PSL40

Distribution 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 supply 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/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.***

Contents

The Distribution Trainer

Introduction and Overview

Figure 1 The PSL40 Distribution Trainer

The Distribution Trainer covers core experiments in power distribution courses at degree level or their equivalent. The Trainer has two separate circuits, one in each of the Console panels. Each circuit has its own power supply and is designed for a specific group of experiments. Protective relays are provided for experiments on faulted systems.

The circuit in the upper panel of the Console is a single-phase circuit and is normally used to demonstrate the principles of a.c. and d.c. distribution of electrical energy in radial and ring systems.

The circuit in the lower panel of the Console is a three phase circuit comprising two, three–phase transformers and transmission lines for experiments relating to medium voltage transmission or distribution.

Experiments on Supply Systems and Transmission Lines

Introduction

This section includes recommended experiments for the Distribution Trainer. They begin with the most basic experiments and gradually become more complex. TecQuipment recommends that you perform the experiments in order, so that you become familiar with the apparatus before you move to a more complex experiment.

Safety

These experiments are not all that may be done on the apparatus, there is no limit to the amount of different experiments that can be done. However, for all experiments that you do, obey these simple safety rules:

Always

- Make sure you know where the emergency stop button is
- Inform your supervisor that you are to use the apparatus
- Check the insulation of the connection leads before you use them

Never

- Work alone on this apparatus
- Place any drinks or liquid on or near to the apparatus
- Use the apparatus if any liquid has been spilled on to any of its surfaces
- Use unshrouded or unsuitable leads on this apparatus

WARNING ***Always switch off the electrical supply between each experiment and before you make changes to any connections and leads.***

