

## **Protection 5**

### **1.0 Introduction**

Recall there are five basic classes of relays:

- Magnitude relays
- Directional relays
- Ratio (impedance) relays
- Differential relays
- Pilot relays

We provide only a very brief overview of differential and pilot relays in these notes. This material addresses section 13.5-13.7 in your text.

### **2.0 Differential relays**

Differential relays are used to protect generators (section 13.5), transformers (13.6), and buses and lines (13.7).

Differential relaying schemes are generally the most reliable type of protection scheme, particularly when they can fully deployed within

a single substation, as is the case with generators, transformers, and buses.

The basic principle of a differential relaying scheme is simple. For a component to be protected,

- The faultless component will have current flowing into the component equal to current flowing out of the component,  $I_{in}=I_{out}$ .
- The faulted component will have current flowing in to be different from the current flowing out,  $I_{in}\neq I_{out}$ .

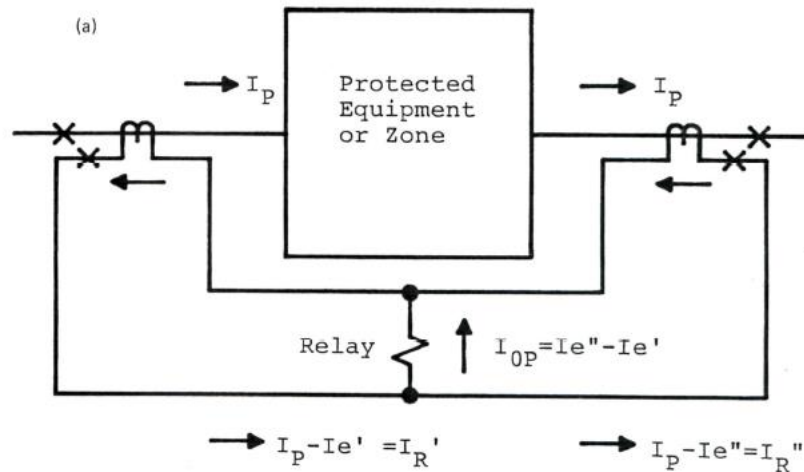
The principle is illustrated in Fig. 1.



**Fig 1**

One important issue in regards to differential protection is that, although the faultless component will have  $I_{in}=I_{out}$ , the corresponding relay currents will not be

exactly the same even if the same CT ratios are the same. This is because no to CTs are exactly the same. Therefore, one must account for this in the relaying logic, as shown in Fig. 2 for a faultless component and in Fig 3 for faulted component [1, p. 182].



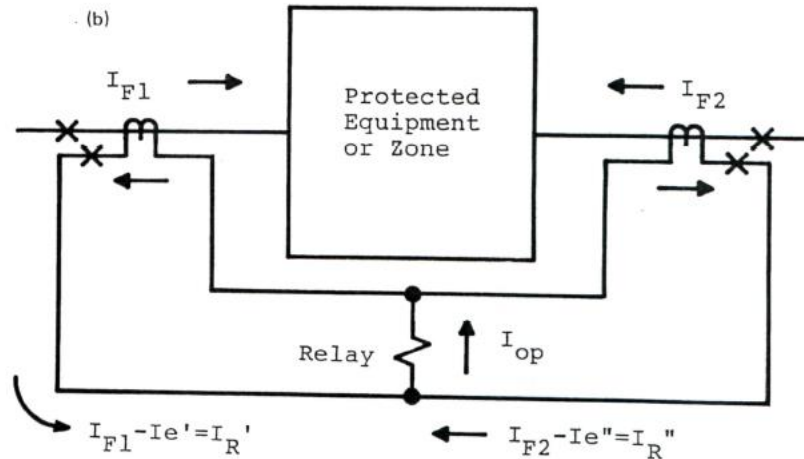
**Fig. 2: Faultless component**

In Fig. 2,  $I_p$  is the relay current corresponding to the line-side current being measured, and  $I_e'$  and  $I_e''$  are the small errors caused by the respective CTs. Applying KCL at the bottom node, we obtain:

$$I_{op} = I_p - I_e' - (I_p - I_e'') = I_e'' - I_e'$$

which is the current through the relay, denoted in Fig 2 as  $I_{op}$ . Under faultless conditions, this would be a very small current.

Figure 3 shows the same situation but under faulted conditions.



**Fig. 3: Faulted component**

Again, applying KCL at the bottom node, we obtain

$$I_{op} = I_{F1} - I_e' + (I_{F2} - I_e'') = I_{F1} + I_{F2} - (I_e' + I_e'')$$

The current under faulted condition is much greater than the current under faultless conditions, and so discriminating between these two conditions is easy. Your text, Fig. 13.10, shows one method for doing this.

Two more comments:

1. The above approach is deployed on each phase, and so all fault types can be effectively detected.

2. Protection of generators, transformers, and buses can be done using a direct wired interconnection of the relay input devices. Protection of transmission lines, because of the physical separation between the terminals of the components, requires so-called pilot protection. In this case, comparison of the quantities at the terminals require a communication channel. There are four types of communication channels used in pilot protection [1, p. 450]:

- a. Pilot wires: can be a dedicated wire or a leased line (e.g., from telephone);
- b. Power line carrier: radio frequencies between 30 and 300 kHz are transmitted over the transmission line;
- c. Microwave: a radio signal between 2 and 12 Ghz is transmitted by line-of-sight paths between terminals.
- d. Fiber optic cable: signals transmitted by light modulation through an electrical nonconducting cable.

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[1]J. Lewis Blackburn, "Protective relaying: principles and applications," Marcel Dekker, 1987.