Module 4

APPLICATIONS OF ELECTRICAL PROTECTION SCHEMES IN THE POWER STATION

OBJECTIVES:

After completing this module you will be able to:

Pages 1–2 ⇔ 4.1 State what is meant by a "Protection Zone".

Pages 2–5 ⇔ 4.2 Given diagrams, show the boundaries of protection zones.

Pages 2–4 ⇔ 4.3 Explain how differential protection is utilized in our stations for the protection of buses and windings.

Pages 4–5 ⇔ 4.4 Explain the reasons for overlapping zones of protection.

Page 5 ⇔ 4.5 Explain the concept of A and B protection.

Page 6 ⇔ 4.6 Explain the concept of breaker failure protection.

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INSTRUCTIONAL TEXT

INTRODUCTION

This module will discuss protection zones, differential protection of buses and windings and the concept of A and B protection.

PROTECTION ZONES

Obj. 4.1 ⇔ **The section of a circuit protected by a given device is referred to as a protection zone.** For example, Figure 4.1 shows a simple motor circuit, which is protected by a fuse. The dotted line represents the area that is protected by the fuse. If a fault occurs within the zone of protection, which includes the motor and motor circuit, the fuse will open and electrically disconnect the motor. This will minimize any damage and prevent the damage from spreading to the electrical supply.

Obj. 4.2 ⇔

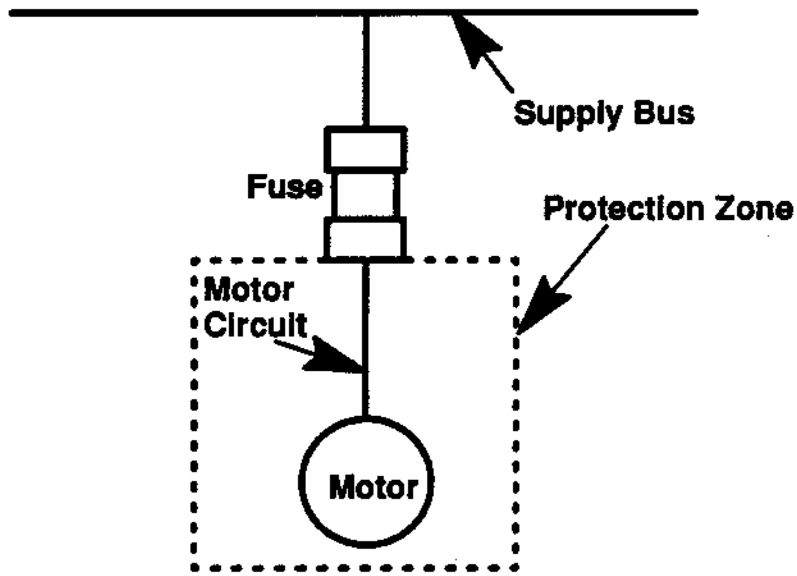

Figure 4.1: Protection Zone For A Motor Circuit

DIFFERENTIAL PROTECTION

It is to some extent possible to protect buses and windings of generators and transformers with overcurrent relays and fuses. However, this is not usually done because:

a) Fuses take too long to blow, unless the fault current is very high;

b) Overcurrent relays have to be time delayed to take care of starting surges, and in any case, only operate when greater than full load current flows;

c) Fault currents flowing for a long time produce excessive damage.

Obj. 4.3 ⇔

As an alternate means of electrical protection, we can use the basic idea that the energy that comes in must equal the energy that leaves. This **detection in differences between inflow and outflow currents** and isolation of the circuit if the currents are different, is called **Differential Protection**. The only reason that these currents should be different is if a fault occurs on the busbar, and will be explained below.

Figure 4.2 a) shows a healthy breaker/busbar arrangement, with equal currents I_1 and I_2 flowing in and out of the busbar. In Figure 4.2 b), a faulted busbar is shown, where the current through the "proper" path I_1 is no longer equal to I_2'. If current measuring instrumentation is installed to detect this, and open the breakers, we have achieved differential protection.

