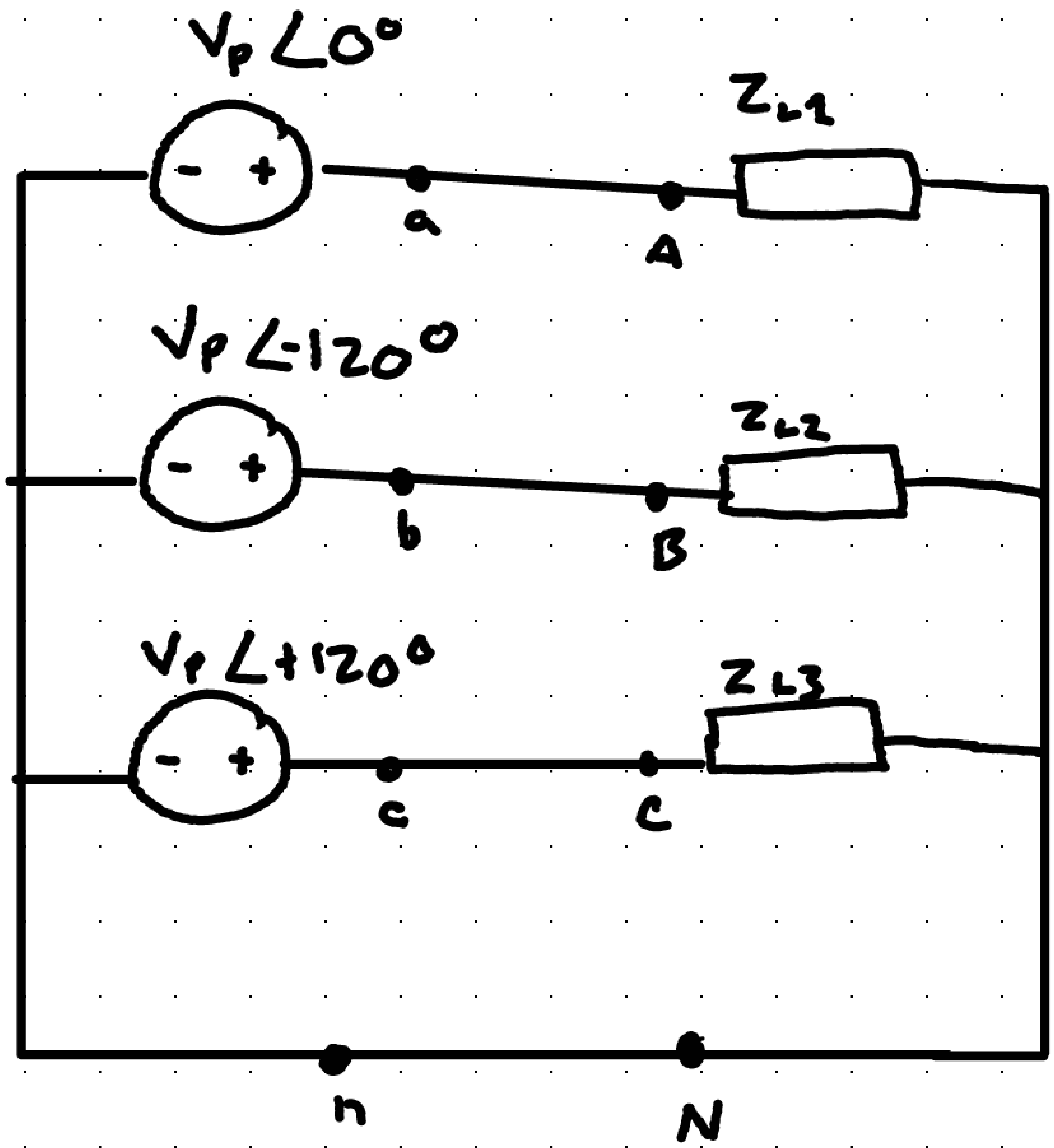
Three phase power

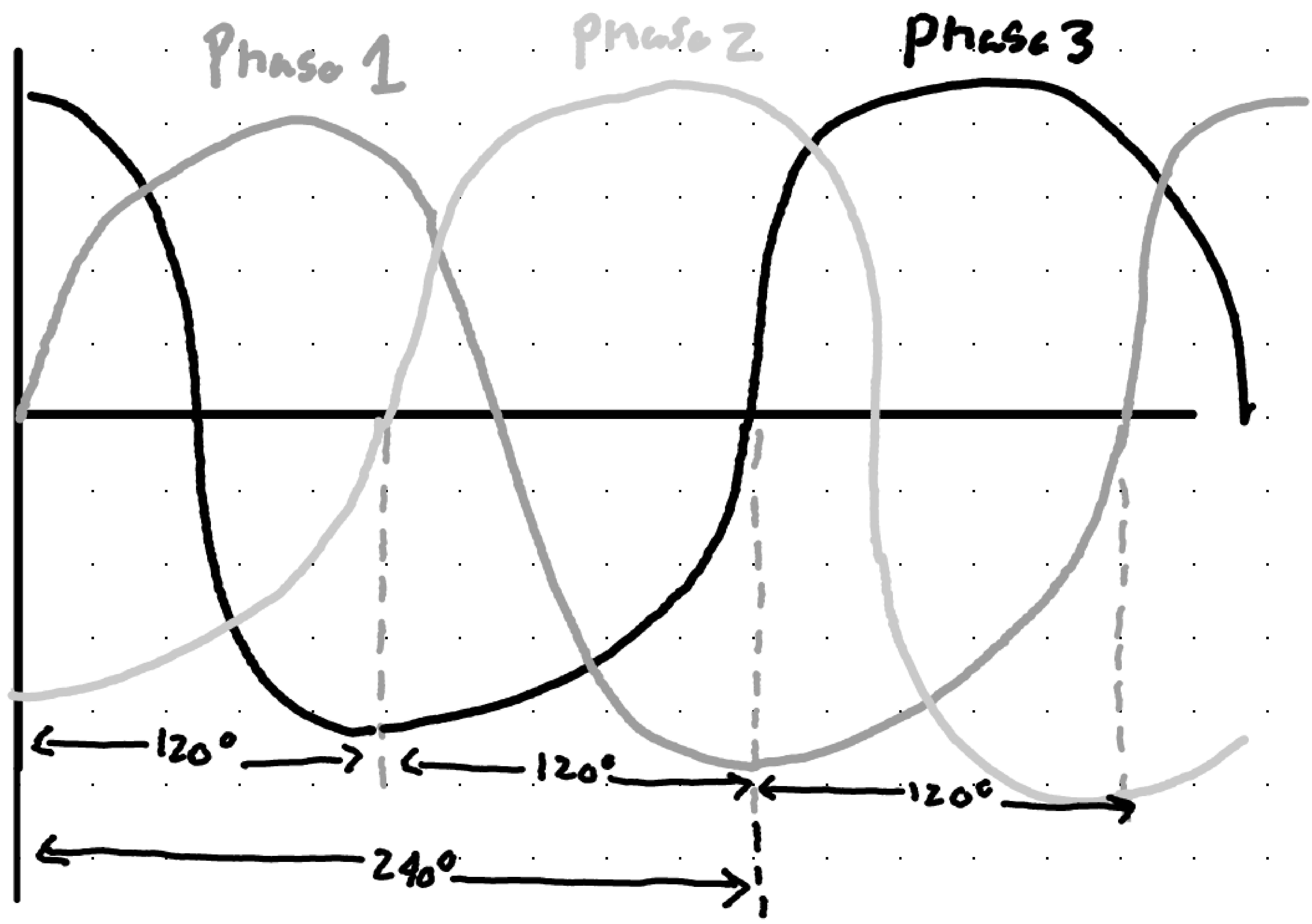


- Three sources connected to three loads using a four wire system
- Sources all have the same frequency, but different phases.

Three-Phase System

- A generator consists of three coils placed 120° apart.
