has two inputs: the reference voltage $V = V\angle 0°$, and current $I = I\angle\phi$. The relay trip and block regions, shown in Figure 10.21, can be described by

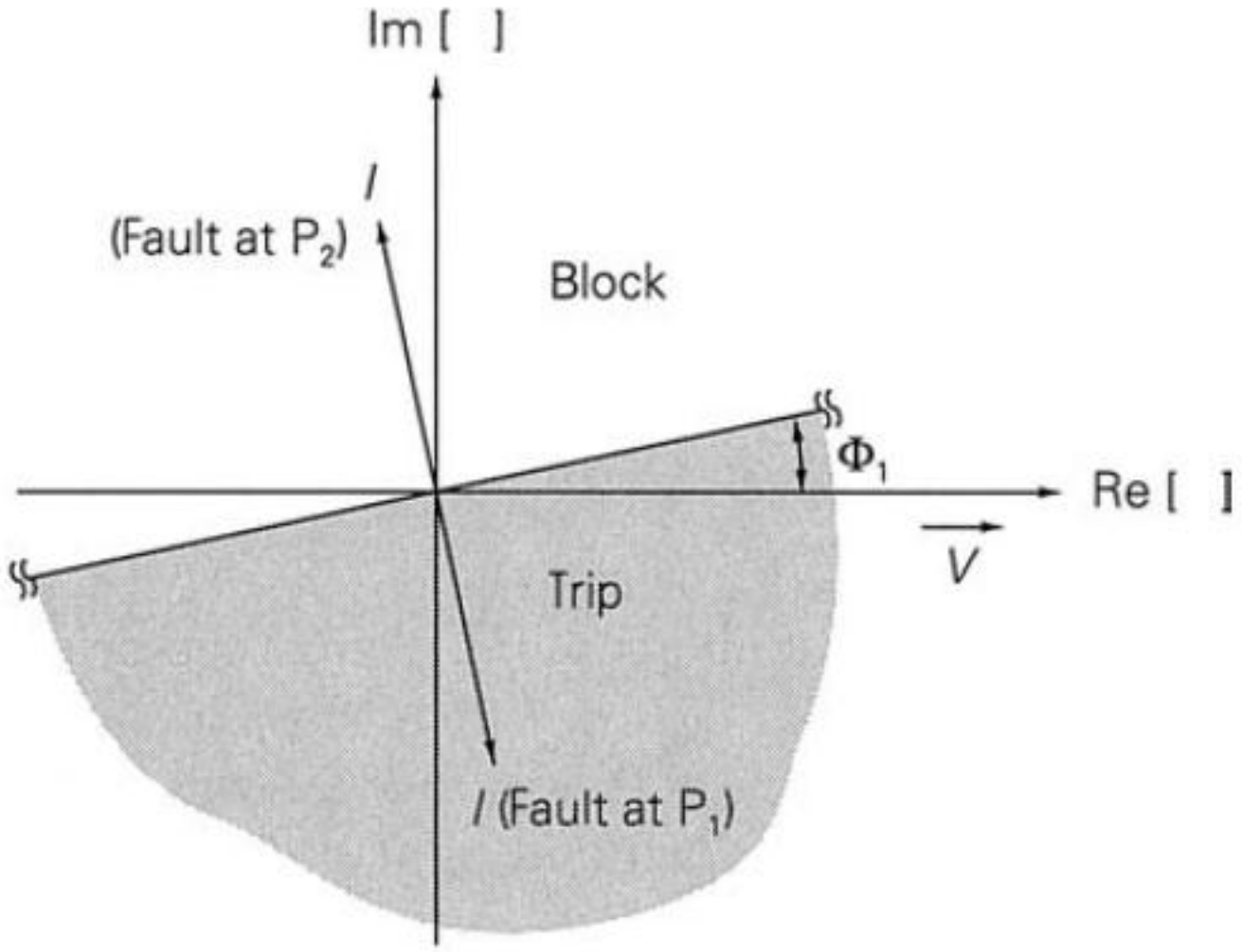
$$-180° < (\phi - \phi_1) < 0° \quad \text{(Trip)}$$

$$\text{Otherwise} \quad \text{(Block)} \tag{10.6.1}$$

where ϕ is the angle of the current with respect to the voltage and ϕ_1, typically 2° to 8°, defines the boundary between the trip and block regions.

