PSL20

Transformer Trainer

User Guide

TecQuipment has taken care to make the contents of this manual accurate and up to date. However, if you find any errors, please let us know so we can rectify the problem.

TecQuipment supplies a Packing Contents List (PCL) with the equipment. Carefully check the contents of the package(s) against the list. If any items are missing or damaged, contact TecQuipment or the local agent.

AB/DB/aw/bs/BW/1118

TECQUIPMENT

Symbols used in this manual

NOTE	*Important information*
CAUTION	*Failure to carry out this instruction could cause damage to the apparatus, other equipment, personal property, or the environment.*
WARNING	***Failure to carry out this instruction could cause personal injury.***

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The Transformer Trainer

Introduction

Figure 1 The Transformer Trainer (PSL20)

Transformers are key elements of any power system. They reduce transmission costs and efficiently distribute electrical power to consumers. Most are mechanically simple, with two or more windings coupled by a magnetic circuit, but their theory and variety of uses is complex. They work with powers of a few kilowatts up to several hundred megawatts.

The TecQuipment Transformer Trainer (PSL20) is part of TecQuipment's Power System Laboratory (PSL) range. You can install and use it stand-alone for transformer based experiments, but you may also connect it to other parts of the range for even more experiments.

The Trainer includes different transformers, power supplies, instruments and loads. It allows students to do a full range of experiments that show the characteristics and performance of power transformers.

Tests on the Educational Transformers

Safety During Experiments

Any laboratory equipment operating at high voltages is dangerous and must be maintained and operated with care by responsible personnel including students. There are many safety features in this equipment but you must obey these rules:

- REMEMBER - If you are using other modules, the supply from the other module may be connected to some of the circuits in this unit.
- NEVER remove connecting leads when there is a voltage on the circuit.
- NEVER use water or a damp cloth to clean the front panels.
- ALWAYS work in pairs.
- BE AWARE of resuscitation techniques.
- NEVER use damaged leads. Inspect all leads before use.

Take Care - Even With Low Voltage

Always take care. Remember that transformers increase and decrease (step up and step down) voltages. So, even when you connect a low voltage to the transformer, all its connections will be live, and some may have high voltages. This is especially important with the three-phase transformer because it has a shared core.

Insulated Connectors and Instruments

For safety, always use shrouded connectors to the transformers and any instruments you use. Never use connectors with bare or exposed metal.

Disconnect Power

Always switch off the supply before you change your circuit.

Important Notes

Before Each Use

Ask a qualified person to:

- Inspect all connecting leads, and replace any that show signs of damage or wear.
- Ensure the locks on the rear doors are effective and in place.
- Check the fronts of all the instruments for damage.

- Check that all the indicator lamps operate.

Connection to Supplies

Always use the variable supply (link TP1 and use TP2a as your supply) on all phases and set the autotransformer to minimum before beginning an experiment. This is good practice because:

1) You find connection errors in the circuit before you damage it.

2) The fuses in the autotransformer circuit give added protection. The educational transformers do not have fuses. You can use them in so many different ways that fuses on each tapping are not practical.

3) You can set the correct voltage you need for your test and make small adjustments if necessary.

Parallel Winding Connections

For good reasons, the transformers have no special construction to equalise the reactance between pairs of coils intended for operation in parallel. Therefore the winding sections will not divide the load current equally and one section will take a current corresponding to more than half the load.

The insulation of the transformers has a temperature limit of 155°C, which allows overloading for short periods, when the transformers are used in ambient temperatures below 30°C.

When using the transformers continuously with any windings connected in parallel, reduce the ratings to 0.8 of their nominal values to avoid local overheating.

Abnormal Voltages and Harmonics

You can exceed the nominal working voltages by up to 16% provided you reduce the output currents similarly, so you do not exceed the transformer ratings.

This is useful to show harmonics. For example, when the transformers are on light load, you can see harmonic distortion of the current and voltage waveforms in a three-phase transformer bank connecting the primaries in star arrangement. Use the 120 V connections instead of the 138 V connections. This will give a 15% increase in applied voltage and therefore also in flux density, showing a significant increase in harmonics.