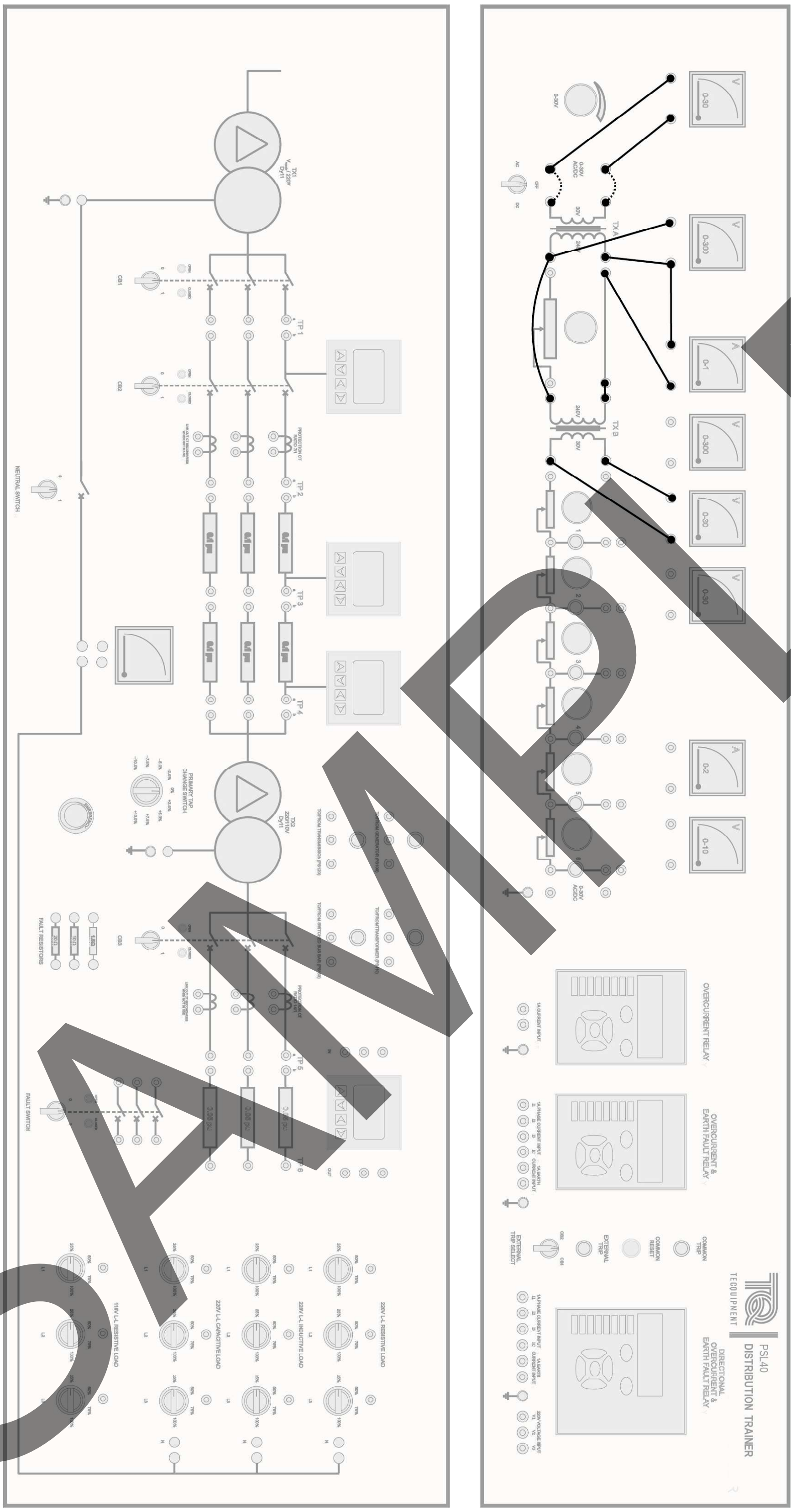

Figure 14 Connections for Experiment 1 - Procedure A and B

Experiment 1: Familiarisation with the Distribution Trainer

Objective

To familiarise the student with the operation and control of each section of the Trainer and the use of the measuring instruments provided.

Procedure A - The A.C and D.C Supplies

1) On the single-phase section of the Trainer, connect the 30 V voltmeter across the 0 to 30 V a.c./d.c. power supply terminals as shown in Figure 14. Leave the rest of the circuit unconnected.

   Switch on the power supply to the Trainer. Increase the control for the 0 to 30 V supply to give an output in 5 Vac steps. At each step, turn the ac/dc switch to dc and record the equivalent dc value.

2) Record the results following the format in Table 6. Plot the d.c. voltage against the a.c. voltage and explain the relationship obtained. Calculate the average value for the conversion factor from a.c. to d.c. voltage for the Rectifier Bridge used in this circuit.

VAC	0	5	10	15	20	25	30
VDC	0						

Table 6 A.C./D.C. Supply Voltage

Procedure B - Transformers TXA and TXB

1) Turn the 0 to 30 V supply to minimum. As shown by the dotted lines in Figure 14, connect the 0 to 30 V a.c./d.c. supply to the primary terminal of Transformer A leaving the terminals of Transformer B open (but connected to a voltmeter). Put the 0 to 30 V switch to the a.c. position.

2) Adjust the a.c. voltage to 30 V. Record the voltage on the primary and secondary sides of Transformers A and B. Take the ammeter reading and record the results in Table 7.

3) Calculate the voltage ratio V_p/V_s for each transformer and compare with the ratios given for each transformer. Explain the difference, if any.

4) Switch off the supply.

Ammeter Reading =		
Voltages	**Transformer A**	**Transformer B**
Primary (V_p)		
Secondary (V_s)		
Calculated V_p/V_s		
V_p/V_s given		
Error in V_p/V_s		

Table 7 Transformer Voltages and Current

Procedure C - Line and Phase Voltage and Current in Resistive Loads

1) Create a blank table of results, similar to Table 8.

2) Connect a three-phase circuit as shown in Figure 15. Make sure that the CTs are short circuited and the neutral switch is closed.

3) Shut CB1 only and use the first multi-function meter record the no-load line voltages.

4) Shut CB1 and CB2. Vary all three resistive loads equally in 25% steps. At each step, record the voltage and the current in each phase. Also use the lower analogue meter to record the current flowing in the neutral line.

5) Find the relationship between the line and phase voltage of the supply lines. Compare the current drawn by each phase for each load setting. Explain why the phase currents are almost the same and that the neutral line current is almost zero.

6) Disconnect the load.

Load	**Phase A**		**Phase B**		**Phase C**		**Neutral Current**
	V	**I**	**V**	**I**	**V**	**I**	
No Load							
25%							
50%							
75%							
100%							

Table 8 Resistive load results

Procedure D - Tests on Transformer 2

1) Connect the circuit as shown in Figure 16. Set the transformer tapping switch to 0%. Close CB1, CB2 and CB3. Measure the voltage between the lines (phase to phase) on the primary and secondary sides of Transformer 2.

2) Calculate the voltage ratio of the transformer and compare with the value given on the front panel. Record the results in Table 9.

Voltage	V_{1-2}	V_{2-3}	V_{3-1}
Primary			
Secondary			
Calculated V_p/V_s =			
Given V_p/V_s ratio =			

Table 9 Transformer 2 Results

3) Use the tap change switch for each position from -10% to +10% and measure the line voltage for the secondary and primary sides of Transformer 2. Calculate the line voltage ratio for each tap position, entering the results in Table 10. From the results obtained, explain what the tappings do.

