OFFICE HOUR
EE 4223/5223
4 MAR '09
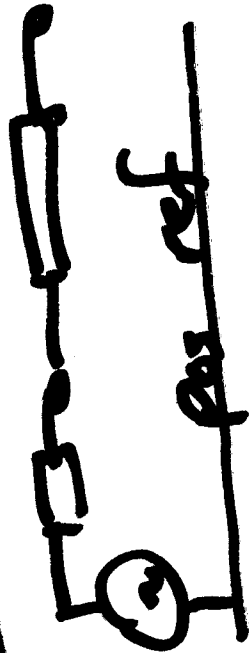
Questions?
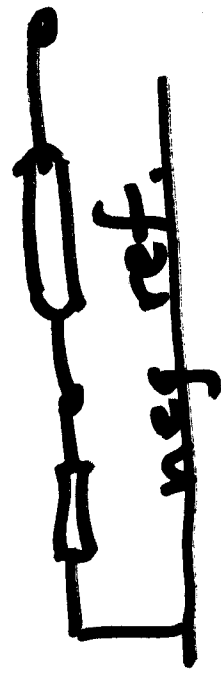
X = 0 ...... 1.0

Z_N

Z_0, L

Z_0

$3Z_N$
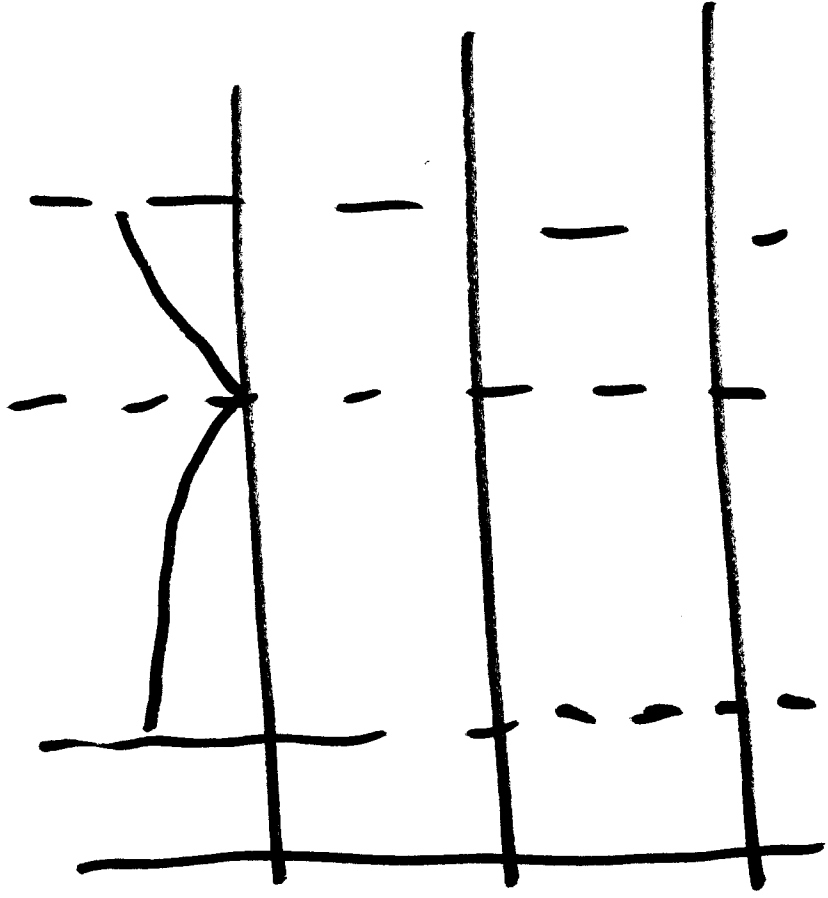
Z_N
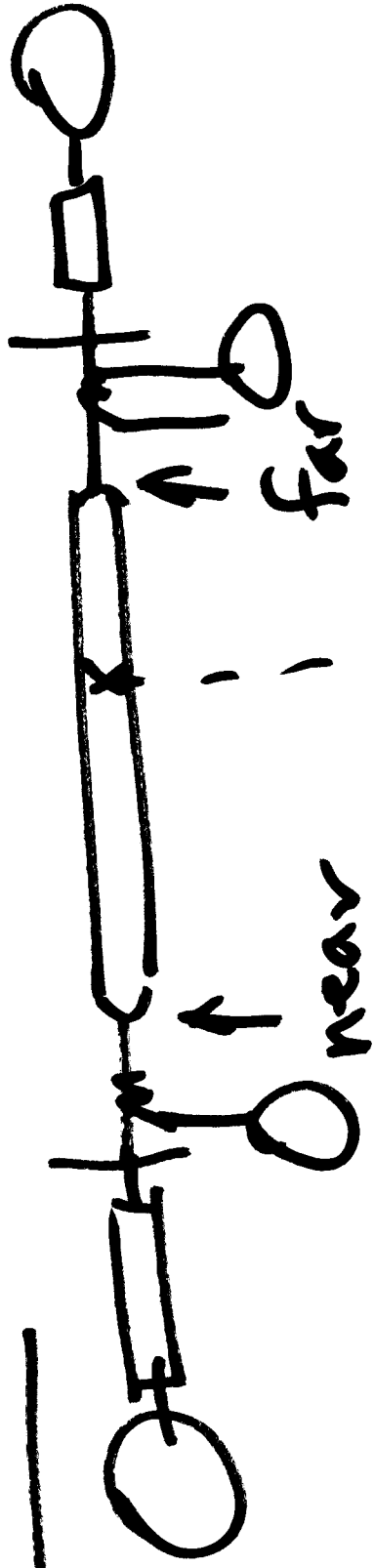
zero ref

