EE493 Protection of Power Systems I

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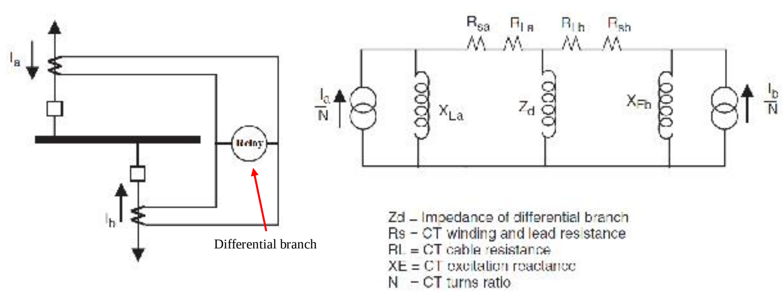
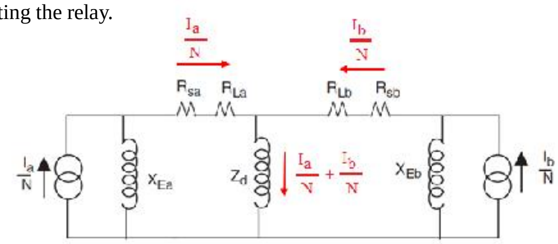
- **Slides 2-7 are from chapter 9 of "Power System Relaying", 4th Edition, Wiley, 2014, by S. Horowitz and A. G. Phadke**

High-impedance voltage differential relays

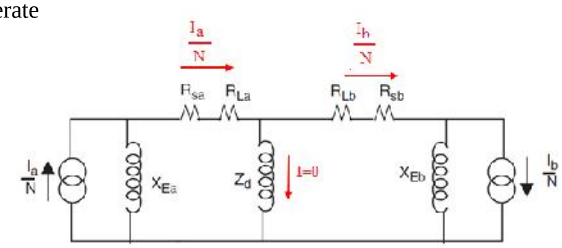
When a percentage differential relay is used for protecting busbars, a completely saturated CT for a close-in external fault may cause mis-operation of relays. To overcome this problem, the most commonly used bus differential relay, particularly on extra high voltage (EHV) buses, is the high-impedance voltage differential relay. This relay design circumvents the effects of CT saturation during external faults by assuming complete saturation for the worst external fault and calculating the error voltage across the operating coil.



When CTs are not saturated X_{Ea}, X_{Eb} can be assumed to be very large. When an internal fault happens currents Ia/N and Ib/N will go through xd and cause a high voltage across the differential branch, hence operating the relay.



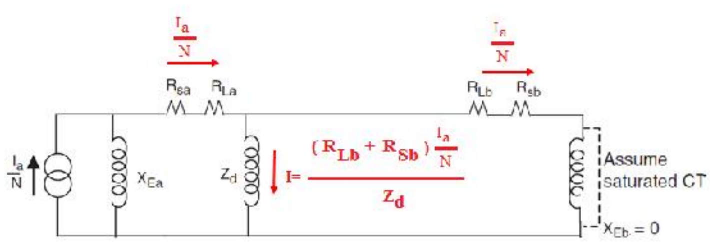
If an external fault occurs on line B, assuming no saturation, Ib/N will equal $-Ia/N$ and circulate around the outer loop, developing no net voltage across the relay. Therefore, the relay does not operate



3

For the external fault at line B, assuming complete CT saturation, X_{Eb} is approximately zero, producing a net error voltage across the relay equal to $(R_{Lb} + R_{sb})Ia/N$. This voltage, cause

$$I = \frac{(R_{Lb} + R_{sb}) \times \frac{I_a}{N}}{Z_d}$$



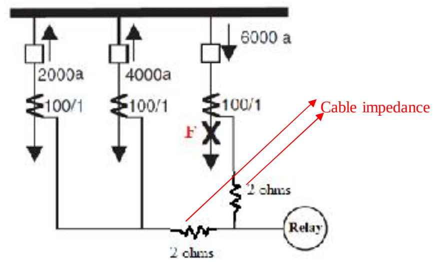
flows over the relay which is much less than

$$I = \frac{I_a}{N} + \frac{I_b}{N}$$

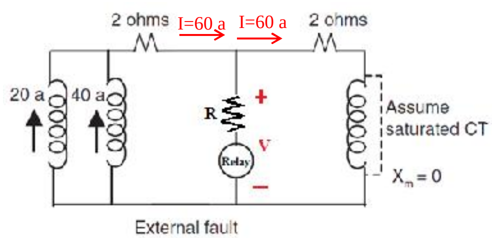
Therefore, the relay does not operate.

4

Example: In the following high-impedance voltage differential relay, the relay operates for currents more that 0.1 A. Determine the value of R such that the relay does not operates for external faults at F. The short circuit fault currents, CT ratios, and impedance of cables are shown in the figure. Assume the equivalent impedance of the relay is 2 Ω.



The equivalent of the network when the CT at the faulted line is saturated is as follows:



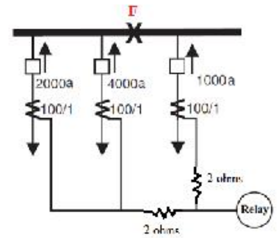
V=6×(2)=120 volts
This voltage causes the following current flows through the relay

$$I_{relay} = \frac{V}{R_{relay} + R} = \frac{120}{2 + R}$$

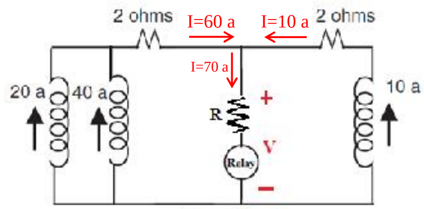
For currents less than 0.1 the relay does not operate. Because, this an external fault, we do not want the relay operates. Therefore:

$$I_{relay} < 0.1 \rightarrow \frac{120}{2 + R} < 0.1 \rightarrow (120 - 0.2) < 0.1 \times R \rightarrow 1198 < R$$

Now lets see what happens if an internal fault occurs. The following figure shows the currents due to a fault at F



The following figure shows the equivalent model of above figure



In this case 70 A flows through the relay and as it is more than 0.1 A, the relay operates correctly for this internal fault