Operation Manual

C-00847 XFMR-4BUSHING (11-11-15)

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Product Description

The LOAD-TRAINER Transformer Simulator is a fully functional electrical trainer allowing simulation of most distribution transformer connection schemes. This device contains actual transformers that completely duplicate in-field situations.

WARNING

This unit can exceed 400 volts in certain configurations. Use caution and treat ALL components and jumpers as if handling live conductors.

WARNING

The unit should NOT be running during hook-up or configuration.

WARNING

Carefully read and fully understand this manual prior to operating, maintaining or testing this device. Improper operation, handling or maintenance of this device can result in death, grievous personal injury and or equipment damage.

The power unit's components are not rated for continuous duty and may heat up during prolonged use.

The power unit should not be on for extended periods of time and should only be on when taking voltage readings.

In addition to reduce the risk of electrical shocks, fire, etc.:

• Do not remove screws, covers or cabinet. Refer servicing to qualified personnel.
• Do not expose this device to rain, moisture or combustible materials.
• Select a place that is level, dry and between 41°F and 95°F. Do not place either unit on a heat generating object.
• Avoid a dusty place or a place subject to vibrations.
• The power cord supplied is configured and rated for standard 120 Volt, 10 Amp receptacles. It is to be used as a disconnect for this device by unplugging the power cord from the receptacle.
Product Line

<table>
<thead>
<tr>
<th>Components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XFMR-3BUSHING</td>
<td>LOAD-TRAINERS THREE BUSHING TRANSFORMER SIMULATOR</td>
</tr>
<tr>
<td>XFMR-4BUSHING</td>
<td>LOAD-TRAINERS FOUR BUSHING TRANSFORMER SIMULATOR</td>
</tr>
<tr>
<td>XFMR-PRM</td>
<td>PHASE ROTATION METER</td>
</tr>
<tr>
<td>XFMR-LEADS</td>
<td>ASSORTMENT OF EXTRA BANANA LEADS</td>
</tr>
<tr>
<td>XFMR-3BUSHING-PRL</td>
<td>ADDITIONAL THREE BUSHING FRONT PANEL</td>
</tr>
<tr>
<td>XFMR-4BUSHING-PRL</td>
<td>ADDITIONAL FOUR BUSHING FRONT PANEL</td>
</tr>
</tbody>
</table>

Components

- Power Supply
- Front Panel
- Multiple-conductor Cord
- Power Cord
- Shipping Cases
- Patch Cords

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front Panel (Large Shipping Case)</td>
</tr>
<tr>
<td>1</td>
<td>Power Supply (Small Shipping Case)</td>
</tr>
<tr>
<td>1</td>
<td>Multiple-conductor cord with polarized plug (Green)</td>
</tr>
<tr>
<td>1</td>
<td>120 Volt, AC Power Cord (Black)</td>
</tr>
<tr>
<td>8</td>
<td>12” red ‘pin’ patch cords</td>
</tr>
<tr>
<td>3</td>
<td>12” black ‘pin’ patch cords</td>
</tr>
<tr>
<td>4</td>
<td>4” black ‘banana’ patch cords</td>
</tr>
<tr>
<td>5</td>
<td>12” red ‘banana’ patch cords</td>
</tr>
<tr>
<td>5</td>
<td>12” black ‘banana’ patch cords</td>
</tr>
</tbody>
</table>
Simulator Description

Simulation of Three-Phase power is created by an electric motor and a 120-to-20 Volt transformer. The motor is coupled to an alternator that provides a three-phase, four-wire output. The 20 Volt output of the transformer is rectified and used to excite the rotor of the alternator. A rheostat on the Front Panel provides fine tuning over the output of the alternator. When the rheostat knob is pointed toward the word ‘DELTA’ the output voltage of the alternator is approximately seven (7) Volts phase-to-phase (VPP). When the knob points to ‘WYE’ the output voltage is approximately seven (7) Volts phase-to-neutral (VPN). See Equation below.

\[
WYE = VPP = \sqrt{3} \cdot VPN = DELTA
\]

Hence:

\[
WYE = VPP = \sqrt{3} \cdot 7 \text{ Volts}
\]
\[
WYE = VPP \approx 12 \text{ Volts}
\]

It is for this reason that a Delta connected primary wired to a WYE system voltage can produce secondary voltages much higher than expected. In addition it may be necessary to fine-tune the rheostat occasionally to obtain the desired voltage output from the transformers.
Front Panel Description

Three Phase Power System
The four lines at the top of the Front Panel represent a three-phase four-wire power system (A, B, C, N). The tip jacks located on the lines are connected to buss bars within the panel and are protected by fast acting thermal circuit breakers and disconnecting switches. The tip jacks are used to make connections from the three-phase four-wire power system supply to the primaries of single-phase transformers.

