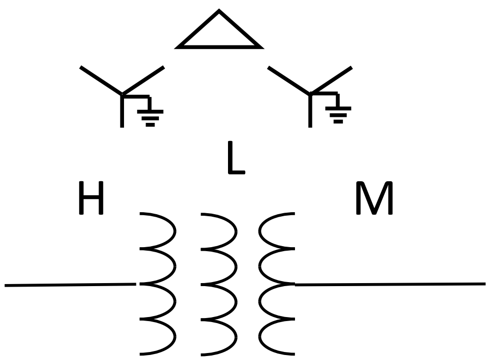
Three-Phase Transformers and Autobanks

Converting pair-wise test data to "T" model data for short-circuit calculations.



First, put them on 100MVA base

$$Z_{HM_{NEW}} = j5.5\% \times \frac{100}{150} = j3.67\%$$

$$Z_{HL_{NEW}} = j36\% \times \frac{100}{150} = j24\%$$

$$Z_{ML_{NEW}} = j28\% \times \frac{100}{150} = j18.7\%$$

150/200/250MVA
115 : 13.2 : 230kV
ZHM = j5.5%
ZHL = j36%
ZML = j28%

Calculate the "T" model for the three-winding bank:

$$Z_H = \frac{Z_{HM} + Z_{HL} - Z_{ML}}{2} = j4.5\%$$

$$Z_M = \frac{Z_{HM} + Z_{ML} - Z_{HL}}{2} = -j0.82\%$$

$$Z_L = \frac{Z_{HL} + Z_{ML} - Z_{HM}}{2} = j19.5\%$$

Note: As a check, add the resulting "T" leakage impedances between turns. E.g. $Z_{HM} = Z_H + Z_M$ etc. and you should get the proper winding-winding test leakage impedances.

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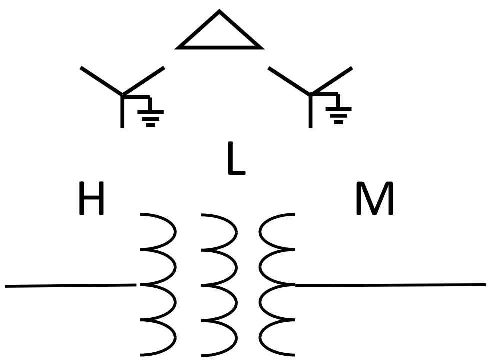
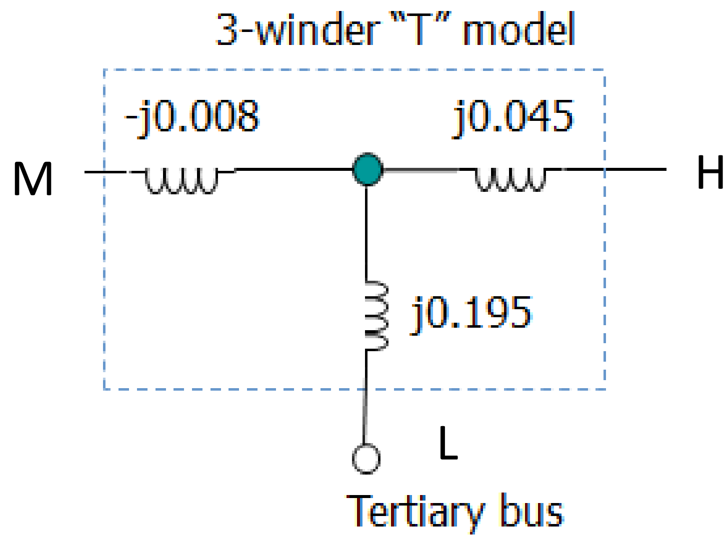
$$Z_L = \frac{Z_{HL} + Z_{ML} - Z_{HM}}{2} = j19.5\%$$





