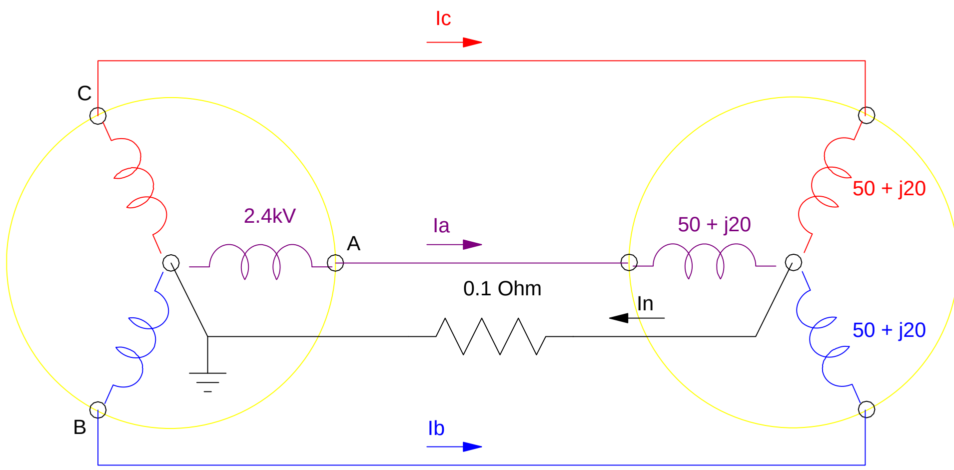
ECE 331 - Solutions to Homework #5

1) A 3-phase transformer in Y configuration drives a 3-phase balanced load in Y configuration. Determine the currents Ia, Ib, Ic an the current on the neutral line, In. Assume the line-to-neutral voltage for all three transformers is 2.4kV rms.



Solution (from SciLab)

```
-->// Y source, Y load

-->Va = 2400;
-->Vb = 2400 * exp(-j*120*%pi/180);
-->Vc = 2400 * exp(-j*240*%pi/180);

-->Za = 50 + j*20;
-->Zb = 50 + j*20;
-->Zc = 50 + j*20;

-->// the voltage at the load neutral:

-->Vx = (Va/Za + Vb/Zb + Vc/Zc) / (1/Za + 1/Zb + 1/Zc + 10)

  - 9.718D-14 - 6.008D-14i
```

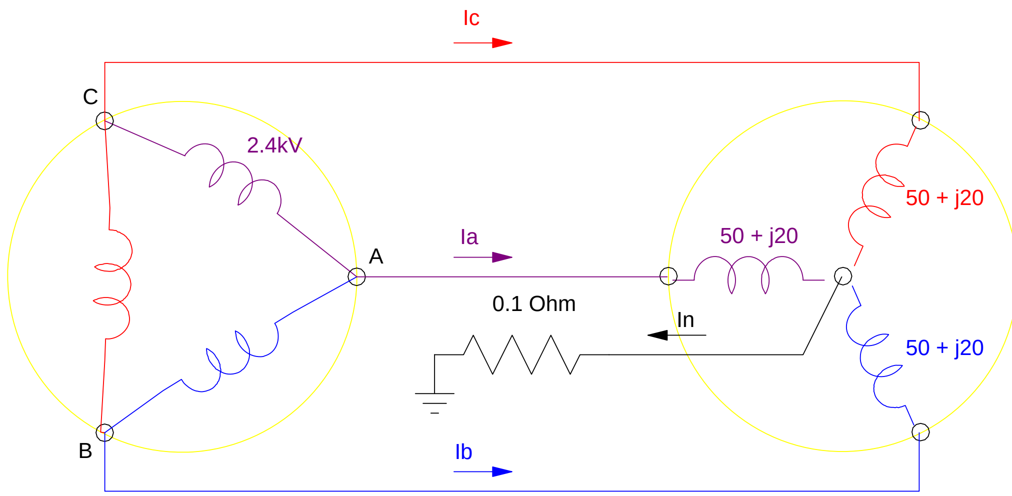
Note that for a balanced load, the currents sum to zero, meaning the voltage at the neutral is zero.

```
-->// Line currents

-->Ia = (Va - Vx) / Za;
-->Ib = (Vb - Vx) / Zb;
-->Ic = (Vc - Vx) / Zc;
-->In = Vx / 0.1;

-->I = [Ia; Ib; Ic; In];
-->[abs(I), atan(imag(I),real(I))*180/%pi]
```

	Amps		Degrees
Ia	44.566881	-	21.801409
Ib	44.566881	-	141.80141
Ic	44.566881		98.198591
In	1.143D-12	-	148.27235