Indicator Lights
An indicator light is to the right of each three-phase power line at the top of the Front Panel. This light will indicate when the line is energized.

Disconnecting Switches
Each three-phase power line has a toggle switch to the right of the indicator light on the Front Panel. Power can be controlled to each line separately.

Circuit Breakers
Fast acting thermal circuit breakers are included on each of the three-phase power lines at the top of the Front Panel and function as fuses for accurate simulations. Simply press the circuit breaker to reset.

Transformer Inputs
Three transformer outlines in the middle of the Front Panel use red input terminals (H1 and H2) which connect to actual transformers located behind the panel. These connections are made using the Pin Patch Cords (small metal ends). The plugs can be stacked, if desired.

Transformer Outputs
Each transformer has four black unlabeled output terminals. They can be thought of as X1, X2, X3 and X4 from right to left respectively.

Load Lines
The lines at the bottom of the Front Panel represent load lines (N, L1, L2, L3). Connections between the transformer output terminals and the load lines are made using the Banana Patch Cords (large metal ends). These can be stacked if desired.

AC Meter
An AC meter is on the lower right of the Front Panel and is used to measure the transformer’s output. Tip jacks utilize Banana Patch Cords connected through the load lines or directly to a transformer.

Delta - Wye Rheostat Knob
A rheostat on the Front Panel provides fine tuning over the output of the alternator. It may be necessary to fine-tune the rheostat to obtain the desired voltage output from the transformers. During Delta configuration, the knob should be pointed to the left; while in Wye configurations the knob should be pointing to the right. See Simulator Description for more information.
## Toggle Switches

The eight (8) Toggle Switches located on the left side of the Front Panel can be used by instructors to simulate real-world scenarios that a student would have to diagnose.

The switches are labeled S1 through S8. The normal position of all switches is UP, toward the top of the unit.

<table>
<thead>
<tr>
<th>Switch</th>
<th>Description</th>
<th>Transformer</th>
<th>TOGGLE POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Phase Paralleling Switch</td>
<td>1 A-B-C</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 A-B-C</td>
<td>MIDDLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B-B-C*</td>
<td>DOWN</td>
</tr>
<tr>
<td>S2</td>
<td>Phase Paralleling Switch</td>
<td>1 A-B-C</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 A-B-B*</td>
<td>MIDDLE</td>
</tr>
<tr>
<td>S3</td>
<td>Secondary Transformer Switch</td>
<td>1 Closed</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Open</td>
<td>MIDDLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Open</td>
<td>DOWN</td>
</tr>
<tr>
<td>S4</td>
<td>Polarity &amp; Primary Transformer Switch</td>
<td>1 Additive</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Open</td>
<td>MIDDLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Subtractive</td>
<td>DOWN</td>
</tr>
<tr>
<td>S5</td>
<td>Secondary Transformer Switch</td>
<td>1 Closed</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Open</td>
<td>MIDDLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Open</td>
<td>DOWN</td>
</tr>
<tr>
<td>S6</td>
<td>Polarity &amp; Primary Transformer Switch</td>
<td>1 Additive</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Open</td>
<td>MIDDLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Subtractive</td>
<td>DOWN</td>
</tr>
<tr>
<td>S7</td>
<td>Secondary Transformer Switch</td>
<td>1 Closed</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Open</td>
<td>MIDDLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Open</td>
<td>DOWN</td>
</tr>
<tr>
<td>S8</td>
<td>Polarity &amp; Primary Transformer Switch</td>
<td>1 Additive</td>
<td>UP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Open</td>
<td>MIDDLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Subtractive</td>
<td>DOWN</td>
</tr>
</tbody>
</table>

