UTS

University of Technology, Sydney
Faculty of Engineering

Subject:	**48530 Power Circuit Theory**
Assignment Number:	**3**
Assignment Title:	**Lab 3 – The Three-Phase Transformer**
Tutorial Group:	

Students Name(s) and Number(s)

Student Number	Family Name	First Name

Declaration of Originality:

The work contained in this assignment, other than that specifically attributed to another source, is that of the author(s). It is recognised that, should this declaration be found to be false, disciplinary action could be taken and the assignments of all students involved will be given zero marks. In the statement below, I have indicated the extent to which I have collaborated with other students, whom I have named.

Statement of Collaboration:

Signature(s)

Marks

Lab Work	/2
Questions	/3
TOTAL	/5

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Assignment Submission Receipt

Assignment Title:	**Lab 3 – The Three-Phase Transformer**
Student's Name:	
Date Submitted:	
Tutor Signature:	

Lab 3 – The Three-Phase Transformer

Transformer sequence voltages, currents and impedances. Leakage and magnetising reactance.

Introduction

Modern electric power systems almost universally use three-phase AC voltages and currents to deliver real power to end-users. The delivery of electric power utilises both a 3-wire system and a 4-wire system, and the loads can be either balanced or unbalanced. It is important to realise what the implications are, in terms of voltage, current and power, for each combination of delivery method and load configuration.

The power factor of a load determines how efficient the delivery of real power to that load can be – the ideal is to have a "unity power factor". Special measures are normally taken in industrial and commercial settings to ensure that the power factor is as close to unity as possible (taking into consideration the usual economic and technical constraints).

A three-phase system has in inherent "order" or *sequence* in terms of the phase of each of the voltages. For a three-phase system there are two possible sequences for the voltage to be in: *abc* or *acb*. The phase sequence is important for three-phase rotating machines, since it determines either a clockwise or anticlockwise direction of rotation.

Unbalanced three-phase systems can lead to large voltages across a load, and is generally an undesirable situation that is avoided in practice.

Objectives

1. To measure the sequence and magnetising impedances of a three-phase transformer.

L3.2

Equipment

- 1 three-phase 240 V, 8A autotransformer – Warburton Franki Variac
- 1 three-phase transformer (Trenco)
- 1 three-phase resistive load, 110 Ω per phase
- 1 AC voltmeter / ammeter – YEW
- 1 digital multimeter
- 1 clip-on auto-ranging wattmeter – YEW
- 1 clip-on power quality clamp meter – Fluke 345

Safety

Cat. B lab

This is a Category B laboratory experiment. Please adhere to the Category B safety guidelines (issued separately).

Warning!

Remember:

1. **Choose suitable METER SCALES and <u>WIND DOWN</u> and <u>SWITCH OFF</u> the supply Variac when making circuit connections.**
2. **<u>Ensure equipment is earthed.</u>**

Theory

1. Winding Arrangement

There are several windings on each limb. The ends of each winding are brought out to terminals and therefore more than one three-phase transformer connection can be made. The primary and secondary windings are concentric. A diagram is shown below:

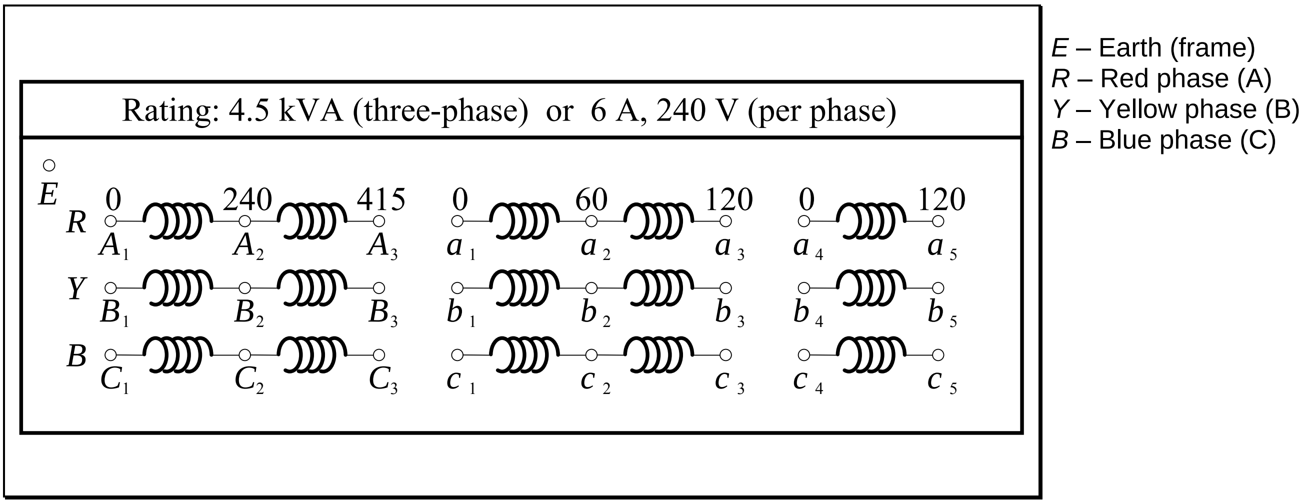


Figure 3.1 – Three-phase transformer windings

2. Magnetic Circuit

The transformer is a three-limbed core type:

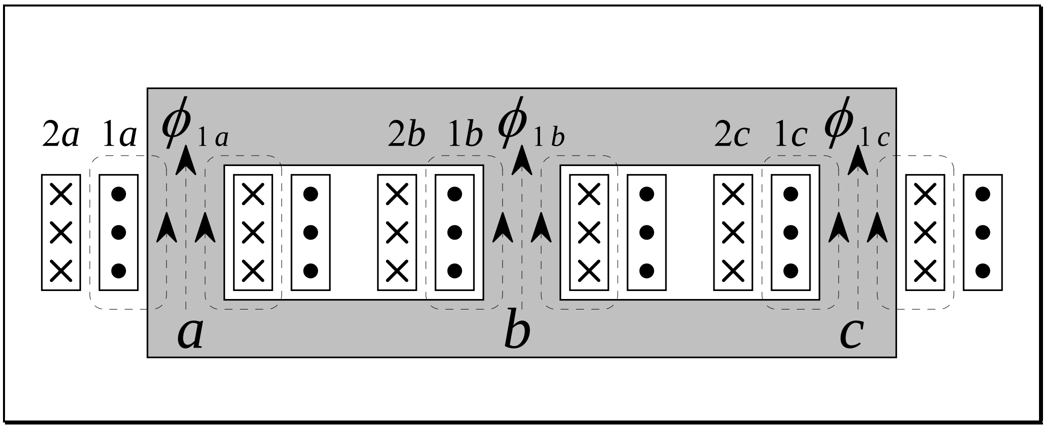


Figure 3.2 – Three-phase transformer construction

The magnetic equivalent circuit is:

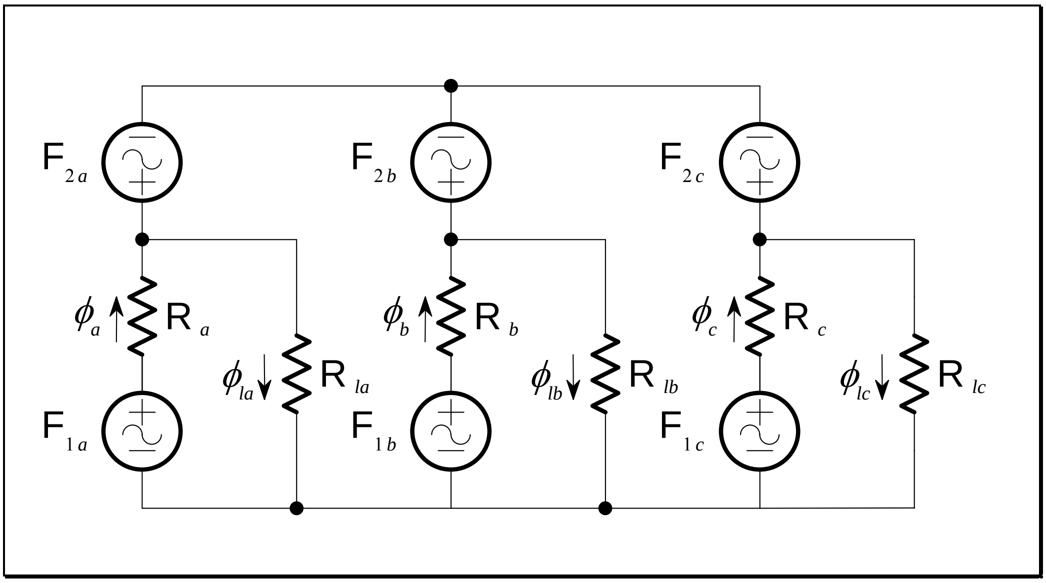


Figure 3.3 – Three-phase transformer magnetic equivalent circuit

In the case of a 3-phase 3-limbed core type transformer there is little zero sequence flux other than that leaking through the air paths from the top to the bottom of the core. In the case of a , the effect of the three-limbed core is similar to that of a high impedance Δ secondary.