Again, the currents sum to zero (In = 0)

Problem 2: A 3-phase transformer in Delta configuration drives a 3-phase balanced load in Y configuration. Determine the currents Ia, Ib, Ic an the current on the neutral line, In. Assume the line-to-line voltage at the transformer is 2.4kV.




```
-->// Delta Source, Y Load
-->// Define the voltages and impedances:

-->Vab = 2400;
-->Vbc = 2400 * exp(-j*120*%pi/180);
-->Vca = 2400 * exp(-j*240*%pi/180);

-->Za = 50 + j*20;
-->Zb = 50 + j*20;
-->Zc = 50 + j*20;

-->// With 4 unknown voltages, write voltage node equations to solve for 4 unknowns:
-->// Writing the voltage node equations:

-->A = [1, 1, 1, 0; 0, 1, -1, 0; -1, 0, 1, 0; -1/Za, -1/Zb, -1/Zc,
1/Za+1/Zb+1/Zc+1/0.1]
-->B = [ 0; Vbc; Vca; 0]
```

$$\begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & -1 & 0 \\ -1 & 0 & 1 & 0 \\ -0.0172+j0.0068 & -0.0172+j0.0069 & -0.01724+j0.0069 & 10.0517-j0.0207 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \\ V_x \end{bmatrix} = \begin{bmatrix} 0 \\ 2400\angle -120^0 \\ 2400\angle -240^0 \\ 0 \end{bmatrix}$$

```
-->//Solving for the line voltages:


-->V = inv(A)*B;
-->[ abs(V), atan(imag(V),real(V))*180/%pi ]
```

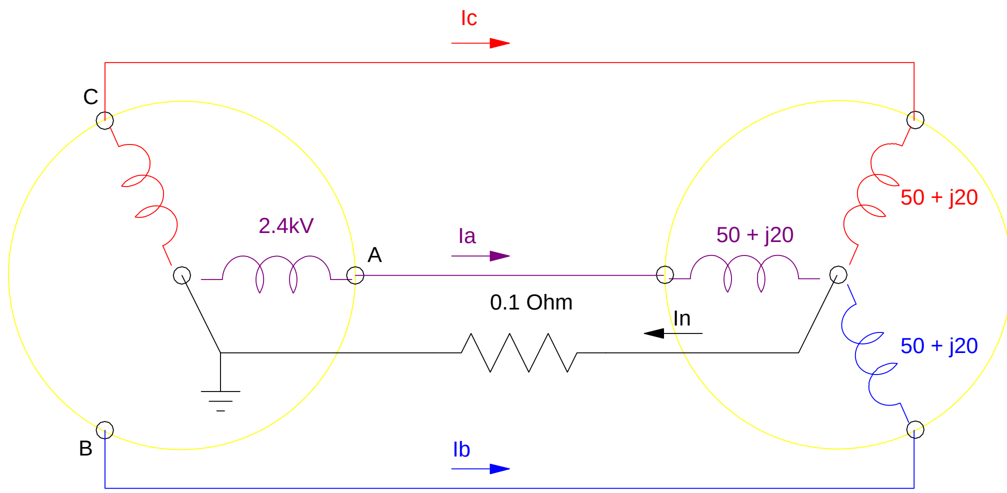
```
      Volts        Degrees
Va    1385.6406  - 30.
Vb    1385.6406  - 150.
Vc    1385.6406    90.
Vx    0.           0.
```

Doesn't matter if the source is delta or Y. If you have a balanced load, the voltages and currents sum to zero. All that changes is line-to-line voltage is $\sqrt{3}$ times bigger than line-to-neutral.

Solving for currents:

```
-->Va = V(1);
-->Vb = V(2);
-->Vc = V(3);
-->Vx = V(4);

-->// Solving for the line currents

-->Ia = (Va - Vx) / Za;
-->Ib = (Vb - Vx) / Zb;
-->Ic = (Vc - Vx) / Zc;
-->In = Vx / 0.1;

-->I = [Ia; Ib; Ic; In];
-->[ abs(I), atan(imag(I),real(I))*180/%pi ]

      Amps         Degrees
Ia    25.730701  - 51.801409
Ib    25.730701  - 171.80141
Ic    25.730701    68.198591
In    0.           0.
```

Problem 3: A 3-phase transformer in Y configuration drives a 3-phase balanced load in Y configuration. Assume phase B transformer is removed. Determine the currents Ia, Ib, Ic an the current on the neutral line, In. Assume the line-to-neutral voltage of each transformer is 2.4kV.