*when both S1 & S2 are down phasing is B-B-B

### Polarity & Primary Switches
(S4/S6/S8)

![Polarity & Primary Switches Diagram](image)

### Secondary Switches
(S3/S5/S7)

![Secondary Switches Diagram](image)

**Note:** The Load-Trainer uses instrument transformers to simulate distribution transformers and are therefore SUBTRACTIVE.
Normal position of all switches is UP, toward the top of the unit.
Operation

The Load-Trainer Transformer Simulator has the capability to connect single-phase and the following types of three-phase transformers:

- Delta-Delta
- Delta-Wye
- Open Delta-Open Delta
- Wye-Delta
- Wye-Wye
- Wye (one leg out)-Open Delta

Simple Single-Phase Transformer Connections

1. The system should be OFF and remain OFF except for observing voltage measurements on the AC meter for short periods of time.
2. Be sure all 8 Toggle Switches are in the UP position for normal operation. Be sure all 3 Disconnecting Switches are ‘ON’ and reset any tripped Circuit Breakers.
3. Using the red ‘pin’ tip patch cords connect a single-phase transformer to a DELTA system primary as shown in Example 1.
4. Set rheostat pointer to ‘DELTA’.
5. Make output connections with the red and black banana patch cords bringing leads down to load lines to a 120 Volt WYE secondary as shown in Example 1.
6. Turn the unit ON. The Power Supply will start and deliver the proper voltage to the transformer.

**NOTE:** The power unit should not be operated for extended periods of time. Run only when taking voltage readings.

7. If connections have been properly made voltage should appear on the AC Meter. These readings should be near normal for the transformer bank being made. Use the rheostat to make minor adjustments.
8. Problems can be introduced after the installation has been shown to operate correctly. This is done by the toggle switches on the left side of the Front Panel (see Figure 1) and at the instructors discretion to simulate real world scenarios.

**NOTE:**
In certain configurations the actual measured device output voltage is greater than or less than the expected voltage for a given simulation. The AC Meter has been scaled at the factory to compensate for the differing output voltages. An independent meter device may display voltages that are not expected.

Examples

The following table summarizes the Connection Diagrams provided on the following pages:

<table>
<thead>
<tr>
<th>Example</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single Phase Transformer w/ Delta Primary &amp; 120 Volt Wye Secondary</td>
</tr>
<tr>
<td>2</td>
<td>Single Phase Transformer w/ Delta Primary &amp; 120 Volt Delta Secondary</td>
</tr>
<tr>
<td>3</td>
<td>Single Phase Transformer w/ Delta Primary &amp; 120 / 240 Volt Delta Secondary</td>
</tr>
<tr>
<td>4</td>
<td>Three Phase Transformer w/ Delta Primary &amp; 120 / 208 Volt Wye Secondary</td>
</tr>
<tr>
<td>5</td>
<td>Three Phase Transformer w/ Delta Primary &amp; 120 Volt Delta Secondary</td>
</tr>
<tr>
<td>6</td>
<td>Three Phase Transformer w/ Delta Primary &amp; 120 / 240 Volt High Leg B Delta Secondary</td>
</tr>
<tr>
<td>7</td>
<td>Three Phase Transformer w/ Open Delta Primary &amp; 120 Volt Open Delta Secondary</td>
</tr>
<tr>
<td>8</td>
<td>Three Phase Transformer w/ Wye Primary &amp; 120 Volt Delta Secondary</td>
</tr>
<tr>
<td>9</td>
<td>Three Phase Transformer w/ Wye Primary &amp; 120 / 208 Volt Wye Secondary</td>
</tr>
<tr>
<td>10</td>
<td>Three Phase Transformer w/ Wye (One Leg Out) &amp; 120 Volt Open Delta Secondary</td>
</tr>
</tbody>
</table>
Example 1

Single Phase Transformer with Delta Primary and 120 Volt Wye Secondary

Toggle Switches: All in the UP Position
Rheostat Knob: Delta

Expected Meter Reading
Phase to Ground: 120 volts
Phase to Phase: 0 volts (not shown)
Example 2
Single Phase Transformer with Delta Primary and 120 Volt Delta Secondary