- The voltage generated are equal in magnitude, but out of phase by 120°

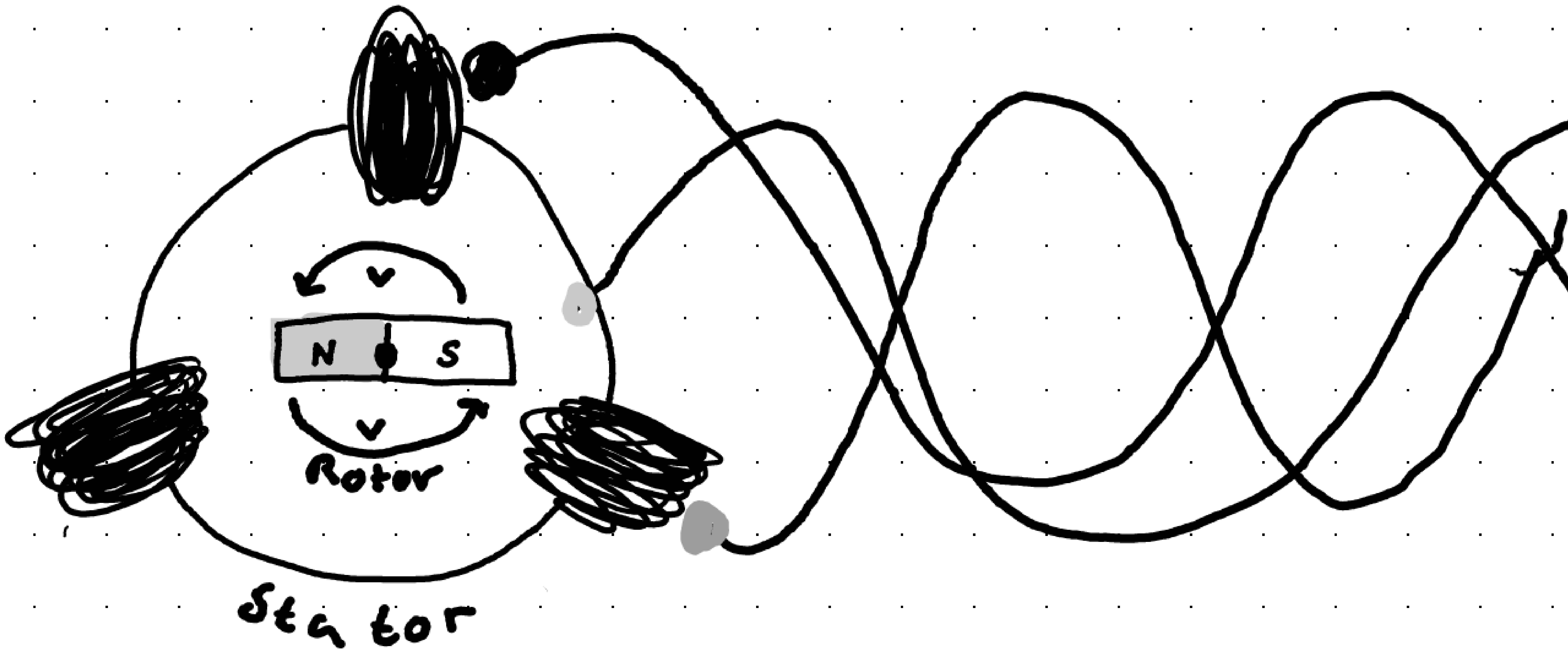
Three phase waveform



Phase 3 lags Phase 1 by 120°
Phase 2 lags Phase 1 by 120°
Phase 2 leads Phase 3 by 120°
Phase 1 leads Phase 3 by 240°

- All electric power systems in the world use the 3-phase system to generate, transmit and distribute electricity