pos ref

neg ref
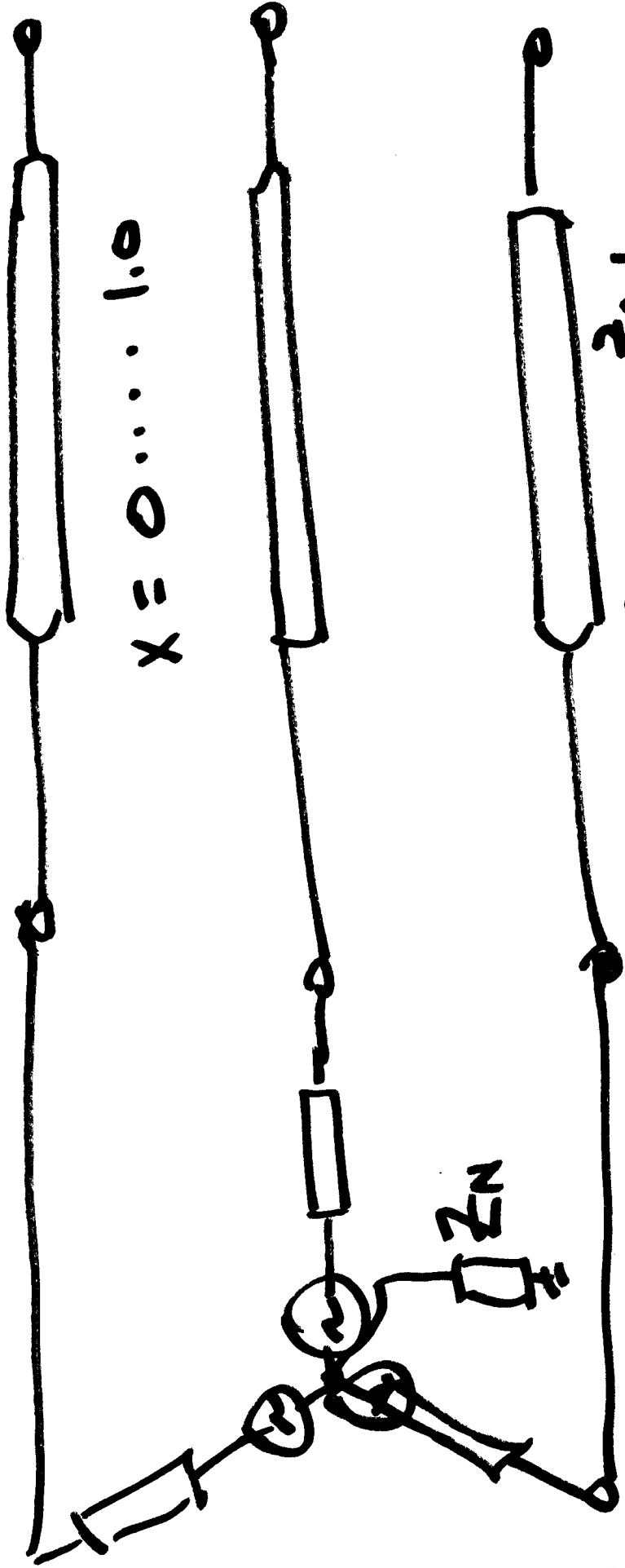
Assume: $Z_1 = Z_2$

Then:
$$Z_0 = 3Z_N + Z_0 + X*Z_{0,L}$$
$$Z_1 = Z_1 + X*Z_{1,L}$$
$$Z_2 = Z_2 + X*Z_{2,L}$$

Relay Applications Tool

$X =$ _____

far

near

$$Z_0, \; Z_1 = Z_2$$

$$Z_S = \begin{bmatrix} 0 & 0 & Z_0 \\ 0 & Z_1 & 0 \\ Z_2 & 0 & 0 \end{bmatrix}$$