Lab Work [1 mark]

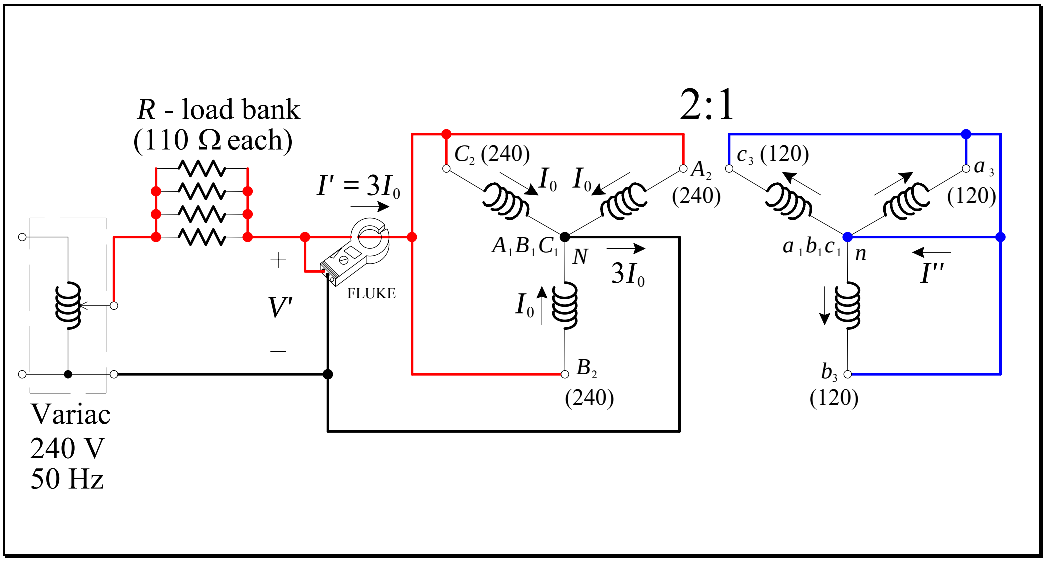
I – Zero Sequence Impedance

1. Y/Y Transformer

1.1 Using the DMM, measure the DC resistance of one phase of the primary 240 V winding and one phase of the secondary 120 V winding.

$R_1 =$	$R_2 =$

1.2 Connect the equipment as shown in the diagram below:



The Fluke clamp meter is used to measure the source voltage and any currents. The DMM is used to measure other voltages

Figure 3.4 – Zero sequence test circuit for a star(earthed)-star transformer

1.3 **<u>Do not connect the supply or turn on the power until circuit connections are checked by a lab tutor</u>**.

1.4 After the circuit has been checked, turn on the Variac and bring up the voltages until the current $|I'| = |3I_0| = 5.4$ A RMS.

L3.6

1.5 Measure voltage and current on the primary side of the transformer:

Primary voltage:	$\lvert V' \rvert =$
Primary current:	$\lvert I' \rvert =$

1.6 Calculate the transformer's parameters (referred to the primary):

$Z_b = \dfrac{(V_{base})^2}{S_{base}} = \dfrac{(\sqrt{3} \times 240)^2}{4500} =$	Ω
$R_0 =$	p.u.
$\lvert Z_0 \rvert = \dfrac{\lvert V_0 \rvert}{\lvert I_0 \rvert} = \dfrac{\lvert V' \rvert}{\lvert I'/3 \rvert} =$	p.u.
$X_0 = \sqrt{\lvert Z_0 \rvert^2 - R_0^2} =$	p.u.

1.7 Measure the secondary neutral current with the Fluke clamp meter:

$\lvert I'' \rvert =$

1.8 Measure the voltage between the neutral points with a DMM:

$\lvert V_{Nn} \rvert =$

1.9 Draw the zero sequence equivalent circuit of the transformer.

Explain:

1.10 <u>Wind down and switch off the Variac.</u>

2. Y⏚/Y Transformer

2.1 Remove the connection to the neutral on the secondary winding.

2.2 Leave the secondary terminals **short-circuited**.

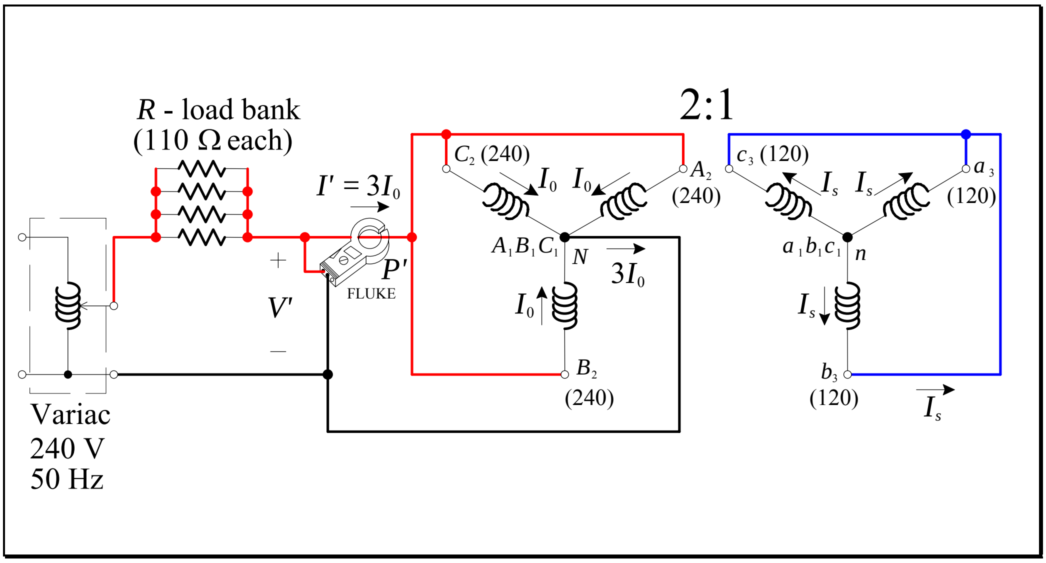


Figure 3.5 – Zero sequence test circuit for a star-star transformer

2.3 If $|I'| = 5.4\text{ A}$, predict:

$|I_s| =$

Explain:

2.4 If $|I'| = 5.4\text{ A}$, would you expect:

- V' (and $\therefore Z_0$) to be:

  a) larger
  b) equal
  c) smaller

  than V' measured in 1.

- Z_0 to be a:

  a) magnetising
  b) leakage

  impedance.

- The current in each primary winding to be:

  a) the same.
  b) different.

Give explanations.

(Use Faraday's Law, Ampère's Law and the magnetic equivalent circuit)

2.5 Turn on the Variac and bring up the voltages until the current $|I'| = |3I_0| = 5.4\text{ A}$.

2.6 Measure voltage, current and power on the primary side of the transformer:

Primary voltage:	$\lvert V' \rvert =$
Primary current:	$\lvert I' \rvert =$
Primary power:	$P' =$
Secondary winding current:	$\lvert I_s \rvert =$

2.7 Calculate the transformer's parameters (referred to the primary):

$\frac{1}{3} R_0 = \frac{P'}{\lvert I' \rvert^2} =$ Compare with the R_0 measured in Part 1.	p.u.
$\lvert Z_0 \rvert = \frac{\lvert V_0 \rvert}{\lvert I_0 \rvert} = \frac{\lvert V' \rvert}{\lvert I'/3 \rvert} =$	p.u.
$X_0 = \sqrt{\lvert Z_0 \rvert^2 - R_0^2} =$	p.u.

2.8 Draw the zero sequence equivalent circuit of the transformer.

Explain:

2.9 Use the clamp meter to measure the current in each **primary** winding:

$\lvert I'_A \rvert =$	$\lvert I'_B \rvert =$	$\lvert I'_C \rvert =$

2.10 If predictions do not equal measurements, try to explain why:

2.11 With the secondary terminals **open-circuited**, set $\lvert I' \rvert = 5.4\ \text{A}$.

2.12 Measure the primary voltage:

$\lvert V' \rvert =$

2.13 Calculate the zero sequence impedance:

$\lvert Z_0 \rvert =$ p.u.