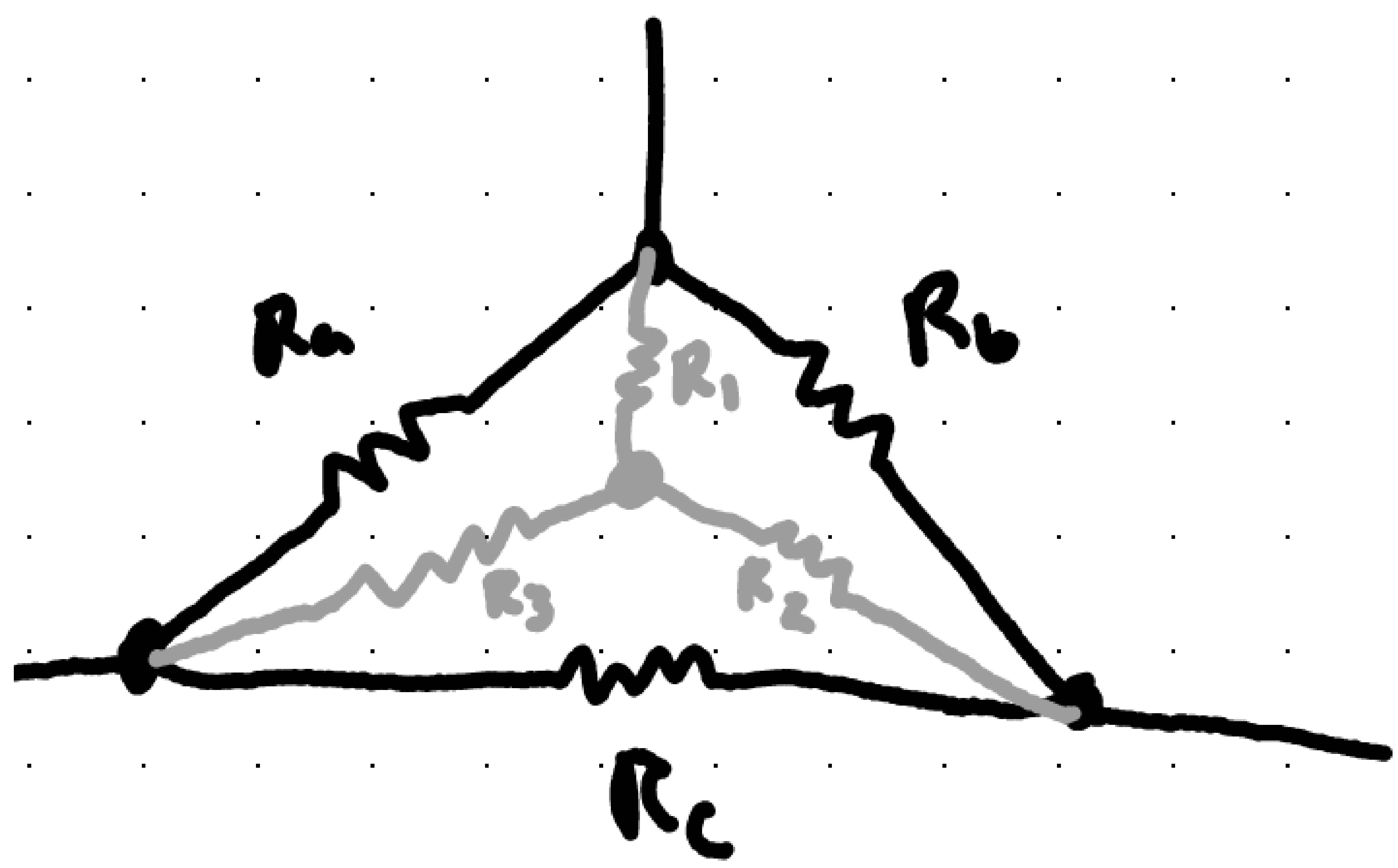
- Instantaneous power of 3-phase is constant (not alternating) and is therefore smoother on electronics.



- As the rotor rotates, its magnetic field induces voltage in the coils
- Again, the induced voltages have equal magnitudes, but are out of phase by 120°

- The generator consists of a rotating magnet (rotor), surrounded by a stationary winding (stator)

Conversion from Delta to wye Connection



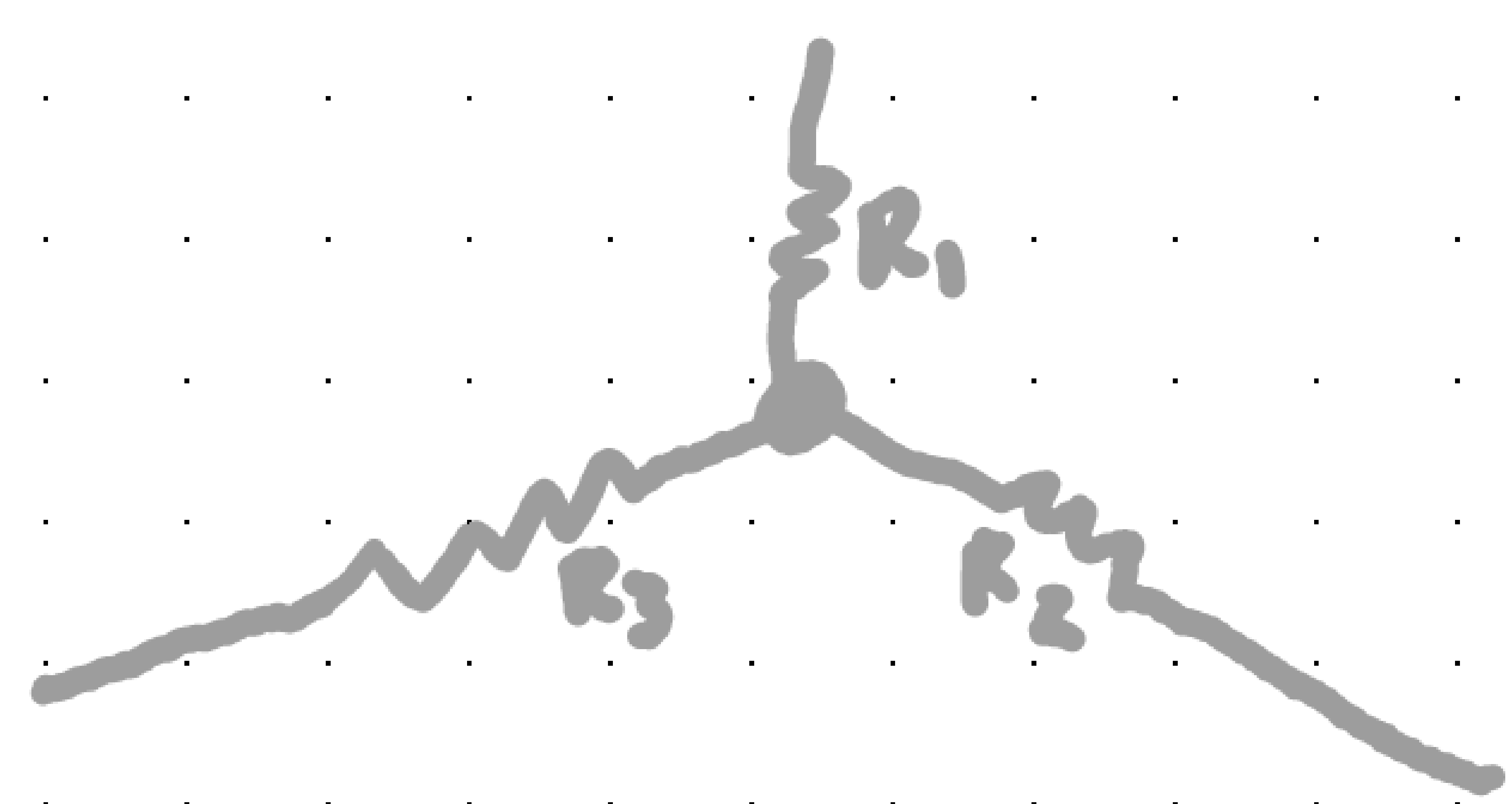
1) From each node, draw a resistor.