	Tapping								
	-10%	-7.5%	-5%	-2.5%	0%	+2.5%	+5%	+7.5%	+10%
V_{RY} (Primary)									
V_{RY} (Secondary)									
Line voltage ratio									

Table 10 Tapped Transformer 2 Results

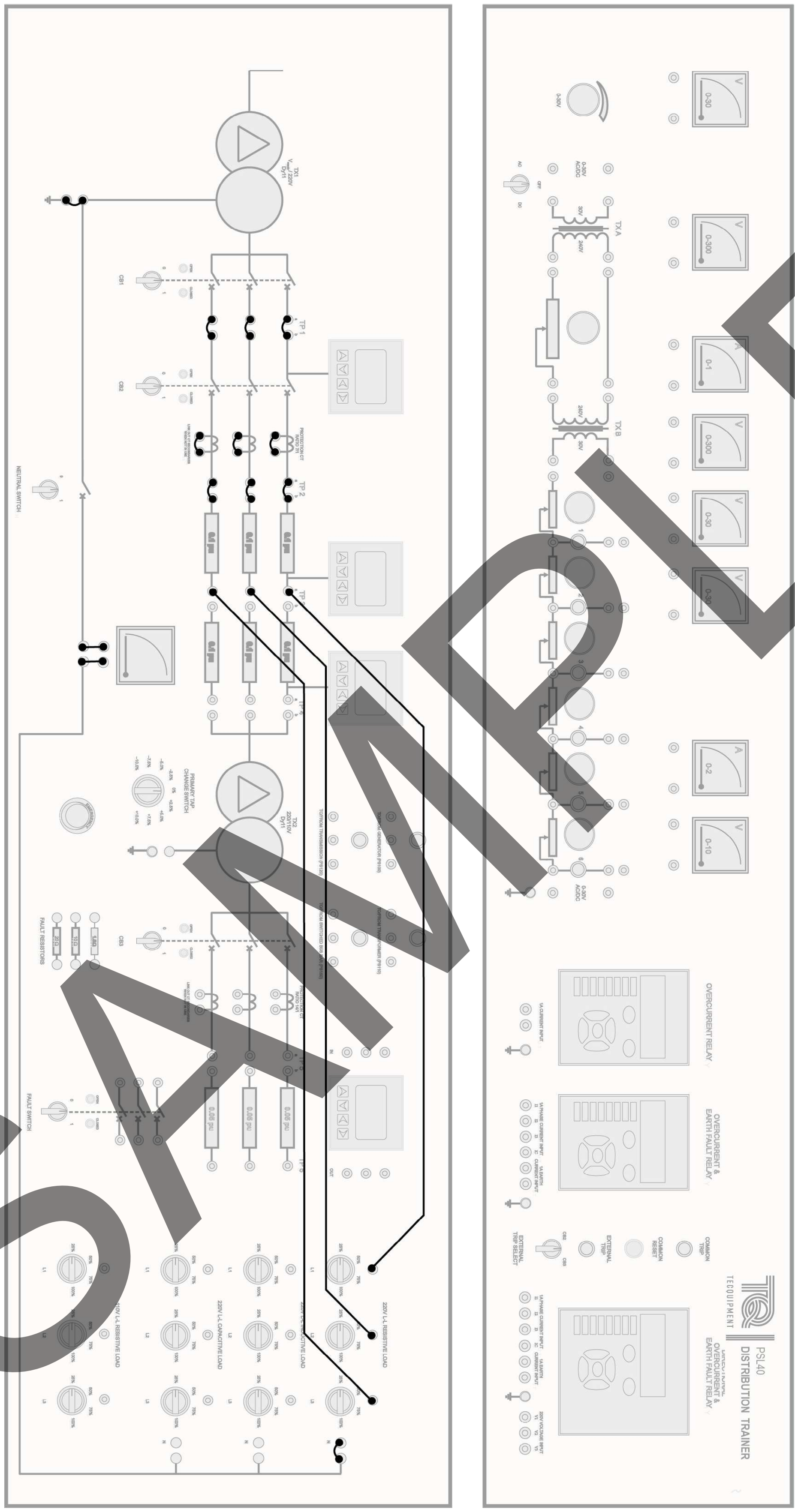

Figure 15 Connections for Experiment 1 - Procedure C

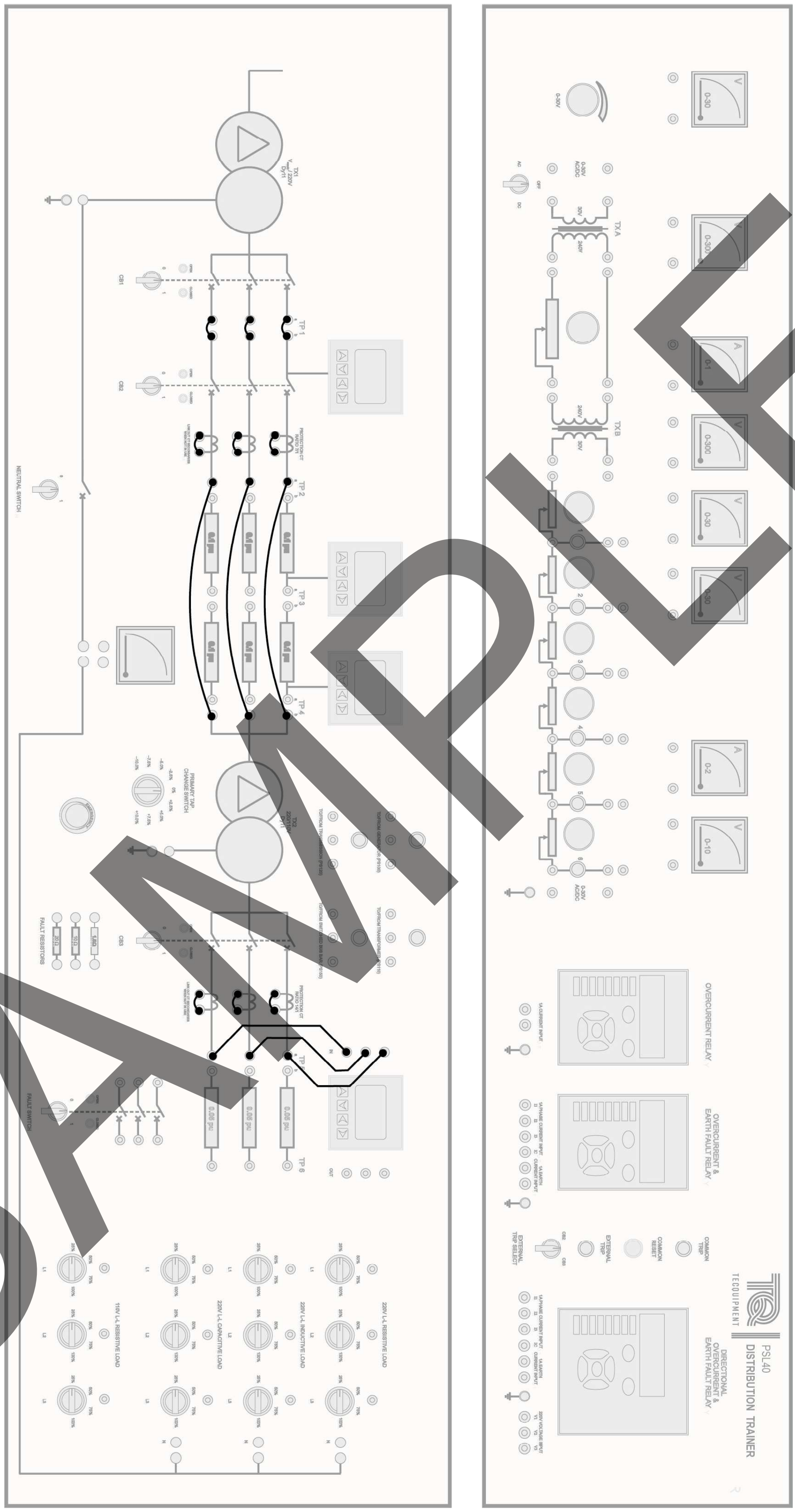

Figure 16 Connections for Experiment 1 - Procedure D

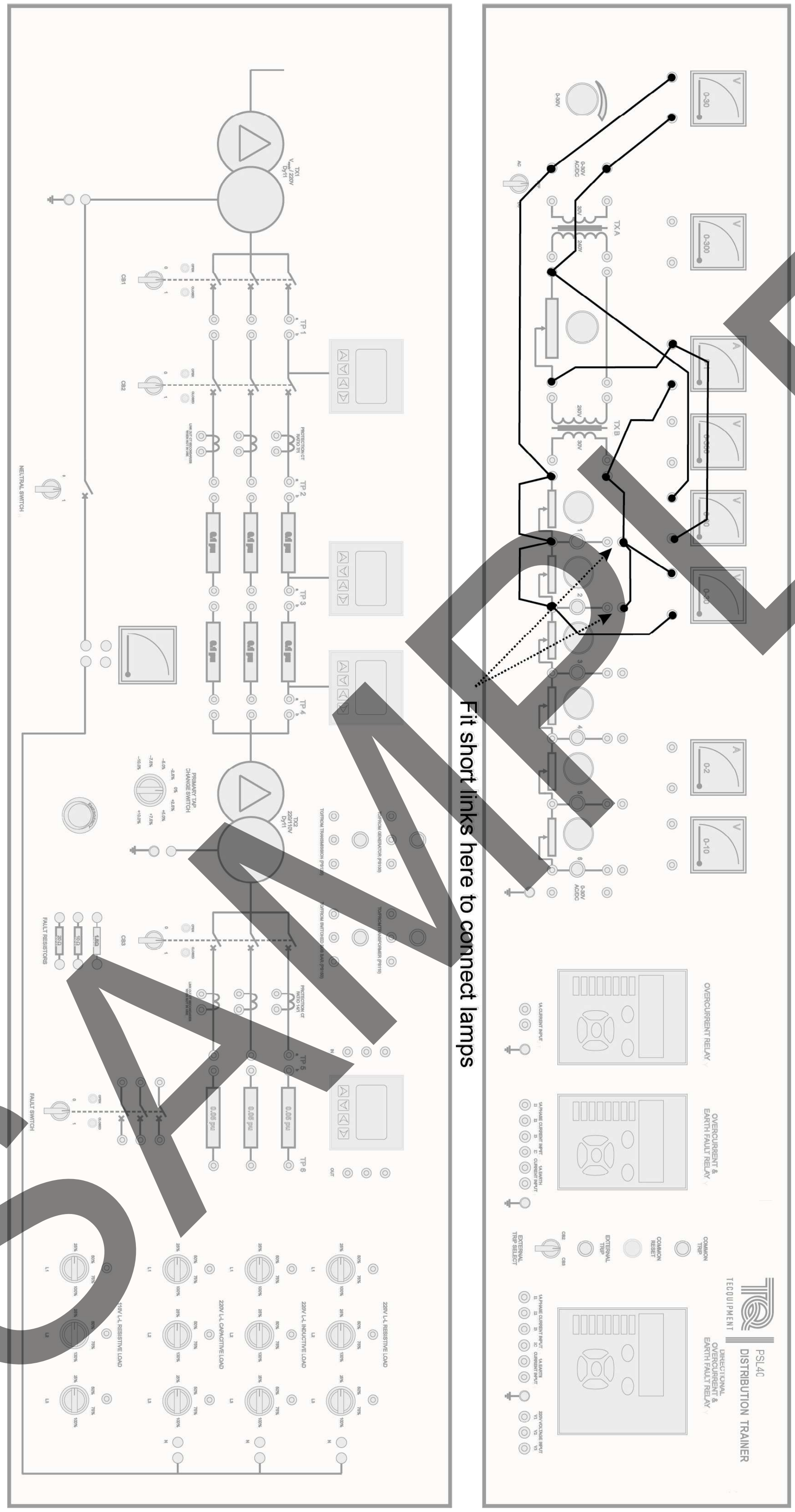

Figure 17 Connections for Experiment 2 Procedure A

Experiments on Faults and Protection

Introduction

Protection equipment is provided first and foremost to ensure the safety of human life. There are also several other important aspects of protection, such as:

- Protection of expensive equipment.
- Efficient running of the system by only isolating the faulty zone.
- Indication of the location of the fault and what kind of fault has occurred, for example a line- to-line fault, winding fault, etc.

The location of the CTS for operating the relays is usually dependent upon the siting of substations. However, by using suitable protection schemes it is possible in general to satisfy the basic requirements of protection. See Appendix 4.

The three-phase section of the Trainer can be used for protection experiments. The three protective relays have variable settings for carrying out relay discrimination and fault experiments.

The system provided consists of a delta/star transformer with the star point connected to earth. The outgoing, 0.10 pu lines from the transformer have three 7.0/1 line CTS mounted in the line that can be used to energise two single–phase Overcurrent and Earth Fault Micom relays, or alternatively the three–phase overcurrent and earth fault Micom relay. The construction and use of the relays are described in section 2 and section 1.4 of this manual.

The three lines feed a second delta star transformer that in turn feeds outgoing 0.05 pu lines, that have a 14/1 CT in each line. See Figure 2.