Positive Sequence

Three-Phase Transformers and Autobanks

$$Z_H = \frac{Z_{HM} + Z_{HL} - Z_{ML}}{2} = j4.5\%$$

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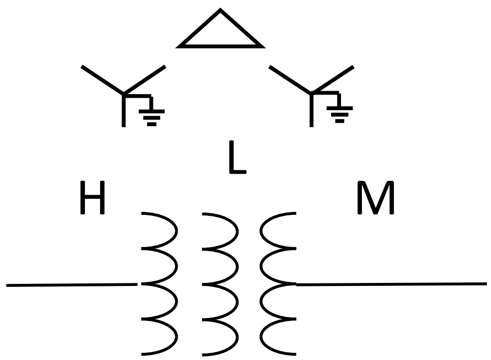
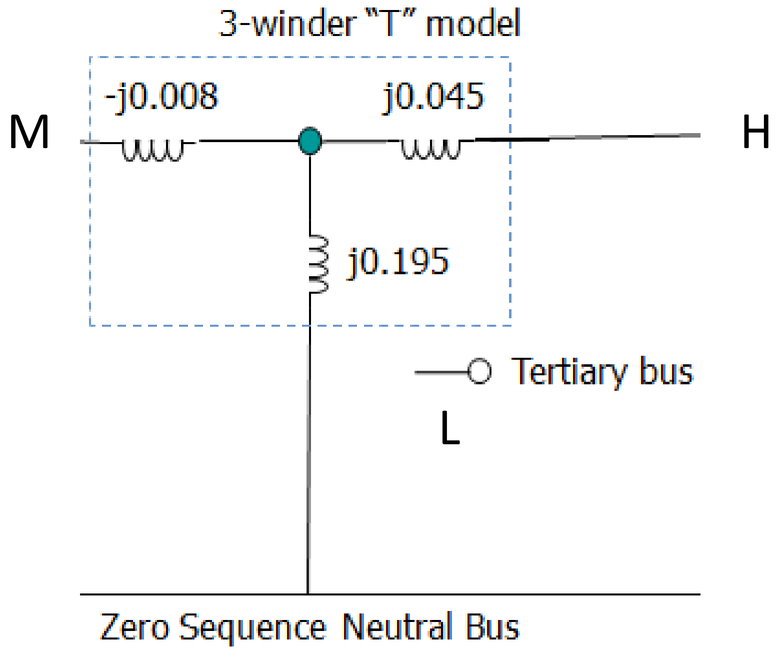
$$Z_L = \frac{Z_{HL} + Z_{ML} - Z_{HM}}{2} = j19.5\%$$