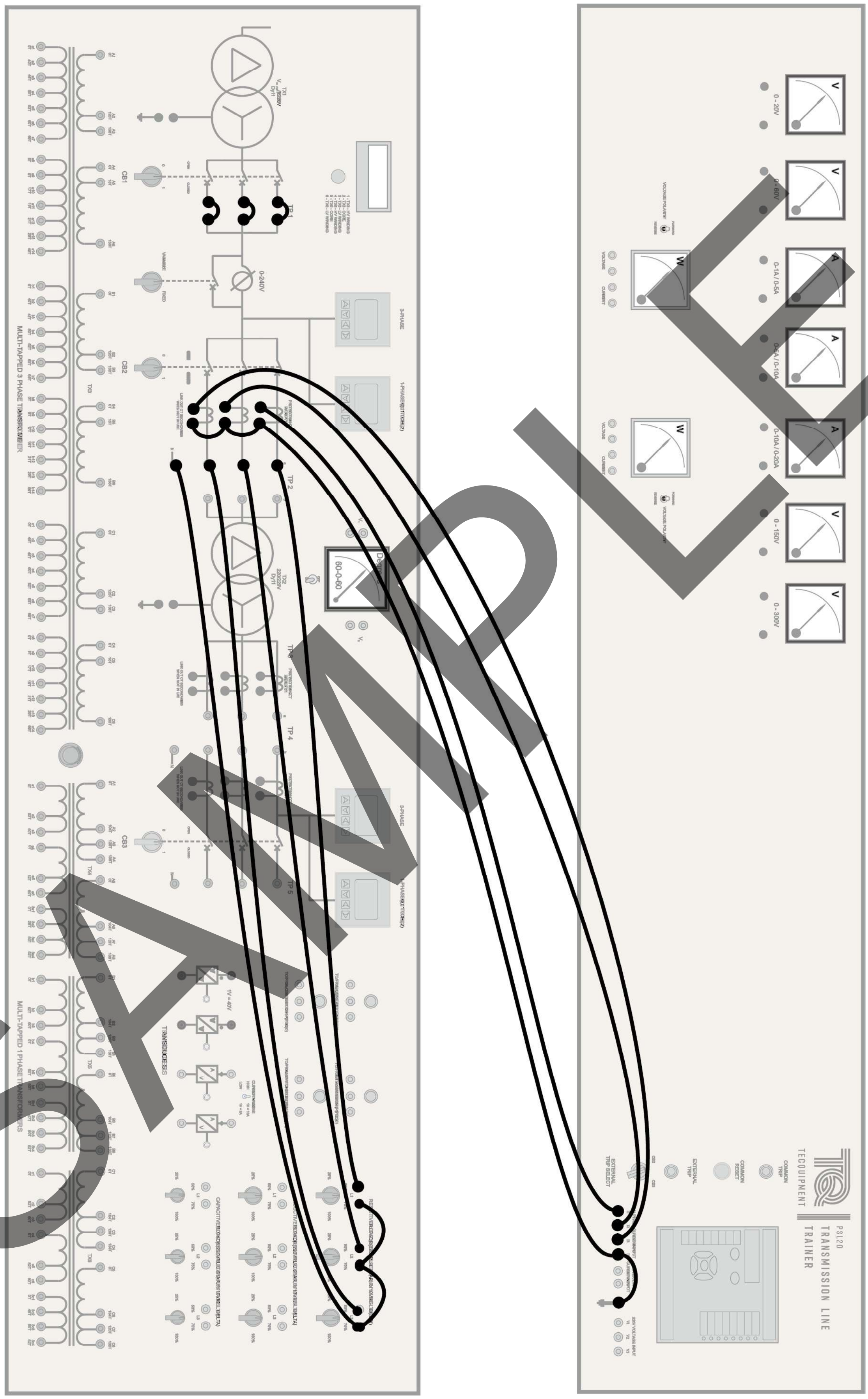

Figure 40 Supply Connections with Protection

Test 1 - Overcurrent Protection with the Relay, and Circuit Familiarisation

Aim

To show how to use a protection relay for overcurrent protection and help students to understand the supply and resistive loads of the three-phase circuit.