Safety

These experiments are not all that may be done on the apparatus, there is no limit to the amount of different experiments that can be done. However, for all experiments that you do, obey these simple safety rules:

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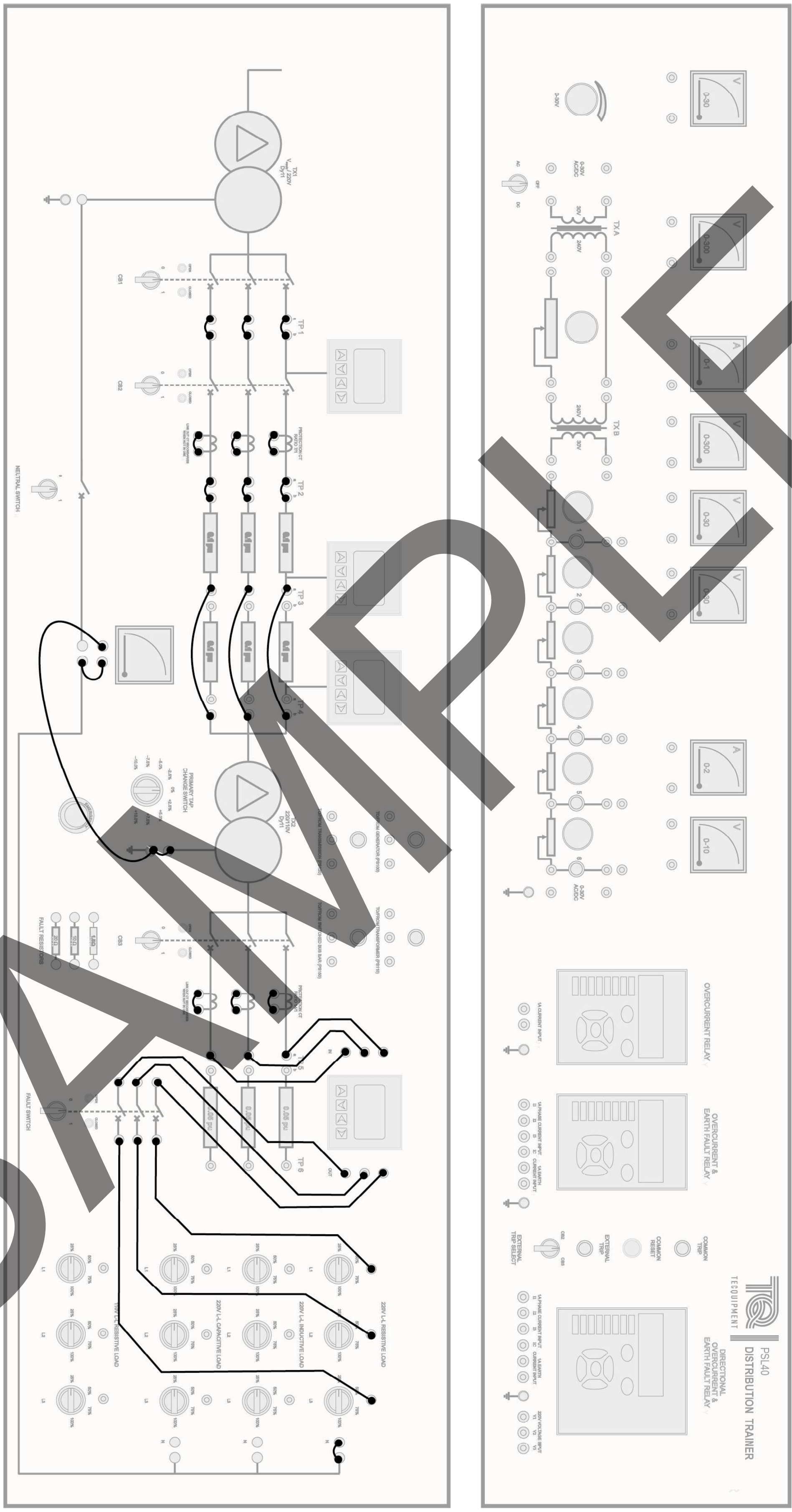

Figure 36 Connections for Experiment 14

Experiment 14: Distribution System Under Faults

Objective

To determine the voltage and current distribution in a network when it is subjected to some of the common faults.

Procedure

1) Connect the secondary of transformer TX2 to the fault switch in series with the resistive load as shown in Figure 36.

2) Short circuit the secondaries of the six CTs.

3) Set the tap–change switch to the nominal voltage position (0%).

4) Set all three load controls to 75%. Close the fault application switch.

5) Switch on the supply and increase the load to 100% (this simulates a line to line to line fault). Take current and voltage readings on both the primary and secondary sides of transformer TX2. Switch the power off and open the fault switch.

6) Using the fault application switch now simulate a double-line-to-ground fault by disconnecting only phase 3 of the load at the Fault Switch. Switch the power on and take the readings for voltages and currents. Switch the power off and leave the circuit connected.

7) Remove the neutral connection between the load neutral and the transformer star point. The circuit now simulates a line-line fault. Switch the power on and take the readings for voltages and currents. Switch the power off.