2.14 Draw the zero sequence equivalent circuit of the transformer.

Explain:

2.15 <u>Wind down and switch off the Variac.</u>

2.16 Compare and explain the results of 2.7 and 2.13.

3. Y/Δ Transformer

3.1 Connect the transformer secondary in a delta. Label the Δ terminals in the figure below:

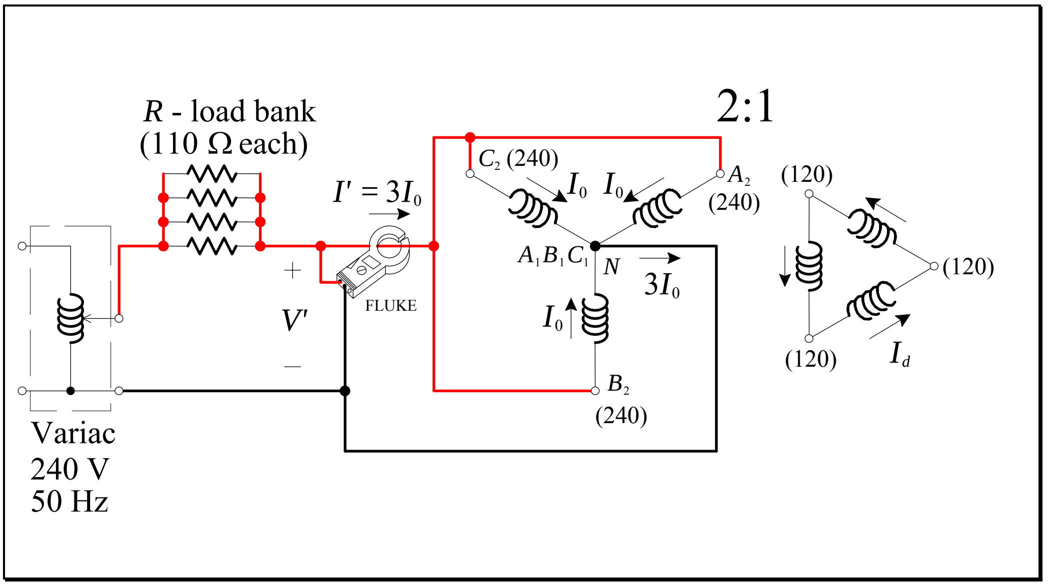


Figure 3.6 – Zero sequence test circuit for a star(earthed)-Δ transformer

3.2 Measure voltage, current and resistance on the primary side of the transformer:

Primary voltage:	$\lvert V' \rvert =$
Primary current:	$\lvert I' \rvert =$
Primary DC resistance (per phase):	$R_0 =$

3.3 Using a DMM, measure voltages to "earth" (the primary neutral) on the secondary side of the transformer:

$\lvert V''_a \rvert =$	$\lvert V''_b \rvert =$	$\lvert V''_c \rvert =$

3.4 Measure the secondary current:

Secondary current:	$\lvert I_d \rvert =$

L3.16

3.5 Calculate the transformer's parameters (referred to the primary):

$$Z_0 = R_0 + jX_0 = \_\_\_\_\_ + j\,\_\_\_\_\_ \quad \text{p.u.}$$

3.6 Draw the zero sequence equivalent circuit of the transformer.

Explain:

3.7 If the secondary line terminals were shorted to "earth" (the primary neutral), what would be the resulting current?

3.8 Is Z_0 a leakage or magnetising impedance?

3.9 Is the delta secondary a short-circuit to zero sequence currents?

4.1 Compare the values of Z_0 calculated for each of the three transformer winding configurations (Parts 1, 2 and 3 above):

II – Positive and Negative Sequence Leakage Impedance

1. **Check the transformer's current rating – do NOT exceed the rating for the following test.**

2. Perform a single-phase short-circuit test on any one of the three phases. (Note: There will be small differences due to the asymmetry of the magnetic circuit.)