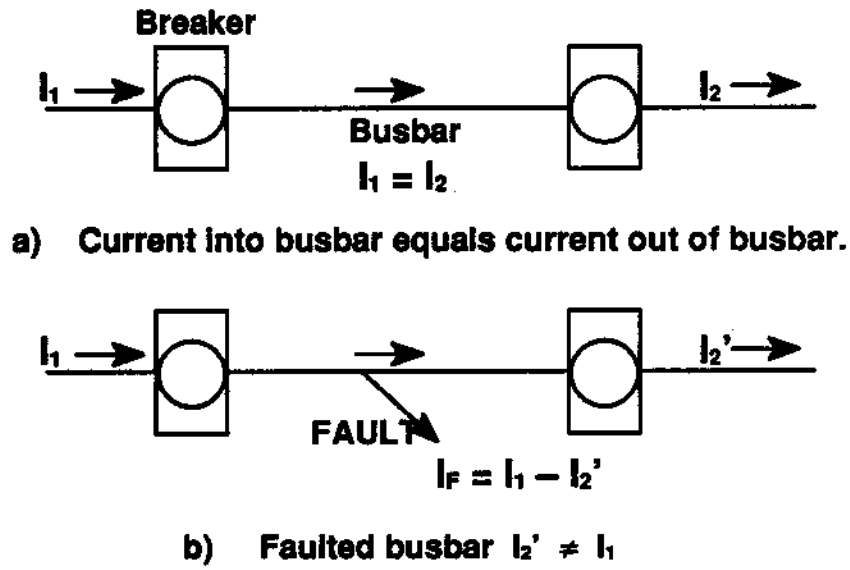

Figure 4.2: Differential Protection

If current transformers (CTs) are installed on the outer sides of the breakers as shown in Figure 4.3, the current signals can be compared, and if different, can be made to open the circuit breakers via a differential relay.

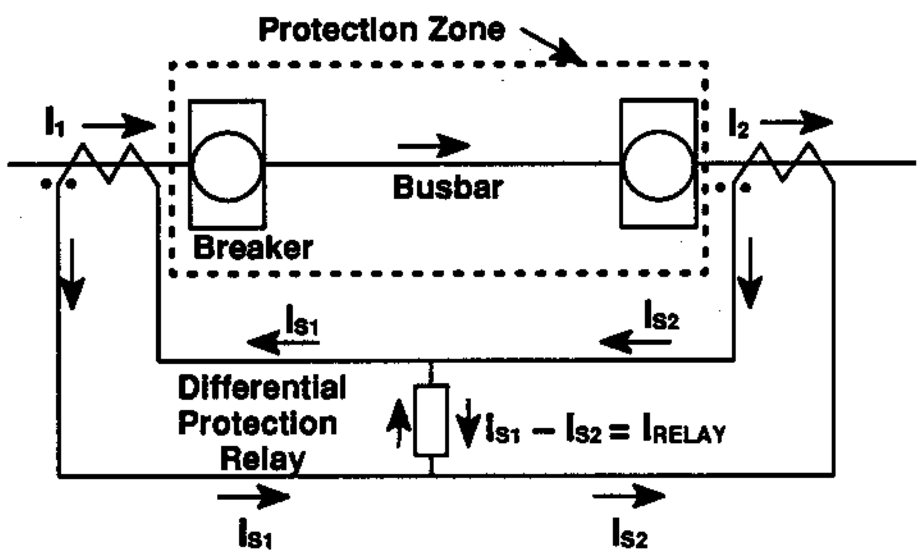

Figure 4.3: Differential Protection

By using current transformers of equal ratio, connected as shown in Figure 4.3, the relay will "compare" the currents in the two secondary circuits. The protection zone in this case is the circuit between the current transformers.