8) Use the fault application switch to simulate a single-line- to- ground fault by disconnecting two phases (2 and 3) of the resistive load at the Fault Switch in Figure 36. Switch the power on and close the fault switch. Take readings for load voltages and currents. Switch the power off.

9) Tabulate the results in Table 34.

Winding	Load conditions	Normal balanced resistive load (line to line to line fault)	Double line to ground fault	Line to line fault	Single line to ground fault
Primary	V_{L1}				
	V_{L2}				
	V_{L3}				
	I_1				
	I_2				
	I_3				
Secondary	V_{L1}				
	V_{L2}				
	V_{L3}				
	I_1				
	I_2				
	I_3				
	I_N				

Table 34 Fault conditions. Readings taken on both primary and secondary of 240/110 V transformer.

Assessment and Conclusions

1) Record observations about the values of the line currents and phase voltages when a symmetrical three–phase short circuit occurs? Draw a simple equivalent circuit which can be used to represent one phase of the distribution network in this case.

2) Record observations with respect to the currents and voltage distribution when single line and double-line-to-ground faults occur? Is there any relationship between the currents or the voltages under these two types of faults?

3) Are the currents or voltages balanced under a single line or double line to ground fault?

4) From the results obtained above, which type of fault would you consider to cause more damage if left unchecked?

5) Is it possible to represent the distribution network when it is subjected to either single line or double line to ground fault by one simple equivalent circuit as is the case in three–phase short circuit fault? See Appendix 3 and the reference books.

6) Summarize your findings about the currents and voltages distribution in each of the above three faults with particular reference to phases which carry most of the fault current in each case.