Procedure

1) Connect the three-phase circuit to the relay and resistive loads as shown in Figure 40. Note that you have connected the loads in star.

2) Set the relay for overcurrent protection of 4.55 A and set the loads to 25%. To set the overcurrent protection of 4.55 A, you set In to 0.65. The relay multiplies this by its own maximum rating (1 A) and the CT ratio that you conect to (7/1), so 0.65 x 1 x 7 = 4.55 A.

3) Set the VARIABLE/FIXED switch (between CB1 and CB2) to the VARIABLE position and adjust the autotransformer (on the lowest panel) to its minimum position, fully anticlockwise.

4) Switch on the supply and shut CB1 and CB2. Use the multifunction meters to measure the voltages and currents, which should be low. Slowly turn the autotransformer to increase the line to line (L-L) voltage to 230 V and note the increase in current and power.

5) Change the settings of each of the loads and note the voltage and current readings. Try all loads at the same values (for example - 50%) and try unbalanced loads at different settings (for example 25%, 50% and 75%).

6) Reduce the supply to minimum. Set the loads to full (100%) and use the autotransformer to slowly increase the voltage, while using the multifunction meters to measure the line voltage and current. The relay should trip before you reach full voltage, protecting the circuit from currents greater than 4.55 A. It should open CB1 and CB2.

7) Reset the relay, turn the autotransformer down and shut CB1 and CB2.

8) Set just one of the loads to 100%, and the others to 25%. Increase the voltage again until the relay trips. Use the relay to find which phase caused the overcurrent trip (it should be the one with the 100% load).