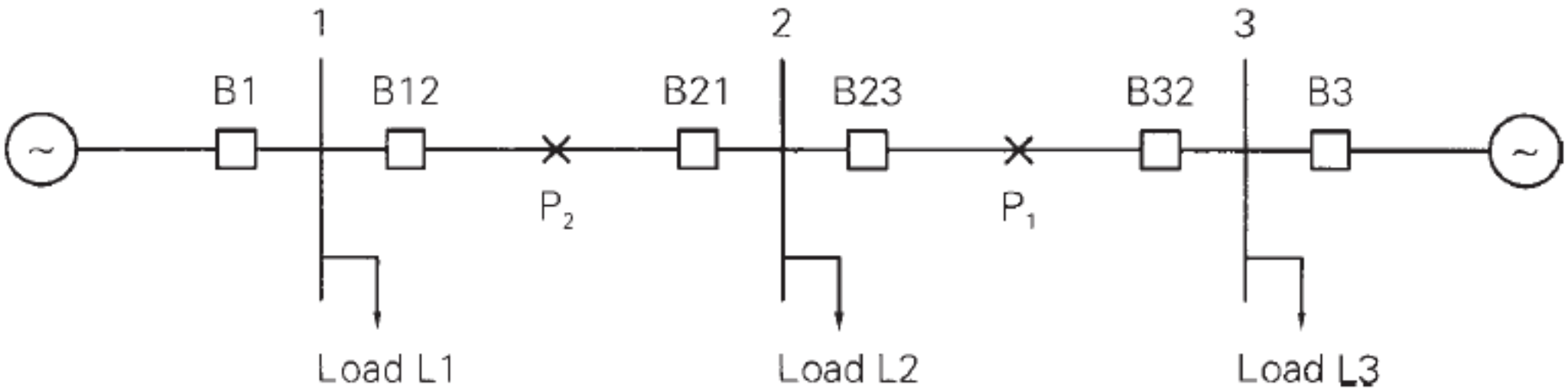
The contacts of the overcurrent relay OC and the directional relay D are connected in series in Figure 10.20, so that the breaker trip coil is energized only when the CT secondary current (1) exceeds the OC relay pickup value, and (2) is in the forward tripping direction.