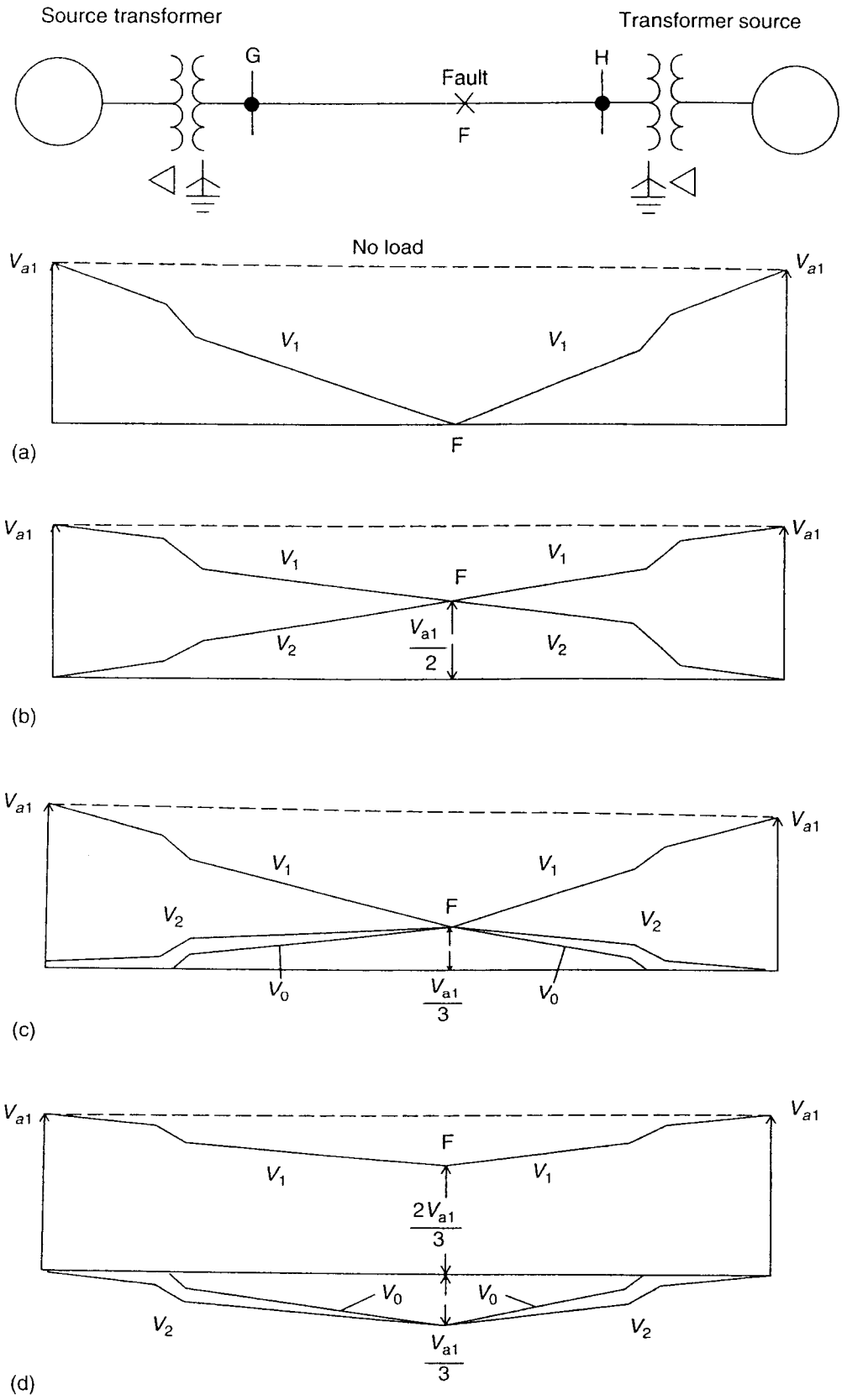$$\sum I_S = 0$$

Z_Δ

Z_Y
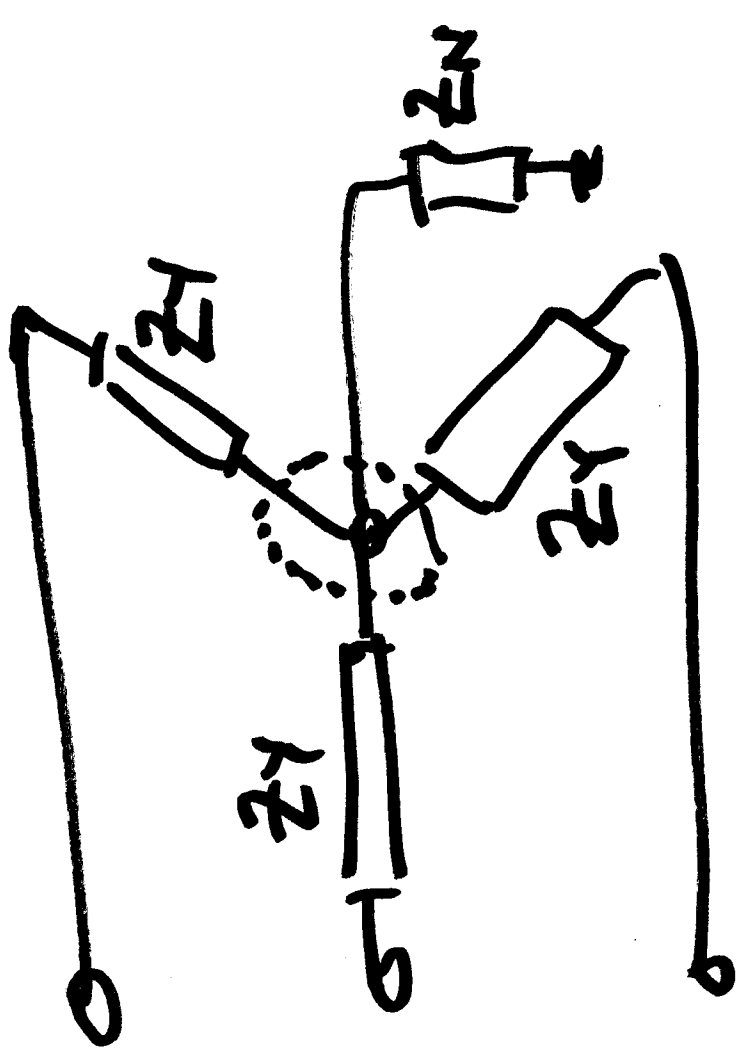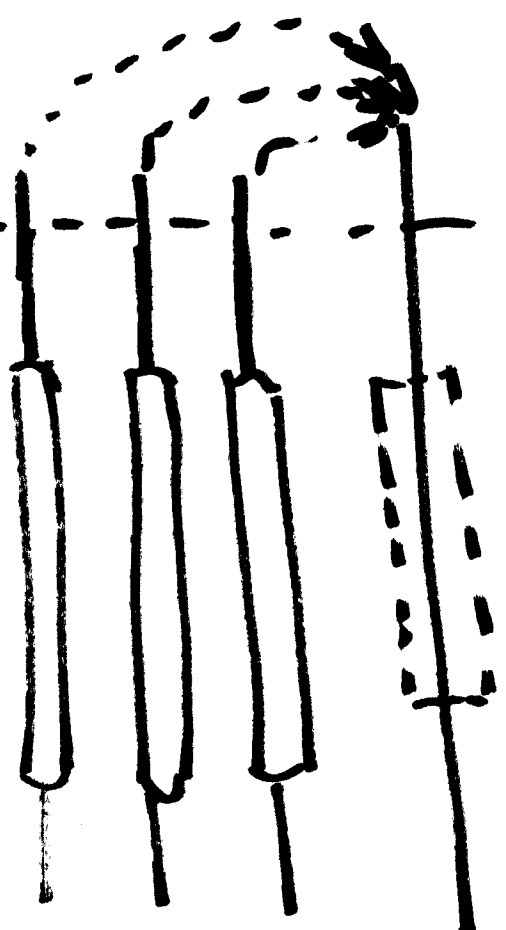
FIGURE 4.31 System sequence voltage profiles during shunt faults: (a) three-phase faults; (b) phase-to-phase faults; (c) two-phase-to-ground faults; (d) phase-to-ground faults.