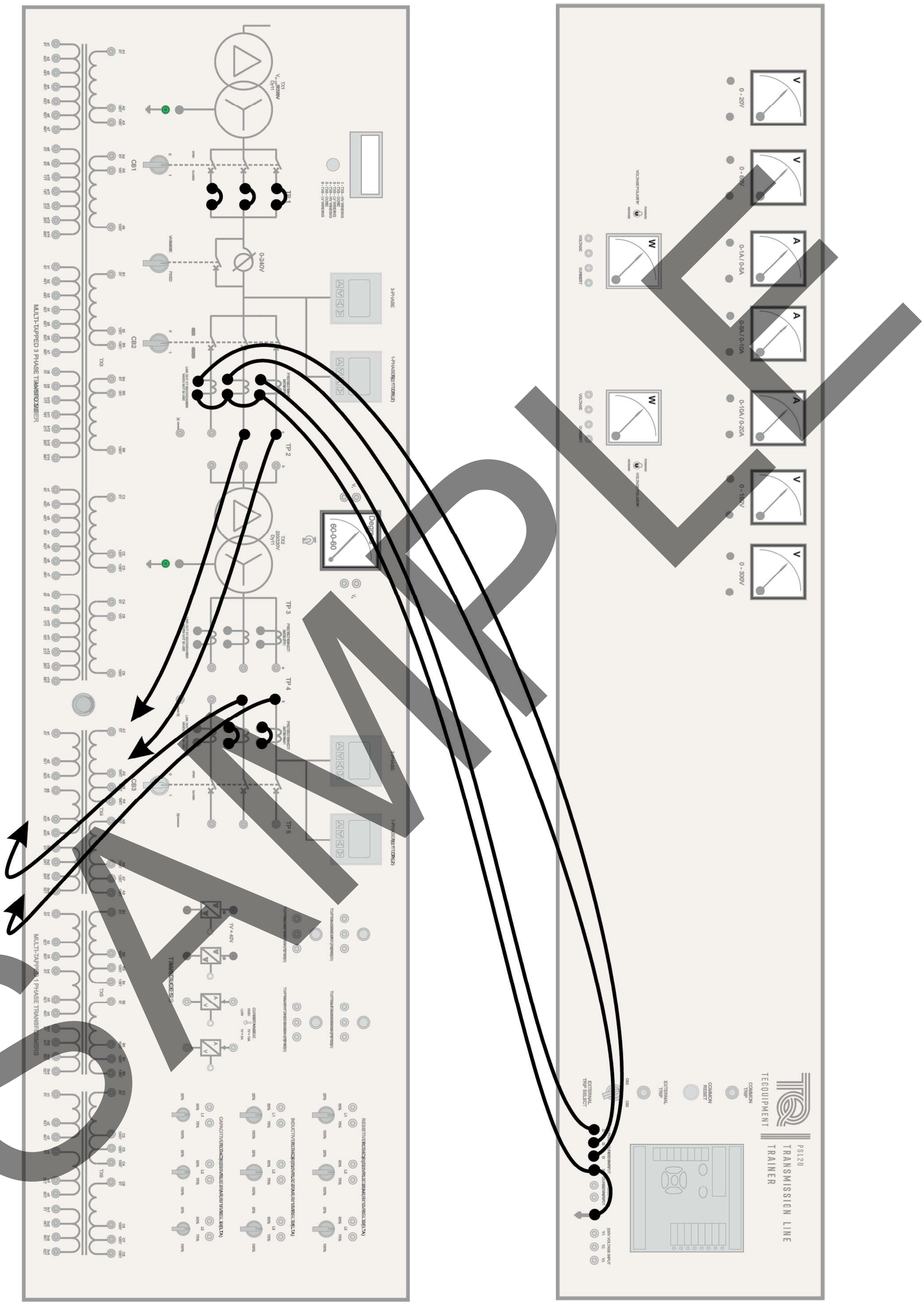

Figure 41 Connection for Experiment 2 Procedure 1 - Single Phase Tests

Test 2 - Single Phase Transformers - No load Voltage and Ratio Checks

Aims

To show students how the one turn per volt educational transformers work.

Procedure 1 - No Load Voltage and Ratio

1) Connect the circuit as in Figure 41. This circuit includes the protection relay in the supply for extra protection during your experiment. The relay does not need its voltage connections of Experiment 1.

2) You use the two flying leads of the supply to energise the primary windings of the transformers. The first (left-hand) 1 phase meter will show the supply voltage. You use the other two flying leads with the second 1 phase meter to measure the voltages on the secondary windings of the transformers.

3) Create a blank results table, similar to Table 14.

4) Use the red transformer (TX4). Connect the supply leads to tappings A1 and A3 of its primary windings and connect the other two flying leads to the secondary tappings a1 and a3 of the transformer. Shut CB1 and CB2 and carefully adjust the primary supply voltage to match the tappings that you connect. For example, if the primary windings has tappings of 0 and 120 turns, apply 120 volts across this winding. ***Use the autotransformer to reduce the supply voltage, then open CB1 before you change any connections.***

5) Measure the voltages on the secondary and tertiary windings as you apply primary voltages and check that they match the number of turns and confirm the one-volt-per turn specification.

6) Now reconnect the supply to the A1 and A2 primary terminals. Set the supply to 104 V and measure the secondary voltage on a1 and a2.

7) As in Table 14, use the primary and secondary voltages of a complete winding to calculate the no load voltage ratio of each transformer.

8) Reduce the supply to 60 V and 52 V (half the normal voltages) and redo each test.

9) Note the ratio between the primary and secondary voltages and see that it approximately matches the turns ratio.

Primary Connections Used	Primary Voltage	Secondary Connections Used	Secondary Voltage	No Load Voltage Ratio (primary/secondary)	Turns ratio
A1 and A3	120 V	a1 and a3			
A1 and A2	104 V	a1 and a2			
A1 and A3	60 V	a1 and a3			
A1 and A2	52 V	a1 and a2			

Table 14 Blank Results Table

Procedure 2 - Series and Parallel Windings

Try the series and parallel primary and secondary connections suggested in Table 4 on page 15, Table 5 on page 16, Table 6 on page 17 and Table 7 on page 18.

Set the primary voltages as shown and measure the secondary voltages. ***Never exceed the recommended voltages.*** Again, calculate the voltage ratio to see that it matches the turns ratio.

Procedure 3 - Phasing of Windings

1) Connect the primary windings in series for a 240 V supply as in HWS1 of Table 4 on page 15.