$$R_1 = \frac{R_a R_b}{R_a + R_b + R_c}$$

$$R_1 = \frac{R_a R_b}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_a R_c}{R_a + R_b + R_c}$$

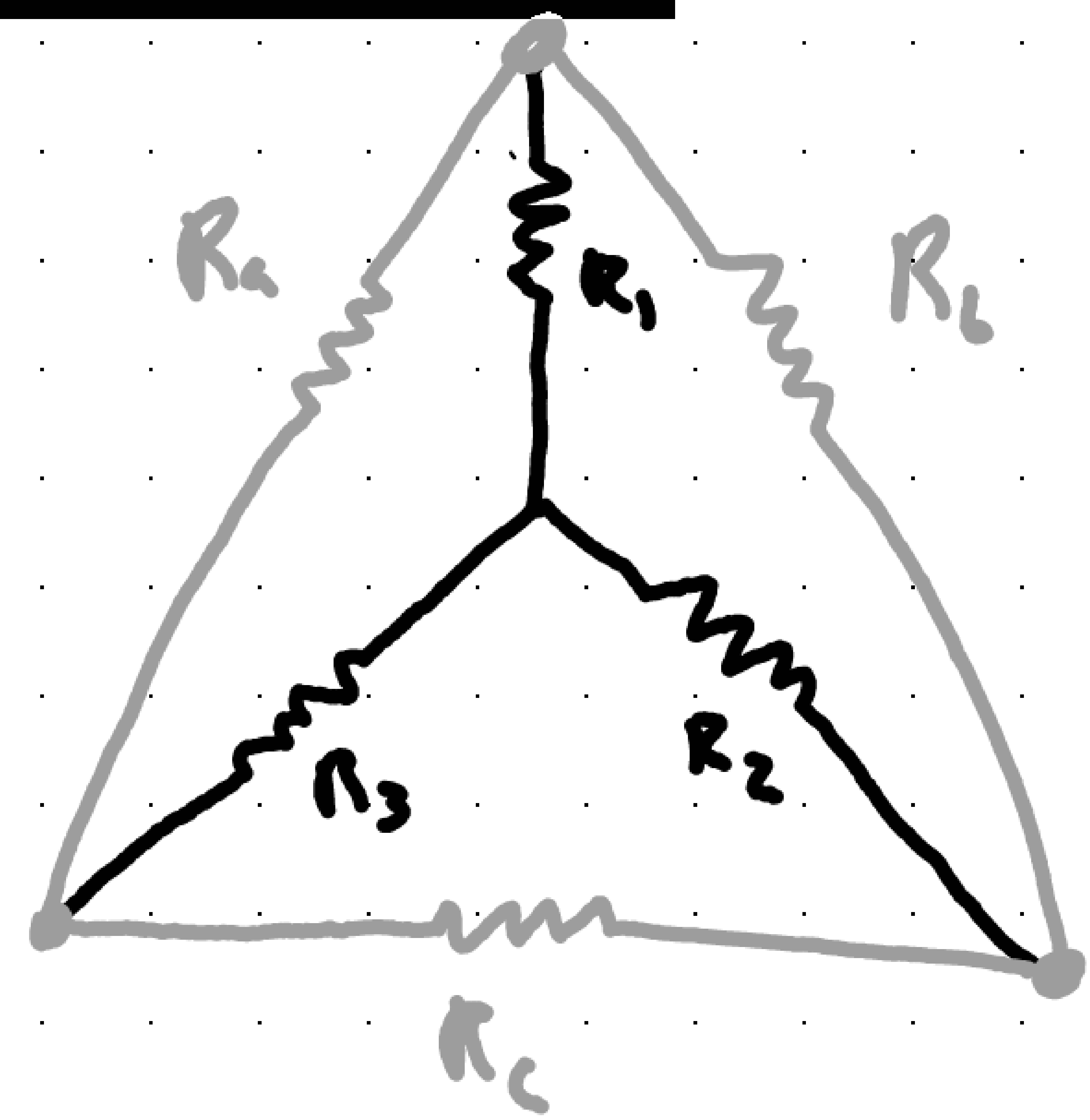


Conversion from Wye to Delta Connection

$$R_a = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$

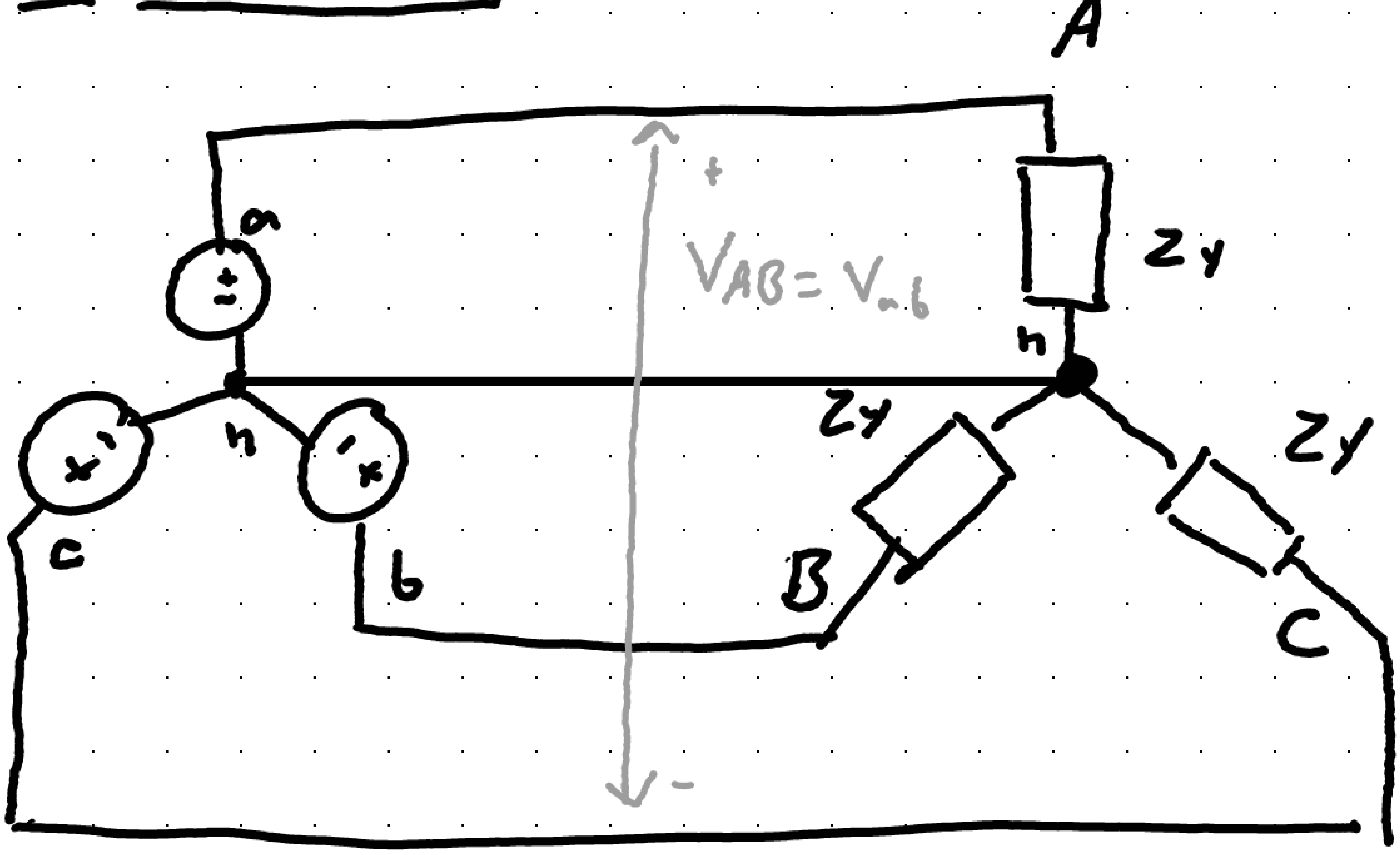
$$R_b = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$R_c = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$



$$\boxed{R_a = R_1 + R_3 + \frac{R_1 R_3}{R_2}}$$