4.16.2 SYSTEM VOLTAGE PROFILES DURING FAULTS

The trends of the sequence voltages for the various faults in Figure 4.29 are illustrated in Figure 4.31. Only the phase a sequence voltages are shown for an ideal case where $Z_1 = Z_2 = Z_0$. This makes the presentation less complex and does not affect the trends shown.

With the common assumption of no load, the system voltage is equal throughout the system, as indicated by the dashed lines. When a solid three-phase fault occurs, the voltage at the fault point becomes zero, but as indicated earlier, does not change in the source until the regulators act to change the generator fields. Meanwhile, the fault should have been cleared by protective relays. Thus, the voltage profile is as shown in Figure 4.31a.

For phase-to-phase faults (see Figure 4.31b), the positive-sequence voltage drops to half value ($Z_1 = Z_2$). This unbalance fault is the source of negative sequence and the V_2 drops, which are zero in the generators, are as shown.

For two-phase-to-ground faults (see Figure 4.31c) with $Z_1 = Z_2 = Z_0$, the positive-sequence voltage at the fault drops to one-third of V_1. The fault at this moment generates both negative and zero sequences that flow through the system, producing voltage drops as shown. The voltage V_2

becomes zero in the generators, whereas V_0 is zero at the grounded transformer neutral point.

The fault voltage for a phase-a-to-ground solid fault is zero and as documented in Figure 4.31d, the sum of the positive-, negative-, and zero-voltage components at the fault add to zero. Thus, the positive-sequence voltage drops to $2/3V_1$ when $Z_1 = Z_2 = Z_0$ at the fault point, where $-1/3V_2$ and $-1/3V_0$ are generated. Subsequently, they drop to zero in the generator or source for the negative sequence and to zero at the grounded transformer bank neutral.

The fundamental concept illustrated in Figure 4.31 is that positive-sequence voltage is always maximum at the generators and minimum at the fault. The negative- and zero-sequence voltages are always maximum at the fault and minimum at the generator or grounded neutral.

It is common to refer to the grounded-wye–delta or similar banks as "ground sources." This is really a misnomer, as the source of zero sequence is the unbalance, the ground fault. However, thus designating these transformers as ground sources is practical, since, by convention ground ($3I_0$) current flows up the grounded neutral, through the system, and down the fault into ground.