2) Connect the secondary windings in series for a secondary voltage of 120 V as in LWS1 of Table 6 on page 17. This connects the 'end' of the second winding with the 'start' of the first.

3) Check that the secondary voltage is 120 V for a 240 V primary.

4) Reverse the phase of one secondary winding (swap a1 and a3). This connects the 'end' of one winding with the 'end' of the second winding.

5) Measure the secondary voltage. You should note that it is zero. One secondary winding has cancelled the other.

If you have the optional oscilloscope, connect each secondary winding across each of the two voltage transducers and connect your oscilloscope to the transducer outputs. Set the oscilloscope to see each voltage waveform and you should see that they are exactly 180 degrees out of phase.

6) Now set one the secondary windings to give 52 turns. You should note an output of 8 V (the difference between 60 V of one winding and 52 V of the other).

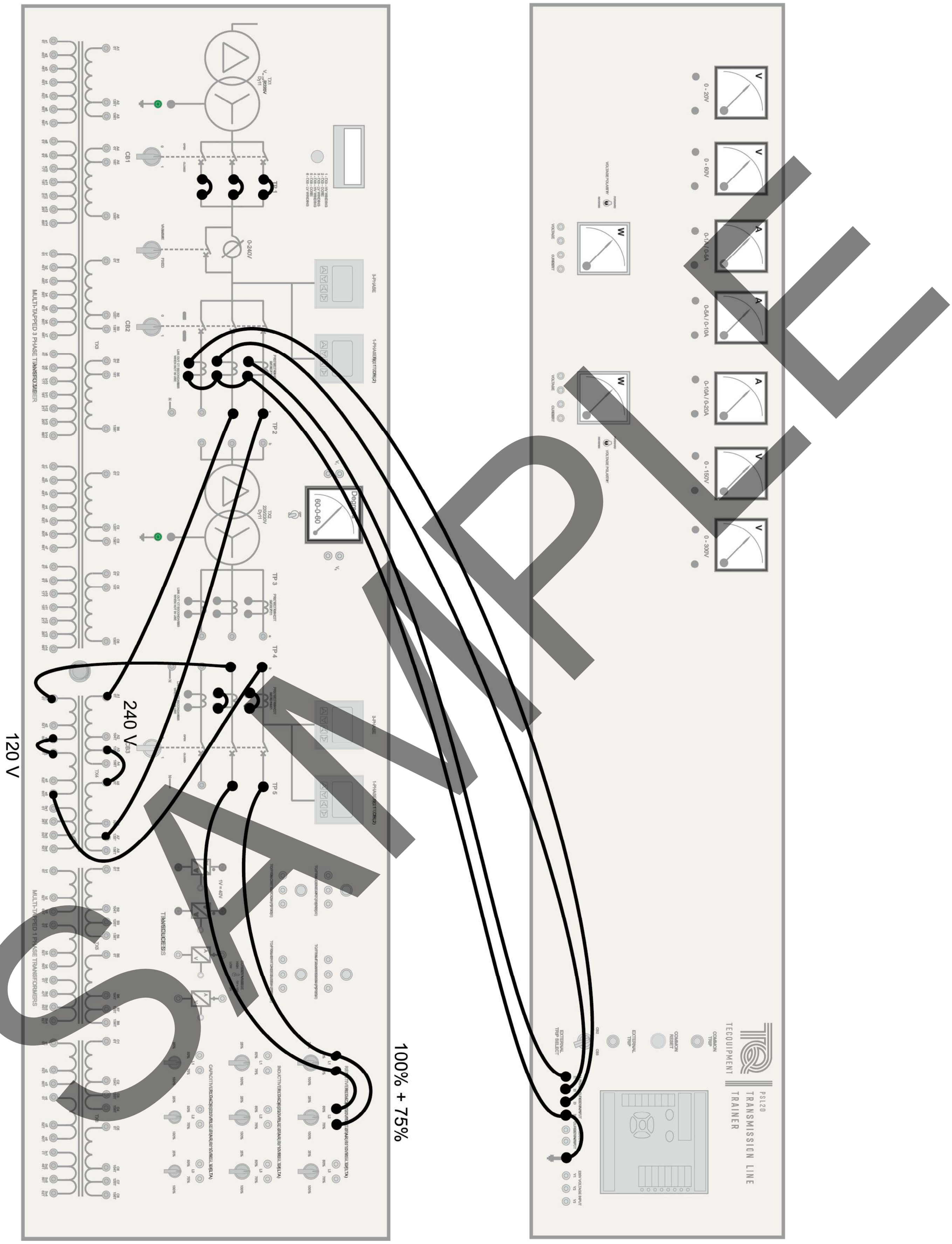

Figure 42 Connections for Test 3 - Single Phase Transformers - On Load (Current) Ratio Checks

Typical Results

NOTE *These results are typical only. Actual results may differ, determined by slight variations in transformer construction, loads and supplies.*

Test 1

This is a simple test to allow the student to understand how to connect and use the relay and loads. The experiment procedure suggests typical results.

Test 2

Procedure 1 - No Load Voltage and Ratio

Primary Connections Used	Primary Voltage	Secondary Connections Used	Secondary Voltage	No Load Voltage Ratio (primary/secondary)	Turns ratio
A1 and A3	120 V	a1 and a3	60.04 V	120/60.04	~ 2:1
A1 and A2	104 V	a1 and a2	51.75 V	104/51.75	~ 2:1
A1 and A3	60 V	a1 and a3	29.92 V	60/29.92	~ 2:1
A1 and A2	52 V	a1 and a2	25.87 V	52/25.87	~ 2:1