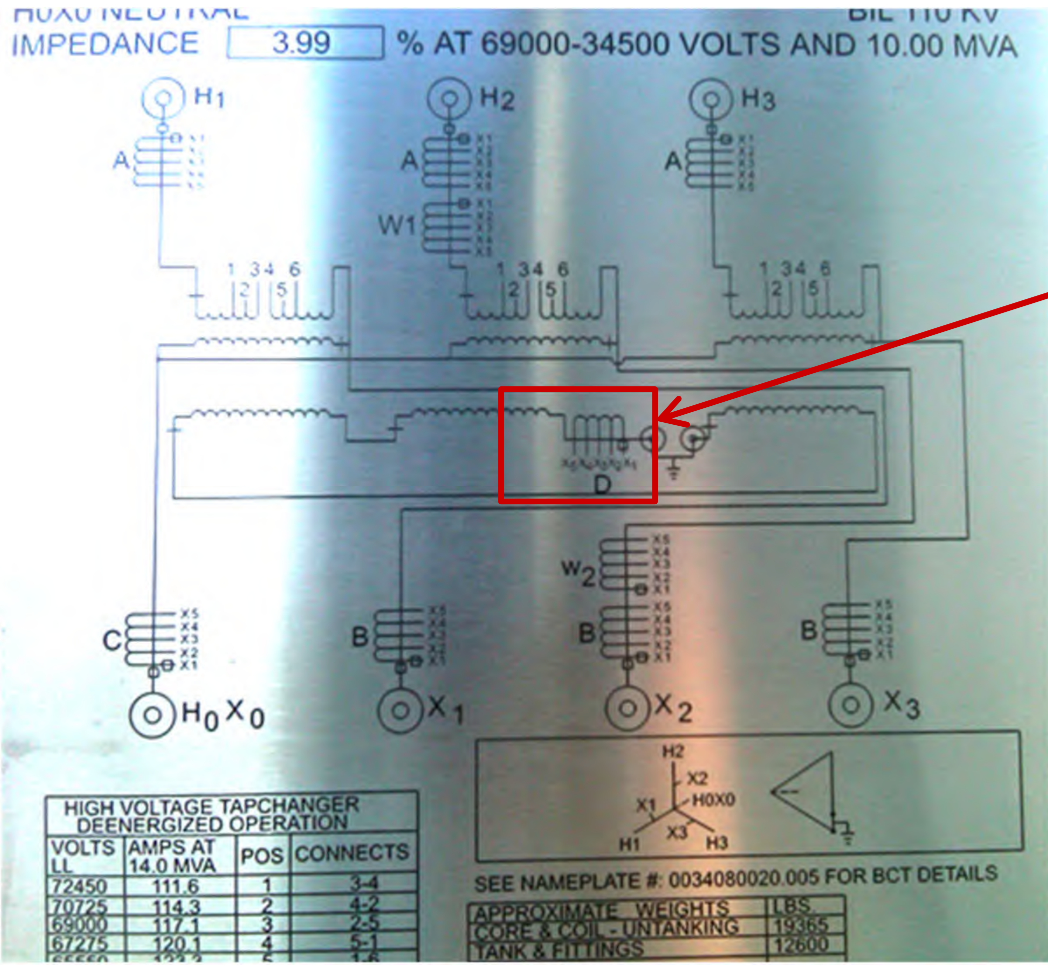


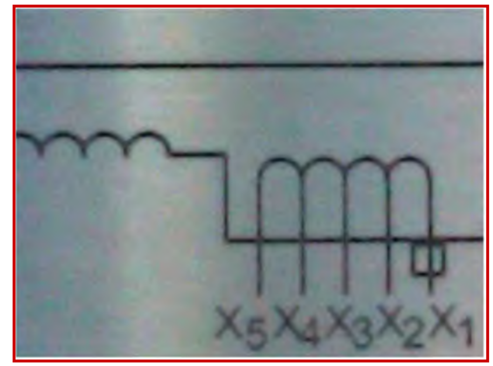


Zero Sequence

Note: Look at test report, zero sequence is often different than positive.

Autobanks as Polarizing Source for Ground Relays



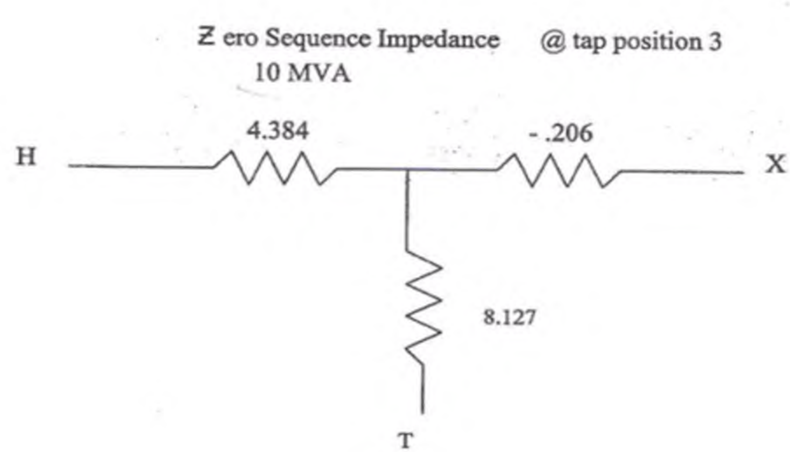


CT inside the delta.

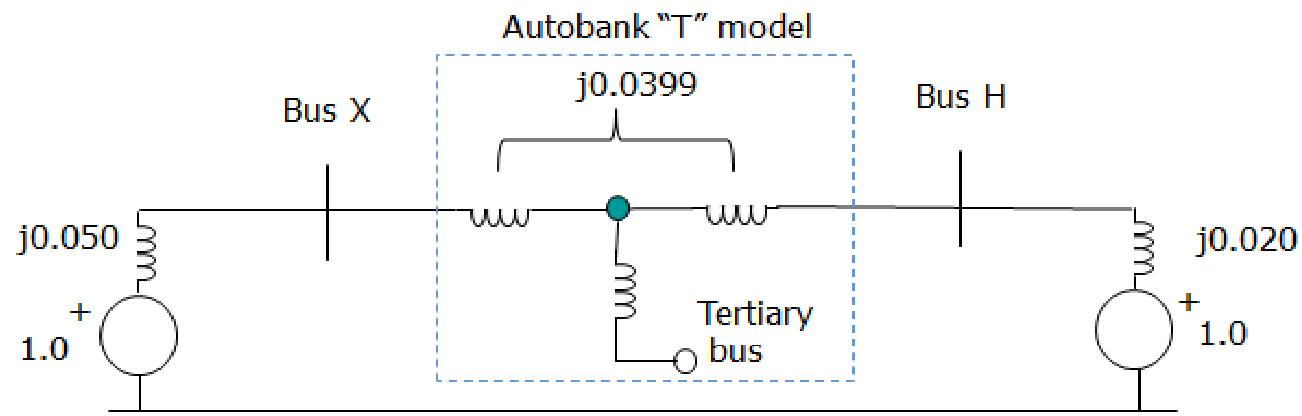
1. From the nameplate we see the H-X impedance is 3.99% on 10MVA base.