To model the loss of phase B, add 1G Ohm impedance to line B:

```
-->// Y source, Y load

-->Va = 2400;
-->Vb = 2400 * exp(-j*120*%pi/180);
-->Vc = 2400 * exp(-j*240*%pi/180);

-->Za = 50 + j*20;
-->Zb = 50 + j*20 + 1e9;                 // open-circuit on line B
-->Zc = 50 + j*20;

-->// the voltage at the load neutral:

-->Vx = (Va/Za + Vb/Zb + Vc/Zc) / (1/Za + 1/Zb + 1/Zc + 1/0.1)

    3.4865692 + 2.7512888i
```

Note : In Y-Y configuration, if you lose one of the transformers,

- You lose that phase (Vb = 3.48 + j2.75 as well)
- The neutral is no longer zero volts

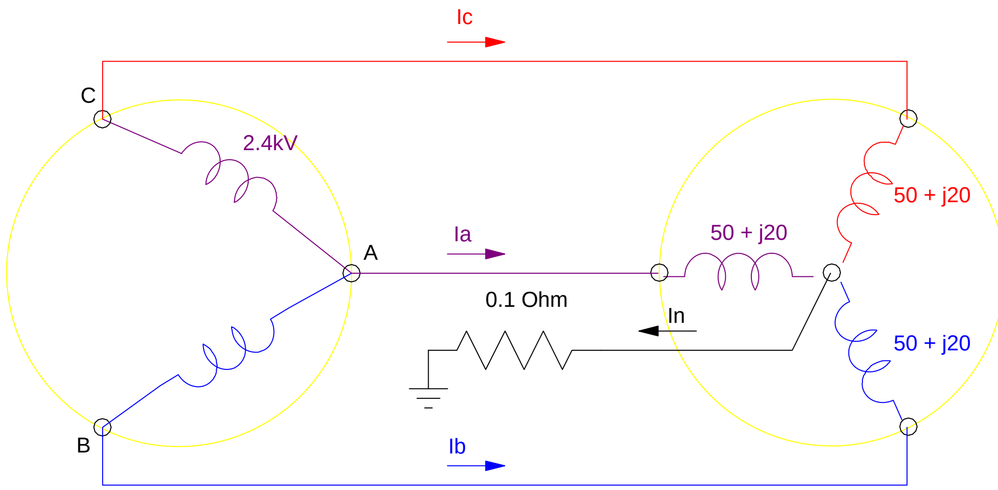
```
-->// Line currents
-->Ia = (Va - Vx) / Za;
-->Ib = (Vb - Vx) / Zb;
-->Ic = (Vc - Vx) / Zc;
-->In = Vx / 0.1;

-->I = [Ia; Ib; Ic; In];
-->[abs(I), atan(imag(I),real(I))*180/%pi]
```

```
       Amps         Degrees
Ia    44.502167  - 21.867187
Ib    0.0000024  - 120.03918              // Ib = 0 due to a line loss
Ic    44.555083    98.303544
In    44.413686    38.277346
```

Likewise, if you lose a line with a Y-source,

- The line current in that phase becomes zero (duh)
- The neutral current becomes **large**. 44.4 Amps in this case

Problem 4: A 3-phase transformer in Delta configuration drives a 3-phase balanced load in Y configuration. Assume the phase BC transformer is removed. Determine the currents Ia, Ib, Ic an the current on the neutral line, In. Assume the line-to-line voltage of each transformer is 2.4kV.




```
-->// Delta Source, Y Load

-->// Define the voltages and impedances:

-->Vab = 2400;
-->Vbc = 2400 * exp(-j*120*%pi/180);
-->Vca = 2400 * exp(-j*240*%pi/180);

-->Za = 50 + j*20;
-->Zb = 50 + j*20;
-->Zc = 50 + j*20;

-->// With 4 unknown voltages, write voltage node equations to solve for 4 unknowns:
-->// Writing the voltage node equations:

-->A = [1, 1, 1, 0; 1, -1, 0, 0; -1, 0, 1, 0; -1/Za, -1/Zb, -1/Zc,
1/Za+1/Zb+1/Zc+1/0.1]

-->B = [ 0; Vab; Vca; 0]

-->//Solving for the line voltages:

-->V = inv(A)*B;

-->[ abs(V), atan(imag(V),real(V))*180/%pi ]

       Volts         Degrees
Va    1385.6406   - 30.
Vb    1385.6406   - 150.
Vc    1385.6406     90.
Vx    0.            0.
```

Note: In delta configuration,

- If you lose a source transformer, there is no affect on the system. The load still has the same voltages as before.