When current into the busbar equals current out, the flow of CT secondary current through the differential relay will be zero (when balanced, the currents in the relay flow in opposite directions and cancel each other out ie. $I_{RELAY} = 0$). When the currents are unbalanced, as in a fault condition, the CT secondary current flowing through the relay will also be unbalanced (ie. $I_{S1} - I_{S2} = I_{RELAY} \neq 0$). This unbalanced current flow through the relay will cause the relay to operate and open both of the breakers.

A home ground fault circuit interrupter installed for outdoor circuits and in bathrooms , works much in the same manner, in which the hot and neutral currents of the circuit are compared. If these two currents are not equal, there is leakage to ground and the circuit is opened to prevent electrocution.

Differential currents between phases can be easily detected, **hence large fault currents need not be present for the protection system to operate.** This, in combination with high speed magnetic relays, can prevent damage that can occur with large fault currents. For this reason, differential protection is used for generator and transformer winding protection, and will be discussed in later sections of this course.

OVERLAPPING ZONES OF PROTECTION

Let's say we have a number of loads to be supplied at the same voltage. We decide to use two buses for distribution of the loads and arrange them as part of a ring bus (this configuration was discussed in Module 2). What would be the best way to apply differential protection to our buses?

Figure 4.4 represents a possible protection scheme. Both buses B_1 and B_2 are protected by a single differential arrangement. A fault occurring anywhere on either bus will cause relay R_2 to operate and trip breakers A and C. But, is there a problem with this set–up?

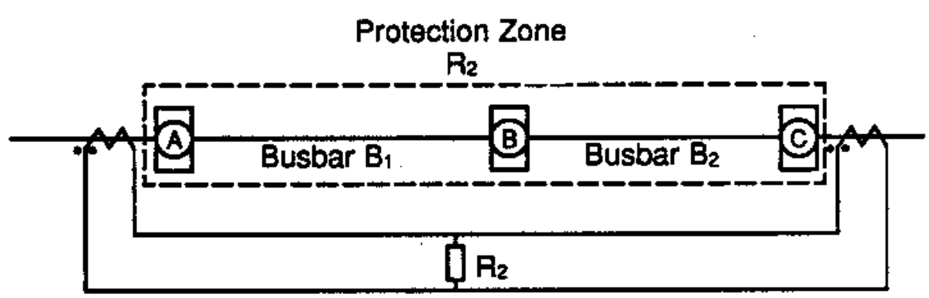

Figure 4.4: One Zone of Protection Both Busbars Protected

A fault on busbar B_1 will cause the protection circuit to operate and disconnect power to it and to busbar B_2, the unaffected bus. We may not want to lose power to all our loads due to a fault occurring on a single bus. It would be better if busbar B_2 could remain energized when B_1 is disconnected.

NOTES & REFERENCES

A modification as described below can be made to provide this sort of protection for the pair of busbars.

Obj. 4.4 ⇔

Using a second set of current transformers, wired as shown in Figure 4.5, the B_1 bus can be protected by differential protection relay R_1. A **fault** on this bus **will cause both circuit breakers feeding it** (breakers A and B) to open. Busbar B_2 will be unaffected, since it has a source of power other than directly from B_1 (from the ring bus arrangement). Similarly, a fault on busbar B_2 will cause R_2 to operate and open breakers B and C to isolate the bus. The two protection zones overlap on breaker B (it operates in the case of a fault on either bus). This arrangement provides optimum protection of both busbars.