3 Phase System



Phase Voltages

Balanced Three Phase Generator

$V_{an} = V_p \angle 0°$

$V_{bn} = V_p \angle -120°$

$V_{cn} = V_p \angle -240°$

Line Voltages

$V_{AB} = \sqrt{3}\, V_p \angle 30°$

$V_{BC} = \sqrt{3}\, V_p \angle -90°$ -120

$V_{CA} = \sqrt{3}\, V_p \angle +150°$

Line Currents

$$I_a = I_{AN} = \frac{V_{An}}{Z_Y}$$

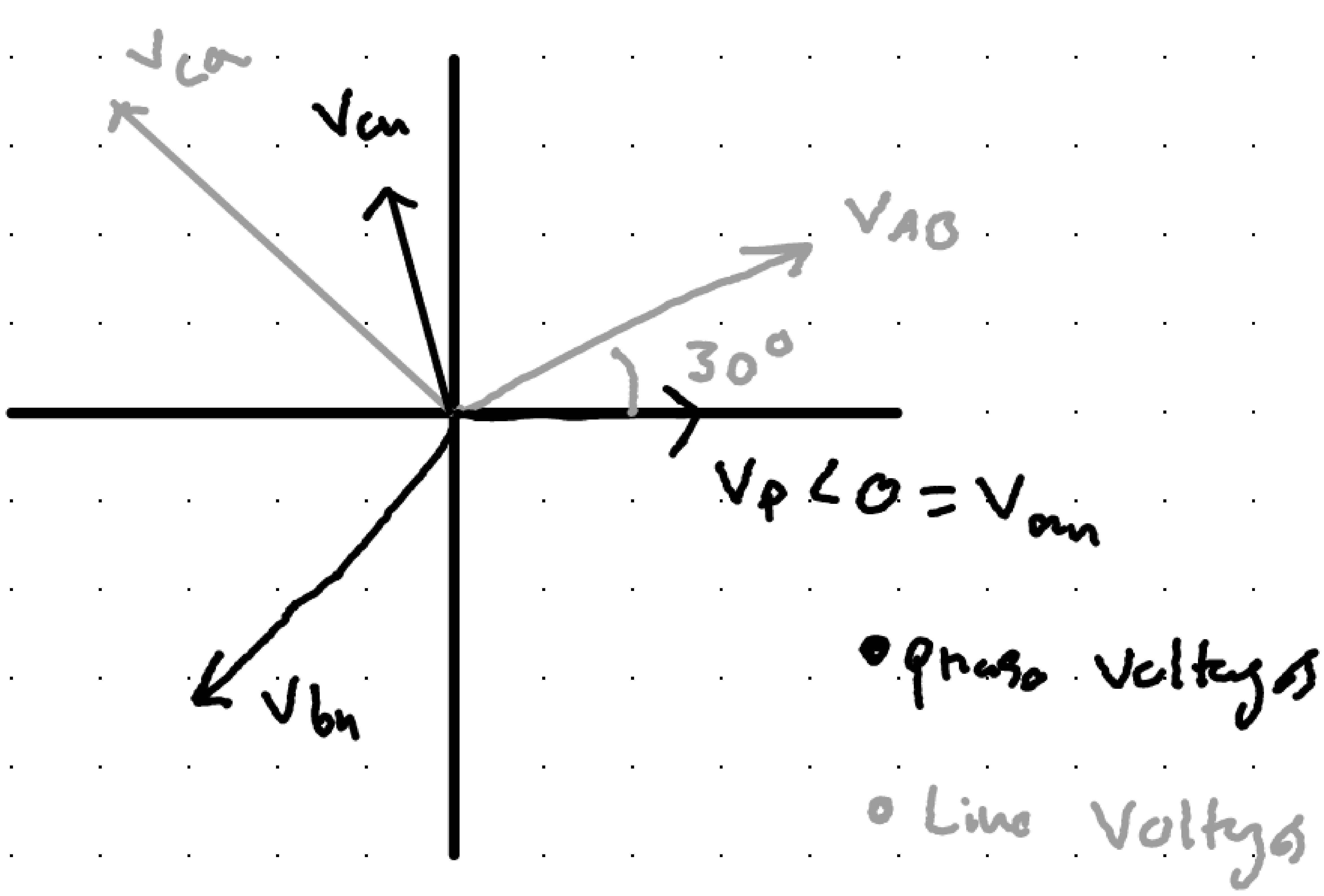
$$I_b = I_a \angle -120°$$

$$I_c = I_b \angle -120°$$

For a balanced 3-phase System:

$$I_n = I_N = 0$$

Phase diagram for voltages



Instantaneous Power

$$p(t) = v(t) \times i(t)$$

for a 3ϕ system $\xrightarrow{}$ Phase

$$P = P_a + P_b + P_c$$

$$= V_{an}(t) * I_a(t)$$
$$+ V_{bn}(t) * I_b(t)$$
$$+ V_{cn}(t) * I_c(t)$$

There is a proof to say..

$$P(t) = 3|V_p||I_p|\cos\phi \text{ W}$$

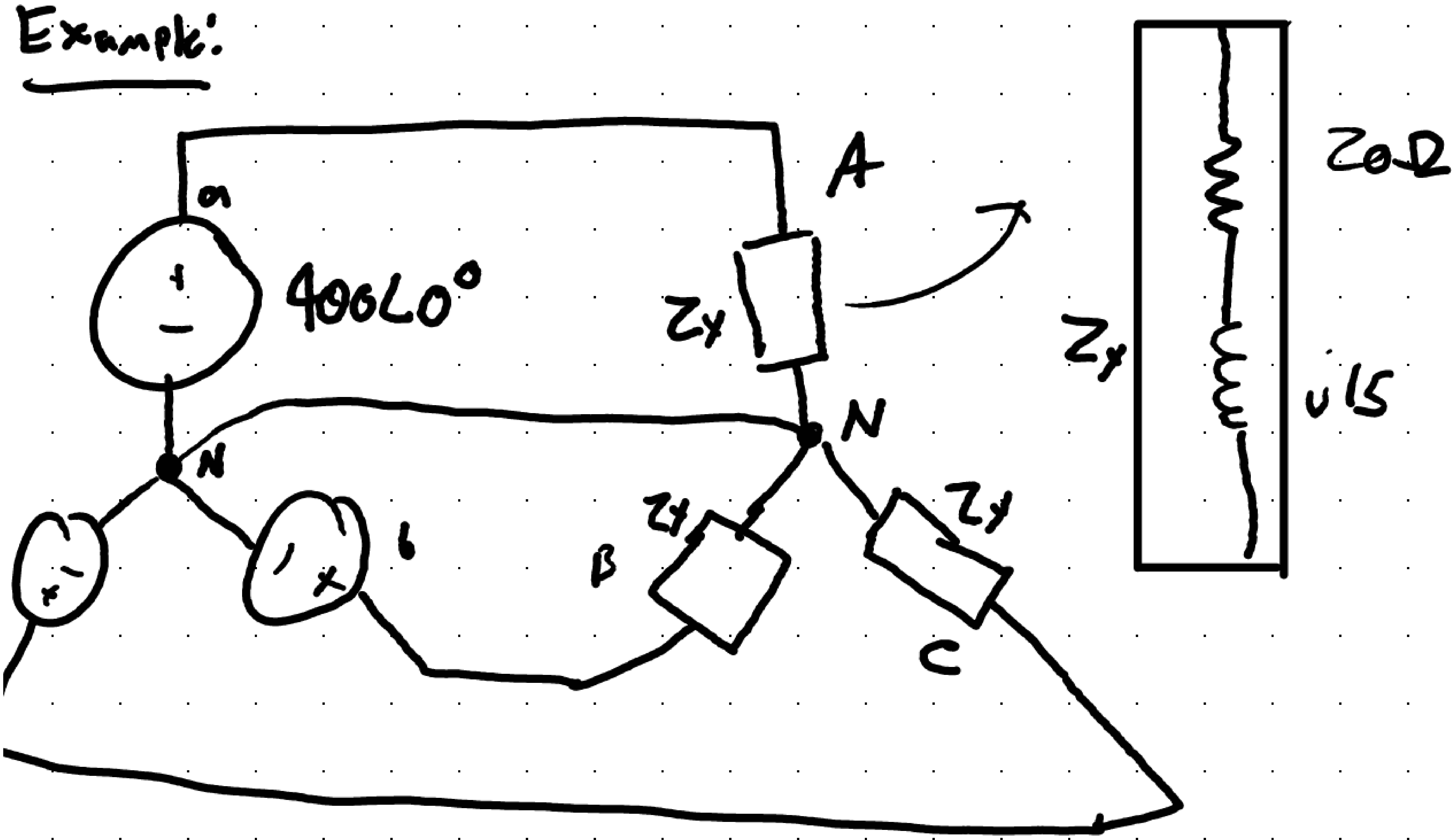
for $\phi = 0$ (purely Resistive)