DIRECTIONAL RELAYS



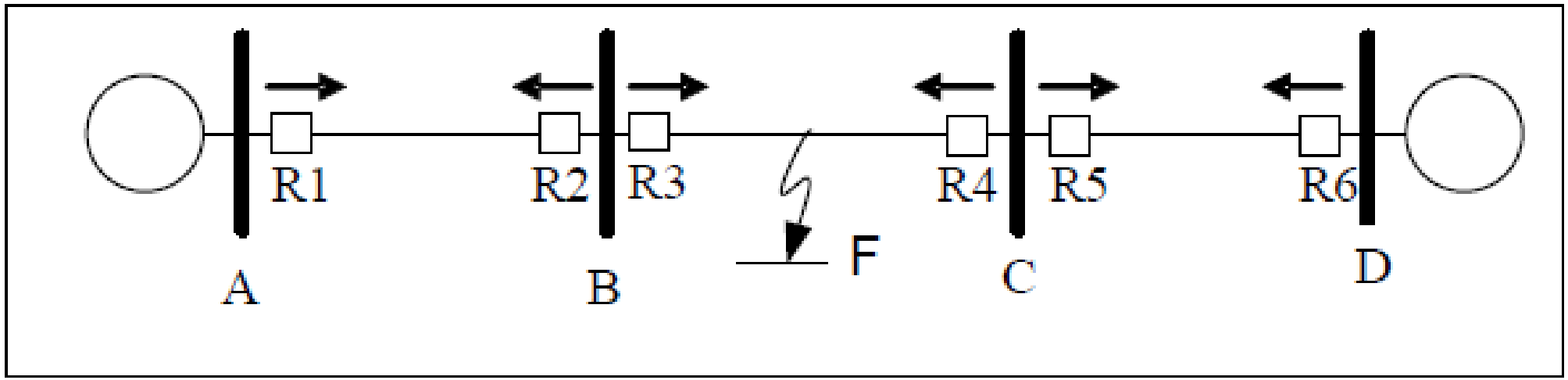
DIRECTIONAL RELAYS

PROTECTION OF TWO-SOURCE SYSTEM WITH DIRECTIONAL RELAYS



DIRECTIONAL RELAYS

PROTECTION OF TWO-SOURCE SYSTEM WITH DIRECTIONAL RELAYS



- **Forward Faults**
- **Reverse Faults**

DIRECTIONAL RELAYS

PROTECTION OF TWO-SOURCE SYSTEM WITH DIRECTIONAL RELAYS

It becomes difficult and in some cases impossible to coordinate overcurrent relays when there are two or more sources at different locations. Consider the system with two sources shown in previous Figure. Suppose there is a fault at P1. We want B23 and B32 to clear the fault so that service to the three loads continues without interruption. Using time-delay overcurrent relays, we could set B23 faster than B21. Now consider a fault at P2 instead. Breaker B23 will open faster than B21, and load L2 will be disconnected. When a fault can be fed from both the left and right, overcurrent relays cannot be coordinated. However, directional relays can be used to overcome this problem.

DIRECTIONAL RELAYS

PROTECTION OF TWO-SOURCE SYSTEM WITH DIRECTIONAL RELAYS

Two-source system protection with directional and time-delay overcurrent relays

Explain how directional and time-delay overcurrent relays can be used to protect the system in Figure 10.22. Which relays should be coordinated for a fault (a) at P_1, (b) at P_2? (c) Is the system also protected against bus faults?

SOLUTION Breakers B12, B21, B23, and B32 should respond only to faults on their "forward" or "line" sides. Directional overcurrent relays connected as shown in Figure 10.20 can be used for these breakers. Overcurrent relays alone can be used for breakers B1 and B3, which do not need to be

DIRECTIONAL RELAYS

PROTECTION OF TWO-SOURCE SYSTEM WITH DIRECTIONAL RELAYS

a. For a fault at P_1, the B21 relay would not operate; B12 should coordinate with B23 so that B23 trips before B12 (and B1). Also, B3 should coordinate with B32.

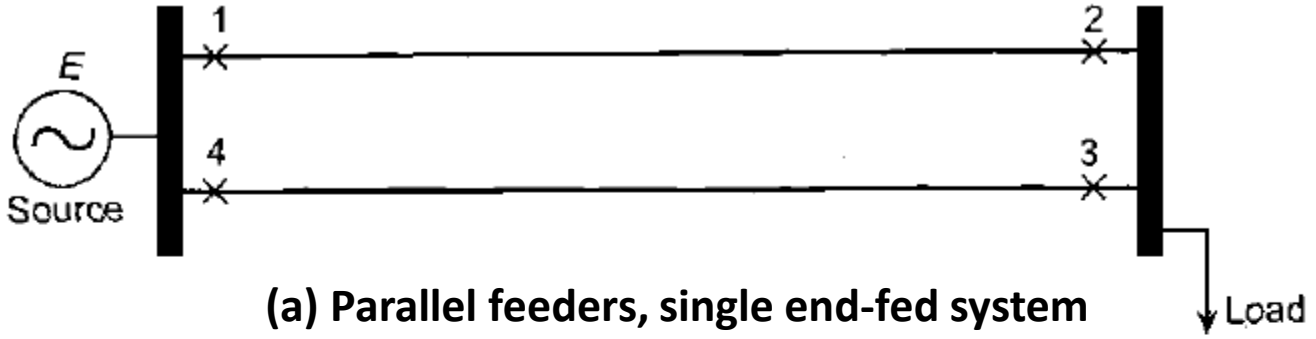
b. For a fault at P_2, B23 would not operate; B32 should coordinate with B21 so that B21 trips before B32 (and B3). Also, B1 should coordinate with B12.