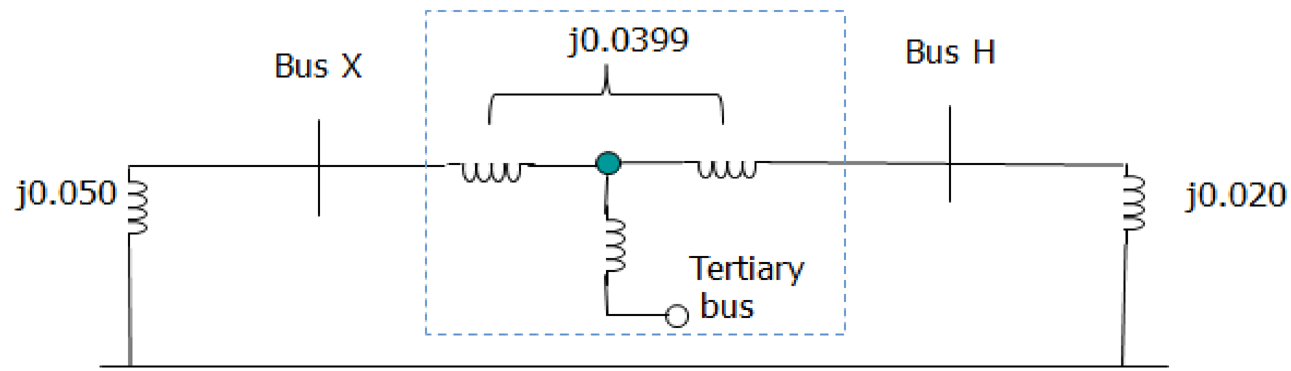
2. To evaluate the effectiveness of the autobank tertiary as a polarizing source we need to know the zero sequence impedance data for the bank. Below is the "T" model as provided by the manufacturer.

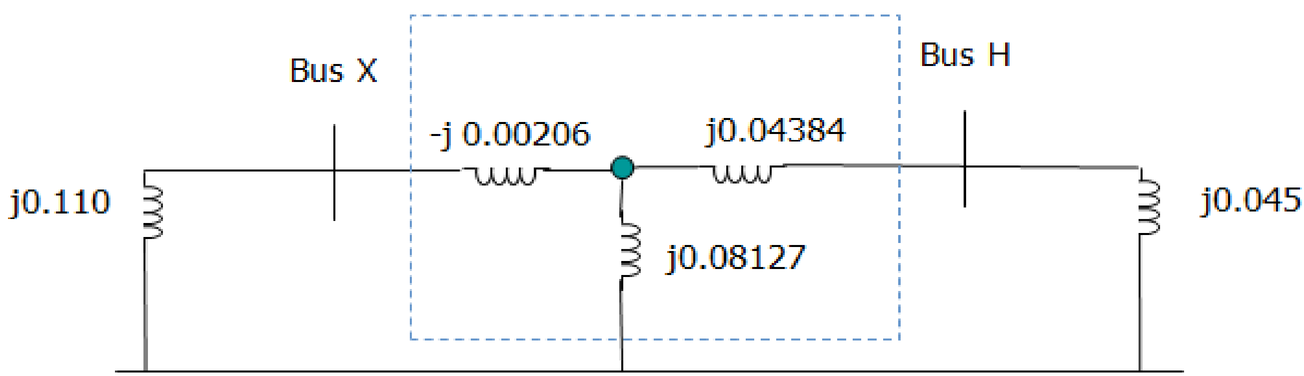
3. The zero-sequence impedance is usually equal to the positive-sequence impedance in an autobank (typically shell core design).