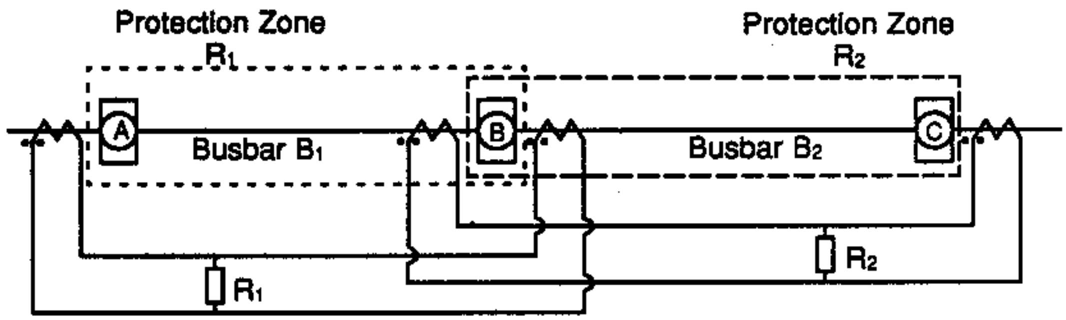

Figure 4.5: Overlapping Protection Both Busbars Protected

Note that a current transformer on the right side of breaker A (not shown) would be connected in a differential protection circuit enclosing the bus that extends from the left of the figure (and the breaker at its other end) to provide fault protection for this bus. This cascading of CTs enclosing busbars and their breakers would continue for all busbars in this circuit.

A differential protection scheme for "T" circuits (where a single feed is split into two supply lines) can be created in a manner similar to the overlapped zones just described. Module 6 considers this type of circuit for the protection of a main and unit service transformer.

A AND B PROTECTION

Obj. 4.5 ⇔

The concept of A and B protection is simply providing **multiple independent signals to trip breakers in the event of a fault.** The breaker will be tripped if it receives *either* an A trip signal *or* a B trip signal. It is not necessary that both signals be received by the breaker to cause it to trip.

In some cases, this is merely providing redundant equipment to provide another tripping signal. For example, separate current transformers and relays could be used to provide two trip signals for differential protection. In other cases, different methods are used to provide back–up protection. For example, using differential protection as the first trip signal, the back–up signals are provided by overcurrent and/or ground protection schemes.

The use and types of A and B protection schemes will be discussed in detail in your station specific training.

BREAKER FAILURE PROTECTION

Obj. 4.6 ⇔

Depending on the site, part or all of the switchyard equipment will be within the control of the station. Due to the **high current flows** within the switchyard components, and **potential for damage if faults are not cleared,** breaker failure protection is provided.

Breaker failure protection is a protection scheme that will **trip surrounding breakers in the event that a circuit breaker fails to clear a fault.** If, for example, a breaker fails to clear a fault, **all of the breakers supplying this breaker and those fed from this breaker will be given a trip signal** via the breaker failure protection scheme.

A breaker will be considered to have failed if, after the trip signal has been generated, the breaker has:

a) not started opening within a preset time frame (determined by switches internal to the breaker),

b) the breaker has not fully opened within a preset time frame (determined by switches internal to the breaker), or

c) if the current has not been broken by the breaker within a preset time (determined by current measurement devices).

SUMMARY OF THE KEY CONCEPTS

- The section of a circuit protected by a given device is referred to as a protection zone.
- This detection in differences between inflow and outflow currents and isolating the circuit if the currents are sufficiently different, is called Differential Protection.
- Overlapping zones of protection can provide differential protection for a series of buses connected by breakers. The overlap ensures that both breakers feeding a particular bus will trip when a fault is detected on that bus. Unaffected buses in the same system can remain energized.
- A and B protection provide additional signals for electrical protection. These may be duplicated protection schemes, or they may be different schemes to provide backup protection.
- Breaker failure protection will cause surrounding breakers to open in the event that a breaker fails to clear a fault. This will ensure that a fault is cleared with a minimum of damage to equipment.