Table 22 Typical Results

Procedure 2 - Series and Parallel Windings

Primary windings in series

Connections Used	Primary Voltage	Secondary Connections Used	Secondary Voltage	No Load Voltage Ratio (primary/secondary)	Turns ratio
HWS1 + LWS1	240 V	a1 and a6	120.3 V	240/120.3	~ 2:1
HWS2 + LWS2	224 V	a1 and a5	112.14 V	224/112.14	~ 2:1
HWS3 + LWS3	208 V	a1 and a5	103.66 V	208/103.66	~ 2:1

Table 23 Typical Results

Primary windings in parallel

Connections Used	Primary Voltage	Secondary Connections Used	Secondary Voltage	No Load Voltage Ratio (primary/secondary)	Turns ratio
HWS4 + LWS1	138 V	a1 and a6	120 V	138/120	~ 1.15:1
HWS5 + LWS2	120 V	a1 and a5	112 V	120/112	~ 1.07:1
HWS6 + LWS3	104 V	a1 and a5	104 V	104/104	~ 1:1

Table 24 Typical Results

Secondary windings in series

Connections Used	Primary Voltage	Secondary Connections Used	Secondary Voltage	No Load Voltage Ratio (primary/secondary)	Turns ratio
HWS1 + LWS1	240 V	a1 and a6	119.5 V	240/119.5	~ 2:1
HWS2 + LWS2	224 V	a1 and a5	111.75 V	224/111.75	~ 2:1
HWS3 + LWS3	208 V	a1 and a5	103.5 V	208/103.5	~ 2:1
HWS3 + LWS4	208 V	a2 and a6	15.9 V	208/15.9	~ 13:1

Table 25 Typical Results

Secondary windings in parallel

Connections Used	Primary Voltage	Secondary Connections Used	Secondary Voltage	No Load Voltage Ratio (primary/secondary)	Turns ratio
HWS1 + LWS5	240 V	a1 and a4 a3 and a6	59.8 V	240/59.8	~ 4:1
HWS2 + LWS6	224 V	a1 and a4 a2 and a5	51.9 V	224/51.9	~ 4.3:1
HWS3 + LWS7	208 V	a2 and a5 a3 and a6	7.95 V	208/7.95	~ 26:1

Table 26 Typical Results

Procedure 3 - Phasing of Windings

This is a simple procedure to show the relative phasing of each transformer, using an optional oscilloscope and connecting the ‘ends’ and ‘starts’ of the windings. The procedure gives suggested results.