$$P_{max} = 3|V_p||I_p| \text{ W}$$

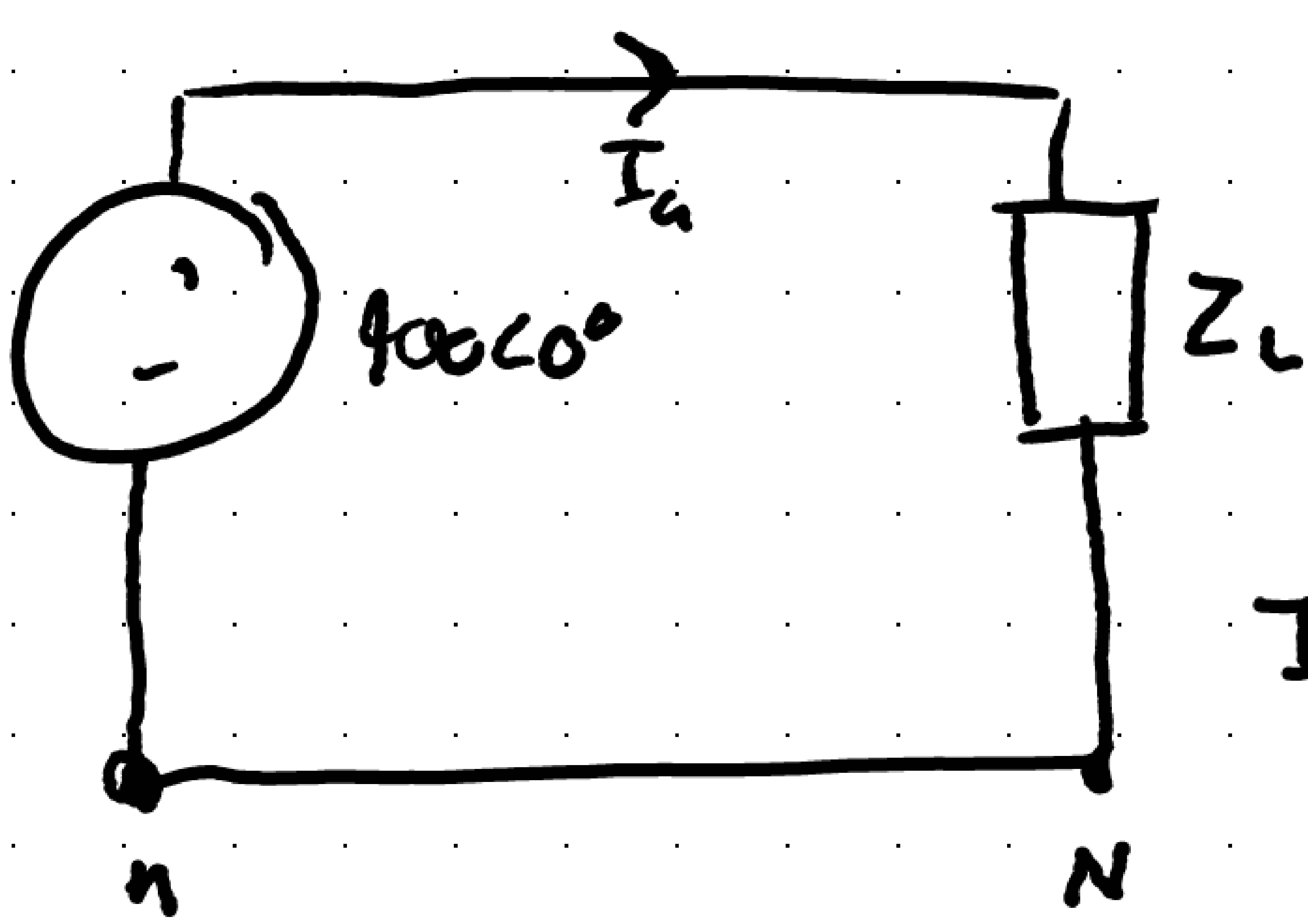
Average Power:

$$P = 3|V_p||I_p|\cos\phi$$

Example:



A Single Phase Equivalent



$$I_a = \frac{V_{an}}{Z_L} = \frac{400\angle 0^\circ}{20 + j15}$$

$$= 16\angle -36.87^\circ \text{ A}$$

$$I_b = I_a \angle -120$$

$$I_c = I_b \angle -120$$

Power Factor, $\cos\phi = \cos(-36.87)$

$= 0.8$

Total power consumed:

$P = \sqrt{3}\,|V_L||I_L|\cos\phi$

Where $V_L = \sqrt{3}V_p \angle 30^\circ$

$|V_L| = \sqrt{3}V_p$

$P = 3|V_p||I_L|\cos\phi$

$P = 3(400)(16)\cos(-36.87)$

$P = 15.36\,KW$

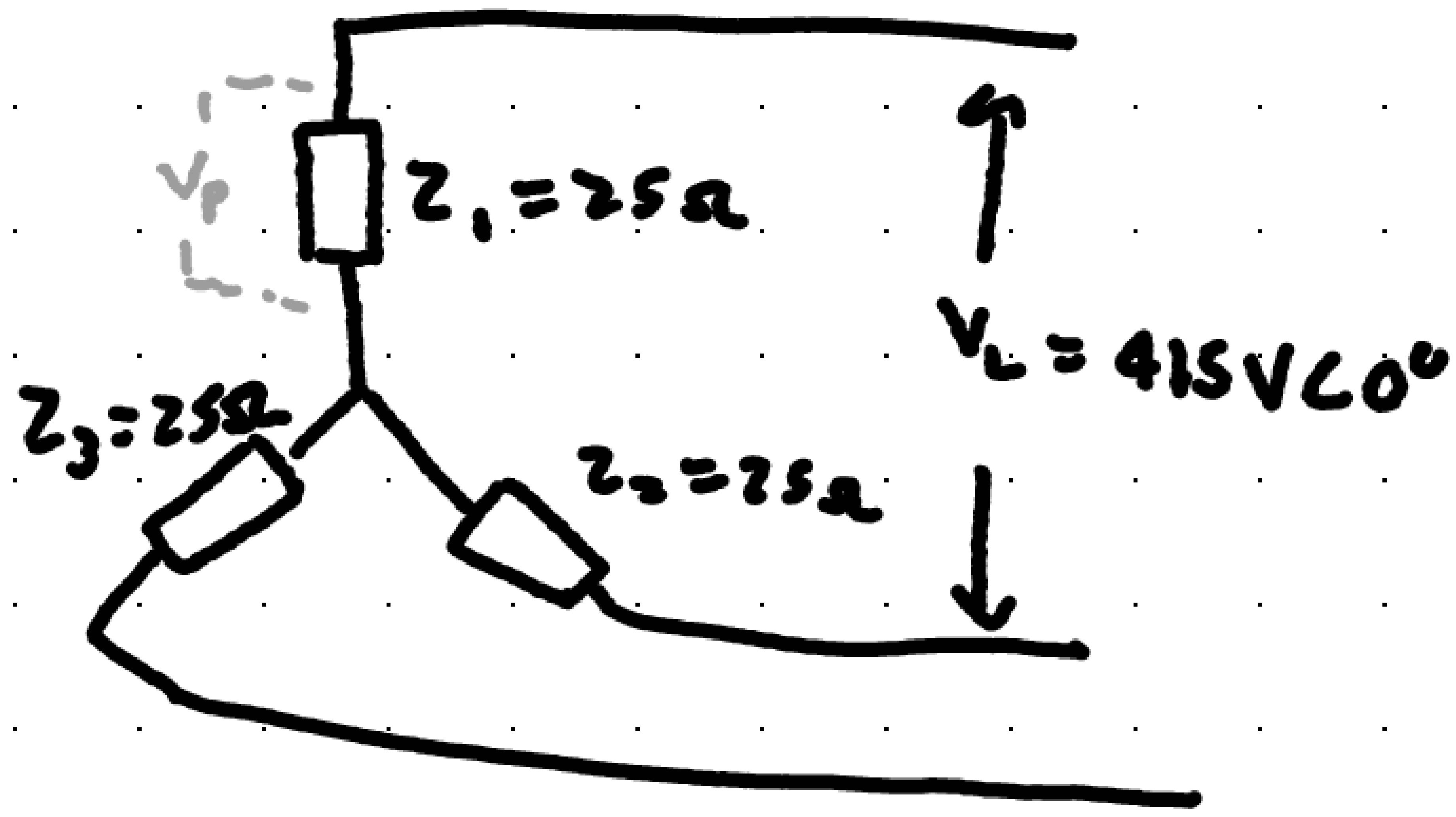
$V_p = 400\angle 0^\circ$

$|V_p| = 400V$

$I_L = I_a = 16\angle -36.87$

$|I_L| = 16A$

Example WYE



$V_L = 415V$

$Z = 25\,\Omega$

Find phase voltage, line current, and phase current.
I_L

$V_p =$
$I_p =$
$I_L =$

$$V_p = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.6V$$

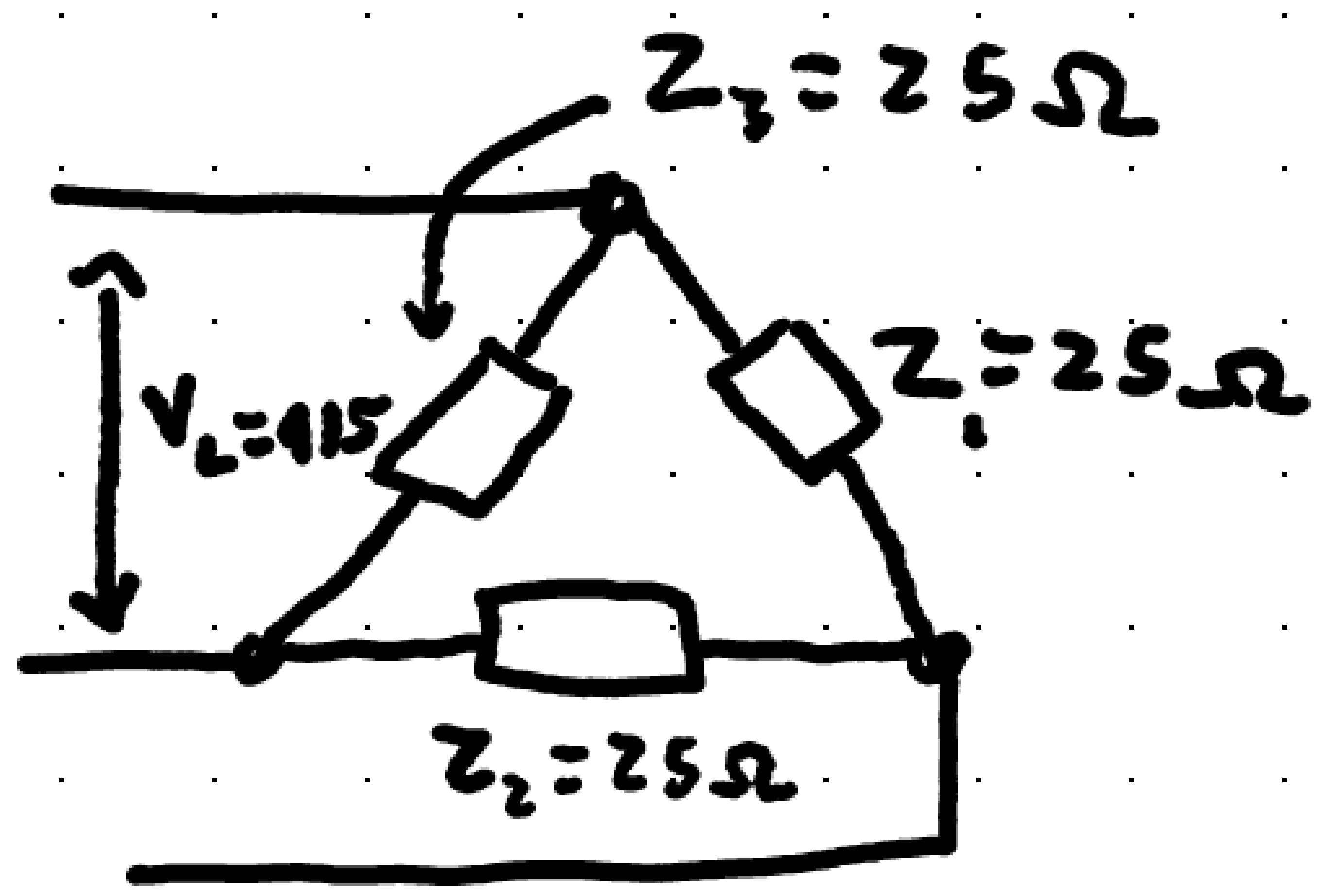
$$I_p = \frac{V_p}{Z_1} = \frac{239.6}{25} = 9.584A$$

$$I_L = I_p = 9.584A$$

I_n WYE ONLY

Example

Delta



$Z = 25\Omega$

$V_L = 415V \angle 0^\circ$

Find:

V_p, I_p, I_L Phase voltage, phase current, line current

$V_p = V_L$ * In delta only

$V_p = 415V \angle 0^\circ$

$I_p = \frac{415}{25} = 16.6A$

$I_L = I_p \times \sqrt{3} = (16.6)(\sqrt{3}) = 28.75A$

In delta

What this demonstrates is that if you take the same load, first connect it in Wye, and then after in delta

The amount of current that flows into the delta system will be ~3X larger