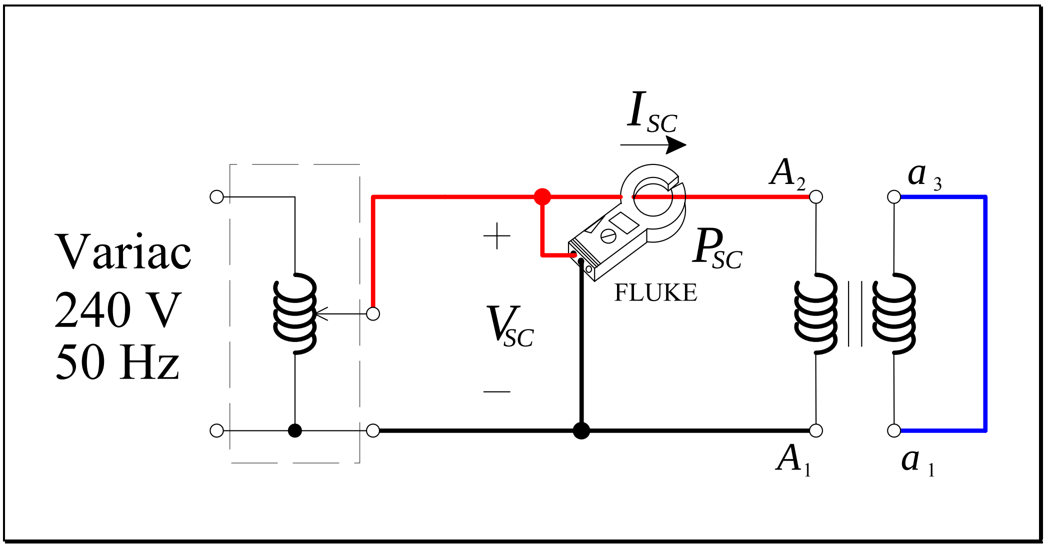


Figure 3.7 – Positive and negative sequence test circuit for leakage *Z*

3. Measure voltage, current and power on the primary side of the transformer:

Primary voltage:	$\left\|V_{SC}\right\| =$
Primary current:	$\left\|I_{SC}\right\| =$
Primary power:	$P_{SC} =$

4. Calculate the transformer's parameters (referred to the primary):

$R_1 = \dfrac{P_{SC}}{\lvert I_{SC}\rvert^2} =$ p.u. Compare with the R_0 measured in Part 1.
$\lvert Z_1\rvert = \lvert Z_2\rvert = \dfrac{\lvert V_{SC}\rvert}{\lvert I_{SC}\rvert} =$ p.u.
$X_1 = \sqrt{\lvert Z_1\rvert^2 - R_1^2} =$ p.u.

5. Compare R_1 and R_0.

Explain.

III – Positive and Negative Sequence Magnetising Impedance

1. **The circuit that would be used is shown below.**

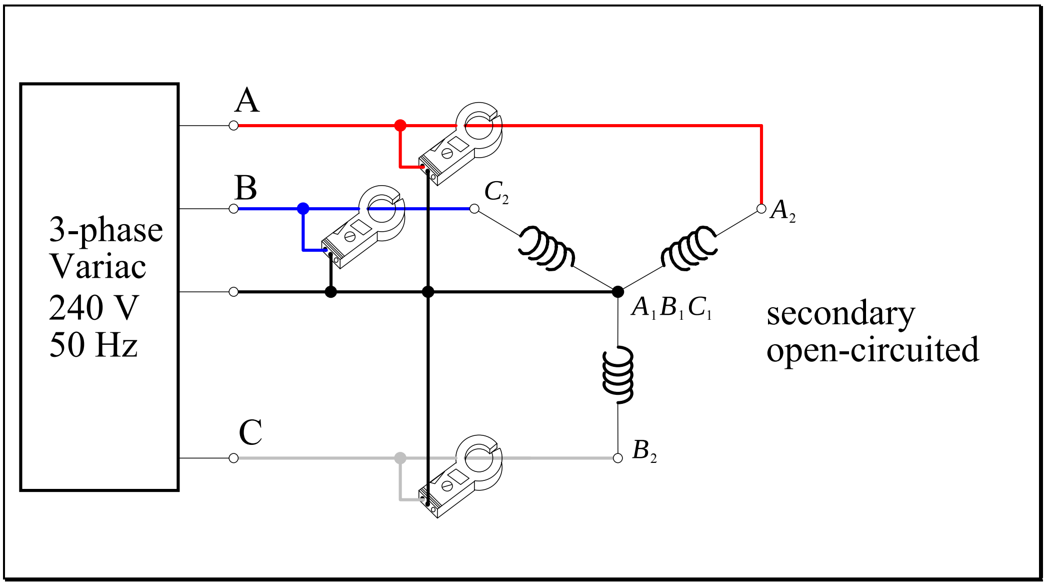


Figure 3.8 – Positive and negative sequence test circuit for magnetising *Z*

2. Explain why such a circuit is used. How would R_{1m}, X_{1m} and Z_{1m} be determined?

Explain.

IV – Zero Sequence Magnetising Impedance

1. How would you determine Z_{0m}? Draw equivalent circuits and write down the relevant equations. Draw the experimental setup, identifying the equipment to be used.

L3.22

Report

Only submit ***ONE*** report per lab group.

Complete the assignment cover sheet and attach your pre-work.

Ensure you have completed:

1. ***Pre-Work*** – hand analysis.

2. ***Lab Work*** – all tables completed.

3. ***Post-Work*** – all questions answered.

The lab report is due in exactly two (2) weeks.