c. Yes, the directional overcurrent relays also protect the system against bus faults. If the fault is at bus 2, relays at B21 and B23 will not operate, but B12 and B32 will operate to clear the fault. B1 and B21 will operate to clear a fault at bus 1. B3 and B23 will clear a fault at bus 3. ■

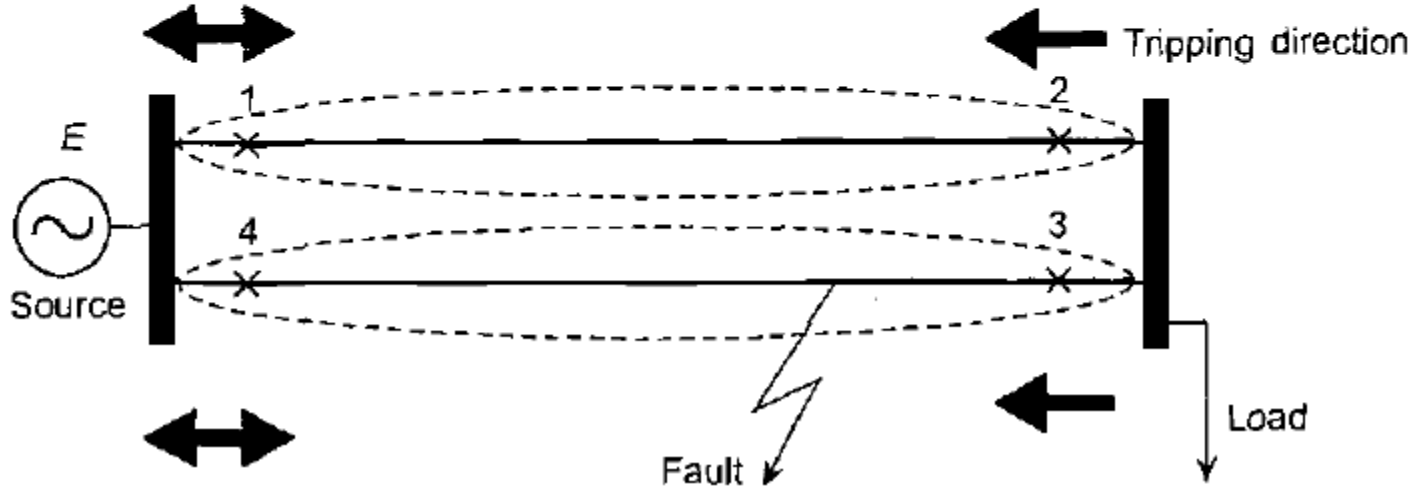
DIRECTIONAL RELAYS

Other Situations Where Directional OC Relays are Necessary

There are other situations where it becomes necessary to use directional relays to supervise OC relays. One such situation is a ***single-end-fed system of parallel feeders***, where a fault on any of the parallel lines is fed not only from the faulted line but from the healthy line as well.