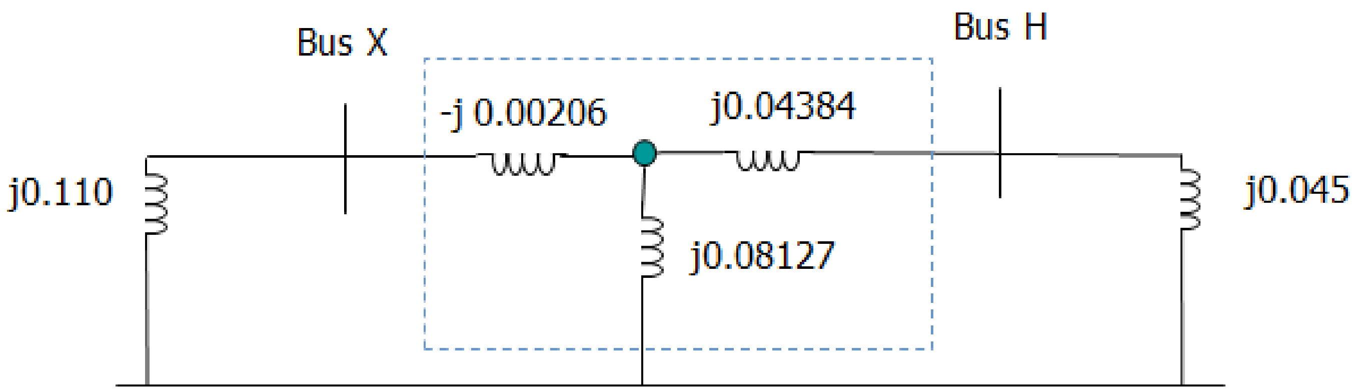
4. Next, build symmetrical component model for short-circuit calculations…