- The neutral voltage is still zero with a balanced load

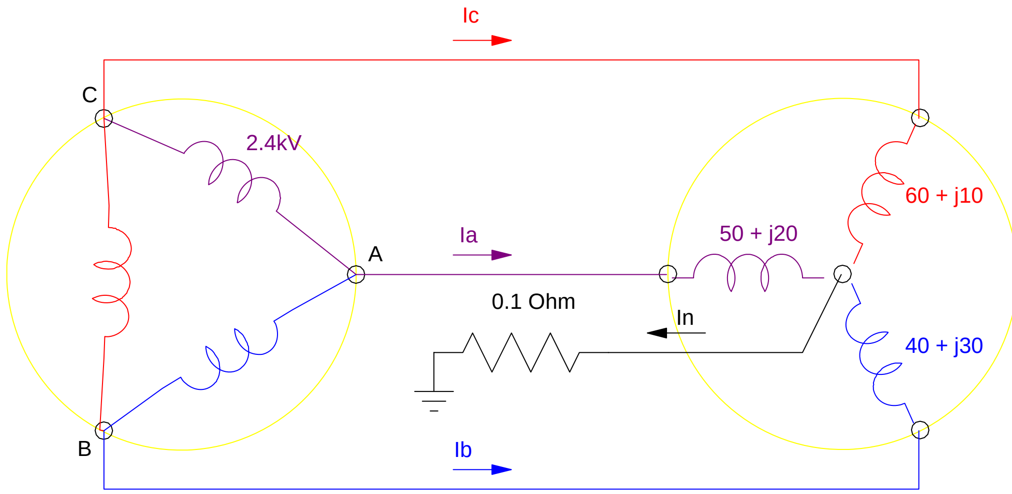
Checking the currents:

```
-->Va = V(1);
-->Vb = V(2);
-->Vc = V(3);
-->Vx = V(4);

-->// Solving for the line currents

-->Ia = (Va - Vx) / Za;
-->Ib = (Vb - Vx) / Zb;
-->Ic = (Vc - Vx) / Zc;
-->In = Vx / 0.1;

-->I = [Ia; Ib; Ic; In];
-->[ abs(I), atan(imag(I),real(I))*180/%pi ]

       Amps         Degrees
Ia    25.730701  - 51.801409
Ib    25.730701  - 171.80141
Ic    25.730701    68.198591
In    0.           0.
```

The line currents are the same as problem #2.

Note that there is a slight difference: the power to the load is distributed between two transformers rather than three.

Problem 5) A 3-phase transformer in Delta configuration drives a 3-phase unbalanced load in Y configuration. Determine the currents Ia, Ib, Ic an the current on the neutral line, In. Assume the line-to-line voltage at the transformer is 2.4kV.




```
-->// Delta Source, Y Load

-->// Define the voltages and impedances:

-->Vab = 2400;
-->Vbc = 2400 * exp(-j*120*%pi/180);
-->Vca = 2400 * exp(-j*240*%pi/180);

-->Za = 50 + j*20;
-->Zb = 30 + j*30;
-->Zc = 60 + j*10;

-->// With 4 unknown voltages, write voltage node equations to solve for 4 unknowns:
-->// Writing the voltage node equations:

-->A = [1, 1, 1, 0; 1, -1, 0, 0; -1, 0, 1, 0; -1/Za, -1/Zb, -1/Zc, 1/Za+1/Zb+1/Zc+10]
-->B = [ 0; Vab; Vca; 0]

// Solving for the line voltages:

-->V = inv(A)*B;
-->[ abs(V), atan(imag(V),real(V))*180/%pi ]

      Volts         Degrees
Va    1385.6406   - 30.
Vb    1385.6406   - 150.
Vc    1385.6406     90.
Vx    1.5917389     138.16146
```

With an unbalanced load, the neutral (Vx) is no longer zero

Checking the line currents:

```
-->Va = V(1);
-->Vb = V(2);
-->Vc = V(3);
-->Vx = V(4);

-->// Solving for the line currents

-->Ia = (Va - Vx) / Za;
-->Ib = (Vb - Vx) / Zb;
-->Ic = (Vc - Vx) / Zc;
-->In = Vx / 0.1;

-->I = [Ia; Ib; Ic; In];
-->[ abs(I), atan(imag(I),real(I))*180/%pi ]

      Amps          Degrees
Ia    25.759631  - 51.814897
Ib    32.648189    165.06256
Ic    22.762345    80.488604
In    15.917389    138.16146
```

With an unbalanced load, the currents no longer match and the neutral current is no longer zero.