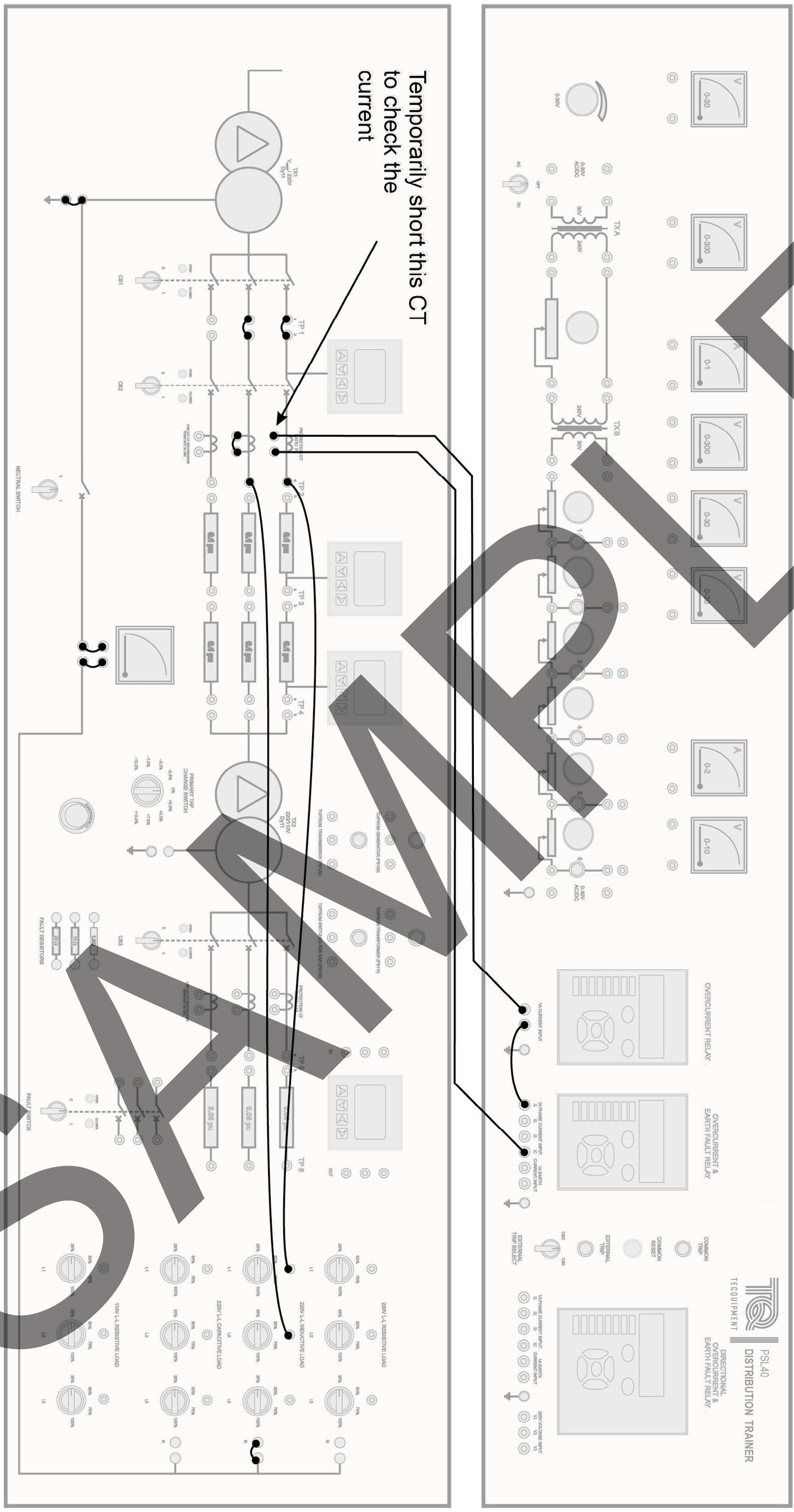

Figure 37 Connections for Experiment 15

Typical Results

Note - these results are for reference only. Your results may be different, determined by your mains supply. Typical results are for 50 Hz.

Experiment 1: Familiarisation with the Distribution Trainer

Procedure A - The A.C and D.C Supplies

VAC	0	5	10	15	20	25	30
VDC	0	4.2	9.2	14.2	19	23.8	29

Procedure B - Transformers TXA and TXB

Ammeter Reading = 0.12 A (0.07 A)		
Voltages	**Transformer A**	**Transformer B**
Primary (V_p)	30	228
Secondary (V_s)	228	29.9
Calculated V_p/V_s	0.132	7.63
V_p/V_s given	0.125	8
Error in V_p/V_s	5.3%	4.6%

Procedure C - Line and Phase Voltage and Current in Resistive Loads

Load	Phase A		Phase B		Phase C		Neutral Current
	V	I	V	I	V	I	
No Load	132	-	132	-	132	-	-
25%	131	1.4	130	1.4	130	1.4	0
50%	128	2.8	128	2.8	128	2.8	0.03
75%	128	4.1	128	4.1	127	4.1	0.08
100%	127	5.5	127	5.4	126	5.4	0.15

Procedure D - Tests on Transformer 2

Voltage	V_{1-2}	V_{2-3}	V_{3-1}
Primary	230	228	228
Secondary	118	118	119
Calculated V_p/V_s =	1.9	1.9	1.9
Given V_p/V_s ratio =	2		

	Tapping								
	-10%	-7.5%	-5%	-2.5%	0%	+2.5%	+5%	+7.5%	+10%
V_{RY} (Primary)	230	229	229	229	229	229	229	228	228
V_{RY} (Secondary)	131	129	124	121	118	115	112	109	106
Line voltage ratio	1.75	1.78	1.84	1.89	1.94	1.99	2.04	2.09	2.13

Experiment 2: A.C./D.C. Transmission

Procedure A - Low voltage line

Sending end voltage (dc) = 24			
Number of lamps	Voltage across lamps (Receive volts)	Line volt drop	Line current
1 Lamp	11.4	11.2	0.04
2 Lamp	5.8	16.1	0.05

Sending end voltage (ac) = 24			
Number of lamps	Voltage across lamps (Receive volts)	Line volt drop	Line current
1 Lamp	11.2	11.3	0.04
2 Lamp	5.8	16.2	0.05

Experiment 14: Distribution System Under Faults

Winding	Load conditions	Normal balanced resistive load (line to line to line fault)	Double line to ground fault	Line to line fault	Single line to ground fault
Primary	V_{L1}	126	128	128	128
	V_{L2}	126	125	125	128
	V_{L3}	126	125	125	128
	I_1	1.63	0.91	0.63	0.9
	I_2	1.52	1.52	1.52	1.04
	I_3	1.6	1.06	0.96	0.27
Secondary	V_{L1}	64	64	65	64
	V_{L2}	64	64	63	65
	V_{L3}	64	64	66	65
	I_1	2.73	2.74	2.36	2.72
	I_2	2.74	2.74	2.36	0
	I_3	2.74	0	0	0
	I_N	0	2.74	0	2.72

Experiment 15: Relay Discrimination

1(a) Relay Discrimination Using Current

Relay A (R_A)		Relay B (R_B)		Fault current (A)	Relay operating (Tick)		Time (s)	
Current TM setting	In Multiplier	Current TM setting	In Multiplier		R_A	R_B	Predicted (from curve)	Actual
1.0	0.25	1.0	0.5	5.3	✓			6
1.0	0.5	1.0	0.25	5.3		✓		6