Autobank "T" model
j0.0399
Bus X
Bus H
j0.050
j0.020
+
1.0
+
1.0
Tertiary
bus

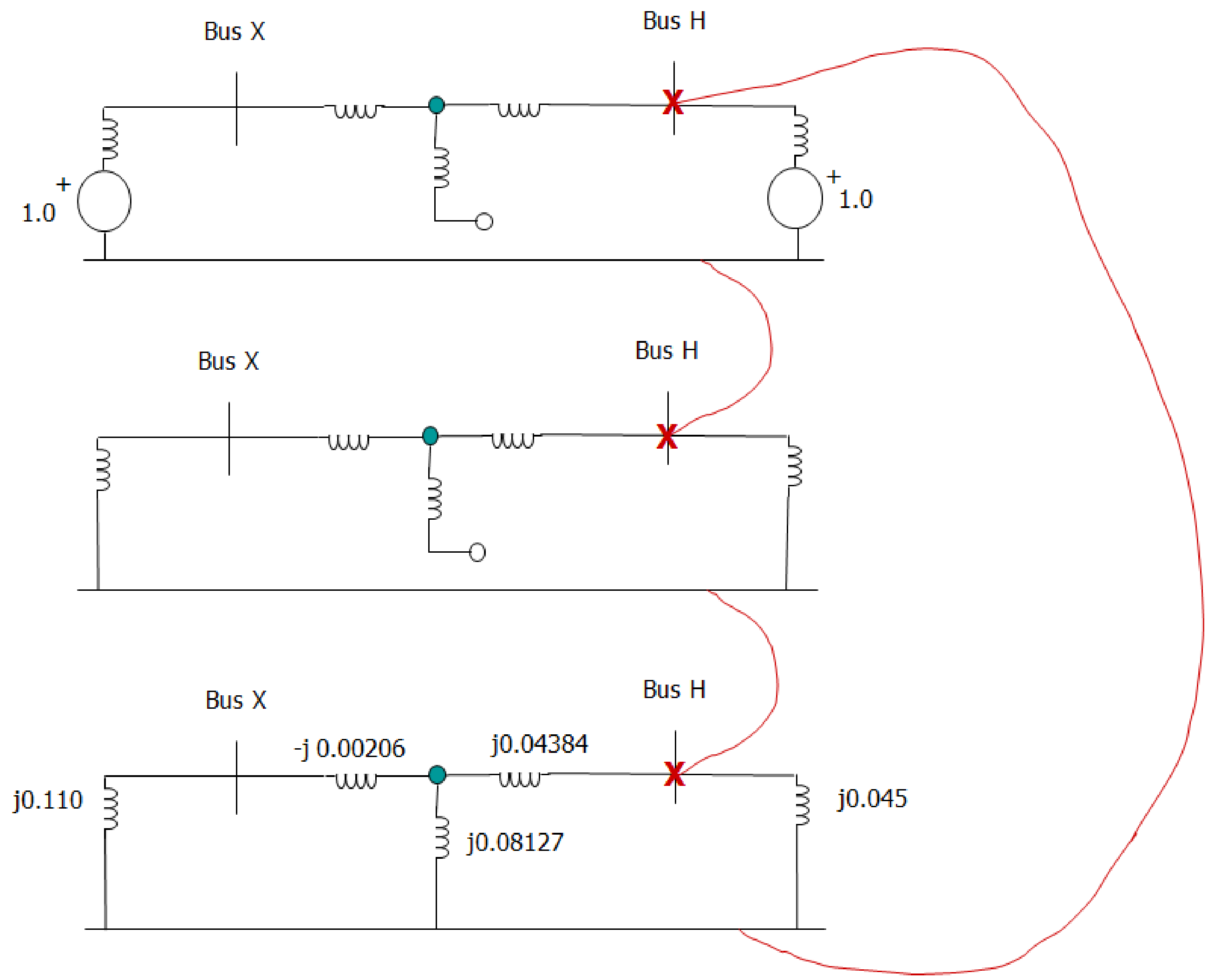

j0.0399
Bus X
Bus H
j0.050
j0.020
Tertiary
bus


Bus X
Bus H
-j 0.00206
j0.04384
j0.110
j0.045
j0.08127

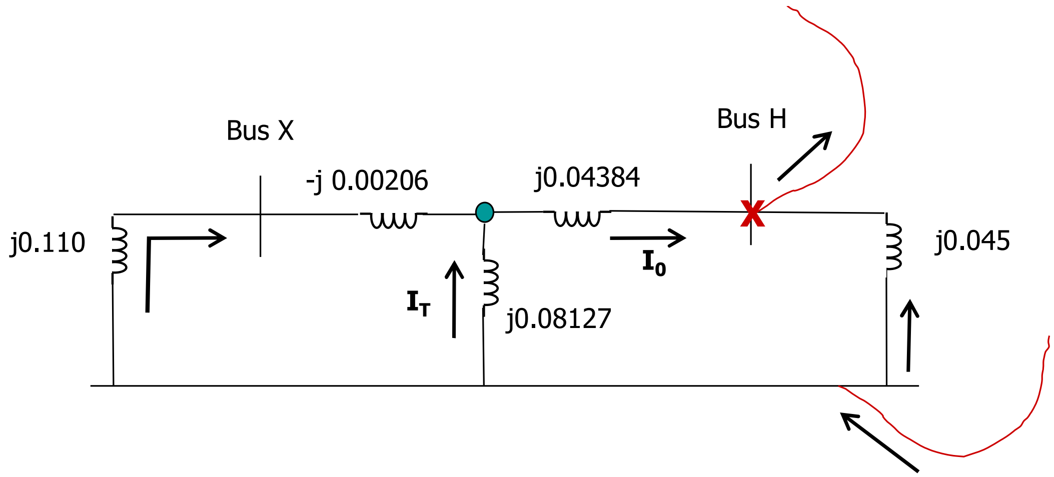
To evaluate the autobank tertiary as a polarizing source we only need look at the zero-sequence network and determine if current in the tertiary has the same relative direction and phase for faults on both sides of the bank.