Pages 8–10 ⇔

You can now do **assignment questions 1 – 6.**

NOTES & REFERENCES

ASSIGNMENT

1. A "Protection Zone" is:

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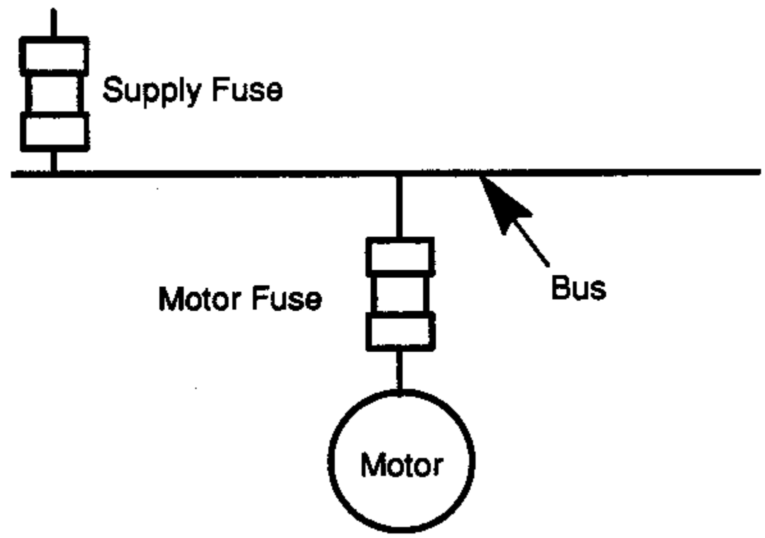
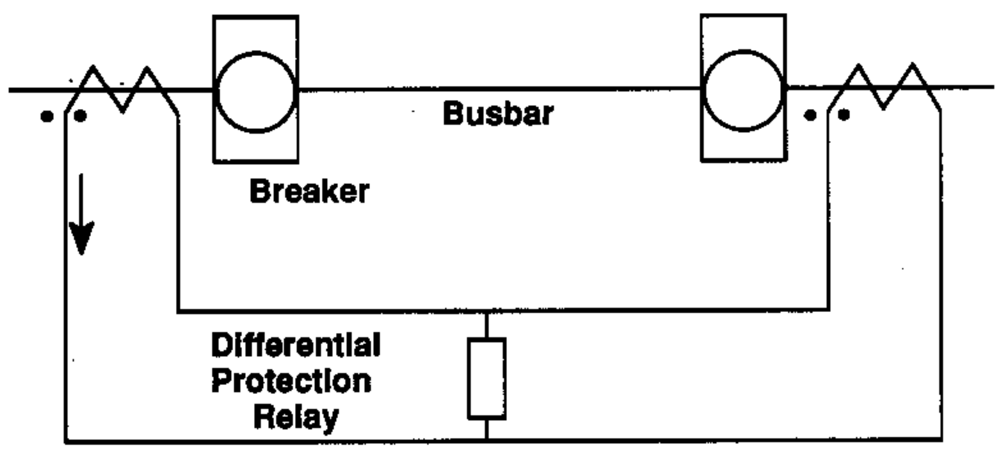
2. Given the following diagrams, show the boundaries of the protection zones for each of the circuits/protective devices.

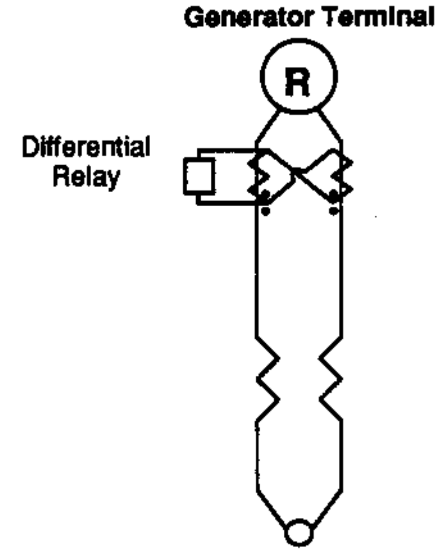


Show the Protection Zone For The Motor Circuit & Supply



Show the Protection Zone for this Differential Protection Scheme

NOTES & REFERENCES



Show the Protection Zone for this Generator Winding Differential Protection Scheme (Split Phase Protection)

3. Explain how differential protection is used for the protection of busbars.

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4. Explain the reasons for overlapping zones of protection.

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5. Explain the concept of A and B protection.

6. Explain the concept of breaker failure protection.

Before you move on to the next module, **review the objectives** and make sure that you can meet their requirements.

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