(a) Parallel feeders, single end-fed system



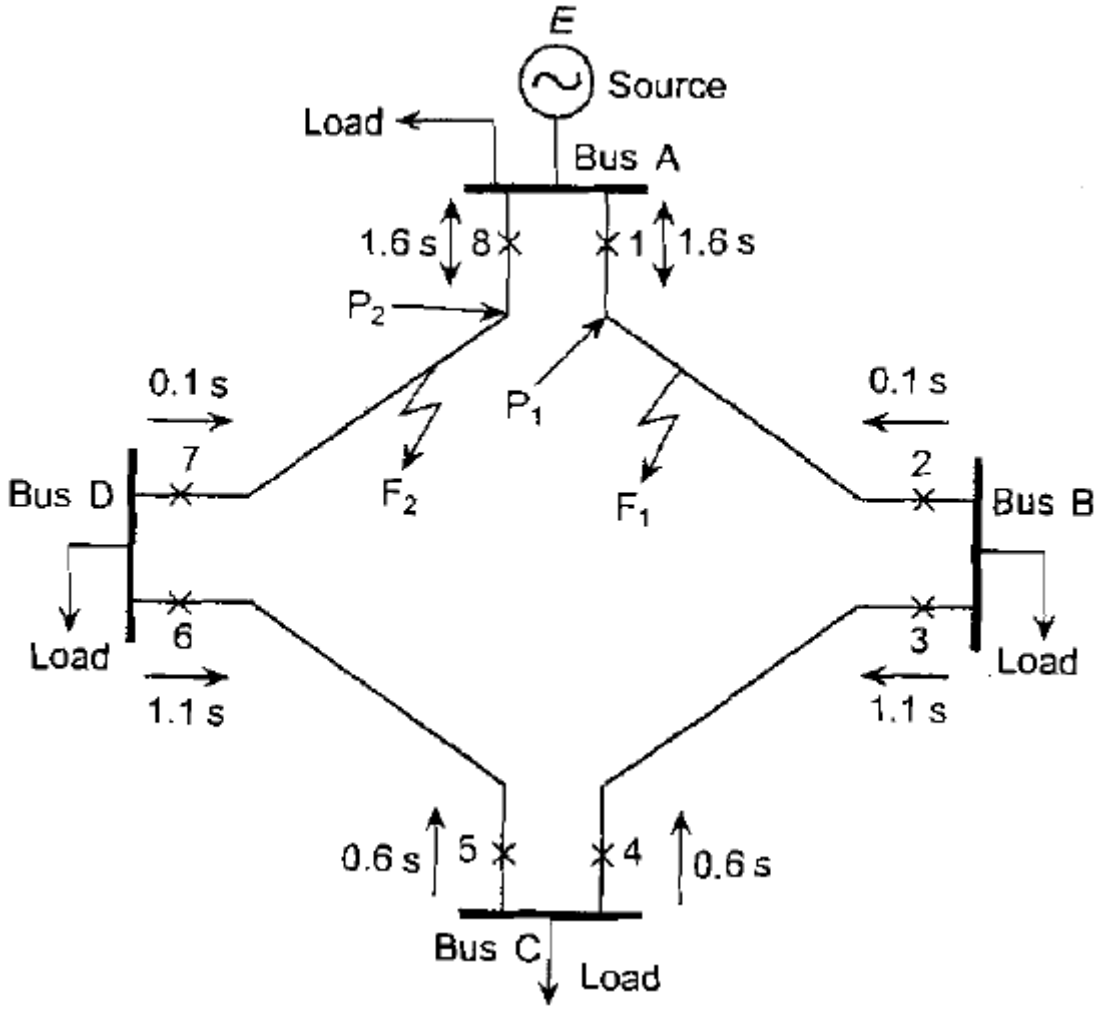
(b) Desired zones and tripping direction of OC relays

Single-end-fed parallel feeder needs directional OC protection

DIRECTIONAL RELAYS

Other Situations Where Directional OC Relays are Necessary

- Consider the ring main feeder system shown here.
- This is another situation where directional supervision of OC relays is called for.
- It is well known that the ring main feeder allows supply to be maintained to all the loads in spite of fault on any section of the feeder.
- A fault in any section causes only the CBs associated with that section to trip out, and because of the ring topology, power flows from the alternate path.



Protection of ring feeder using directional OC relays