Faults on the H side of the bank…



Faults on the H side of the bank…



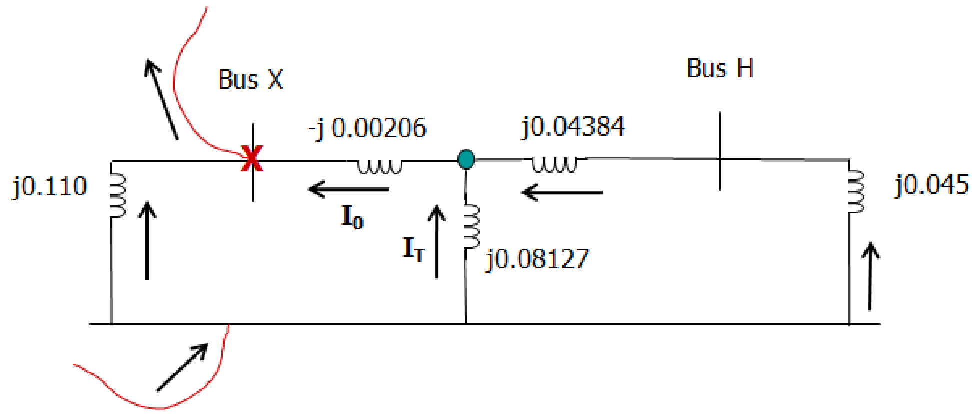
Using simple current division, we can find out how much of the I_0 that flows from the autobank to the fault splits through the tertiary branch.

$$I_T = I_0 \times \frac{(j0.110 - j0.00206)}{(j0.110 - j0.00206 + j0.08127)}$$

$$I_T = 0.57 \times I_0$$

Because this is a positive result, we can expect I_T to have the relative direction indicated by the arrow with a phase angle near the same as that of I_0 (the same if homogenous system). We will compare this result with what we find next for a fault on the X side to determine if this is a consistent polarizing source.

Faults on the X side of the bank…



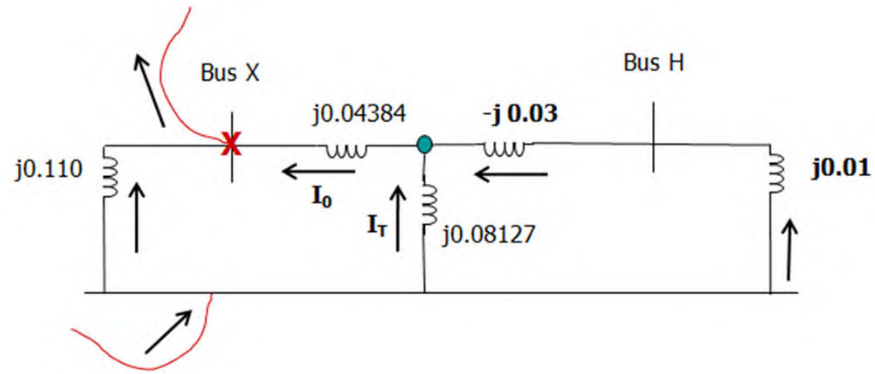
Using simple current division, we can find out how much of the I_0 that flows from the autobank to the fault splits through the tertiary branch.

$$I_T = I_0 \times \frac{(j0.04384 + j0.0450)}{(j0.04384 + j0.0450 + j0.08127)}$$

$$I_T = 0.52 \times I_0$$

Because this is also a positive result, we know that I_T will have the same relative direction and phase angle relationship as before for faults on both sides of the autobank – making it a reliable source for polarizing.

What if the negative branch of the "T" was larger than the zero sequence source impedance on that side of the bank?



Using current division, we can find out how much of the I_0 that flows from the autobank to the fault splits through the tertiary branch at I_T.

$$I_T = I_0 \times \frac{(j0.01 - j0.03)}{(j0.01 - j0.03 + j0.08127)}$$

$$I_T = -0.33 \times I_0$$

Because this is a negative result, we know that I_T will have a phase angle 180° away from I_0 for faults on the X side of the autobank – and because faults on the H side produce polarizing current that is in phase with the I_0 going into bus H from the autobank this is not a consistent polarizing source - making it an unreliable source for polarizing.

A few points…

- All you need to evaluate the autobank tertiary for polarizing is the zero sequence “T” equivalent of the transformer and the minimum expected zero sequence source impedance on each side of the bank.

- The reversal occurs because either the H-side or X-side zero sequence “T” branch is negative AND when added to the zero sequence source impedance on that side the result is negative.

- The negative zero sequence branch typically occurs in the medium voltage branch but sometimes in the high voltage branch (or not at all).

- The impedance of the tertiary branch in the autobank zero sequence “T” is always large such that the denominator of the current division equation will always be positive.

- Even if your studies determine that the current will always have the same relative direction and phase angle relationship for faults on either side of the bank it still may not be a suitable polarizing source – it may not provide adequate current to satisfy the minimum sensitivity of the protective relay for all expected faults. This must be studied as well.