<table>
<thead>
<tr>
<th>Toggle Switches:</th>
<th>All in the UP Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rheostat Knob:</td>
<td>Delta</td>
</tr>
<tr>
<td><strong>Expected Meter Reading</strong></td>
<td></td>
</tr>
<tr>
<td>Phase to Ground:</td>
<td>0 volts (not shown)</td>
</tr>
<tr>
<td>Phase to Phase:</td>
<td>120 volts</td>
</tr>
</tbody>
</table>
Example 3

Single Phase Transformer with Delta Primary and 120/240 Volt Delta Secondary

Toggle Switches: All in the UP Position
Rheostat Knob: Delta

Phase to Ground: 120 volts (not shown)
Phase to Phase: 240 volts

Expected Meter Reading:

Phase to Ground: 120 volts
Phase to Phase: 240 volts

S1  S3  S5  S7
S2  S4  S6  S8
Three Phase Transformer with Delta Primary and 120/208 Volt Wye Secondary

Example 4

<table>
<thead>
<tr>
<th>Toggle Switches:</th>
<th>All in the UP Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rheostat Knob:</td>
<td>Delta</td>
</tr>
<tr>
<td>Expected Meter Reading</td>
<td></td>
</tr>
<tr>
<td>Phase to Ground:</td>
<td>120 volts (not shown)</td>
</tr>
<tr>
<td>Phase to Phase:</td>
<td>208 volts</td>
</tr>
</tbody>
</table>
Example 5

Three Phase Transformer with Delta Primary and 120 Volt Delta Secondary

Toggle Switches: All in the UP Position
Rheostat Knob: Delta
Expected Meter Reading
Phase to Ground: 0 volts (not shown)
Phase to Phase: 120 volts
### Example 6

Three Phase Transformer with Delta Primary and 120/240 Volt High Leg B Delta Secondary

**Toggle Switches:** #3, 5, and 7 DOWN

**Rheostat Knob:** Delta

**Expected Meter Reading**

<table>
<thead>
<tr>
<th>Phase to Ground</th>
<th>L¹ 120 volts (shown) / L² 208 volts / L³ 120 volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase to Phase</td>
<td>240 volts</td>
</tr>
</tbody>
</table>
Example 7
Three Phase Transformer with Open Delta Primary and 120 Volt Open Delta Secondary

Toggle Switches: All in the UP Position
Rheostat Knob: Delta
Expected Meter Reading
Phase to Ground: 0 volts (not shown)
Phase to Phase: 120 volts
Example 8
Three Phase Transformer with Wye Primary and 120 Volt Delta Secondary

Toggle Switches: All in the UP Position

Rheostat Knob: Wye

Expected Meter Reading

Phase to Ground: 0 volts (not shown)

Phase to Phase: 120 volts
Example 9
Three Phase Transformer with Wye Primary and 120/208 Volt Wye Secondary

Toggle Switches: All in the UP Position
Rheostat Knob: Wye
Expected Meter Reading
Phase to Ground: 120 volts (not shown)
Phase to Phase: 208 volts
Example 10
Three Phase Transformer with Wye (One Leg Out) Primary and 120 Volt Open Delta Secondary

Toggle Switches: #3 and 5 DOWN
Rheostat Knob: Wye
Expected Meter Reading
Phase to Ground: 0 volts (not shown)
Phase to Phase: 240 volts
Vector Application to Transformer Connections

One feature of the Load-Trainer Transformer Simulator is the vector application to transformer connections. This unit can be used to teach transformer connections using the vector concept. If desired, the instructor should apply his own arrows as follows: the vector arrows between the H1 and H2 terminals should be fixed in position pointing left (from H2 to H1). Vectors representing the secondary windings can be attached to the front of the panel pointing right and can be reversed to indicate a change in polarity. Switches #4, 6 and 8 are used to change polarity of the secondary windings. Refer to “Toggle Switches” on page 6 for more information about changing polarity.

Transformer Backfeed

Numerous situations can be duplicated to produce a transformer backfeed. An example is the lack of grounding on a Wye-Delta bank. To simulate transformer backfeed connect a Wye-Delta bank (see Example 8) with the H2 terminals of each transformer connected to each other but floating. Run the unit to show proper operation. Open one of the Disconnecting Switches located on the Front Panel to the ‘OFF’ position. The indicator light will go off. Repeat this procedure with the H2 terminals grounded. In this case the open phase will glow indicating a backfeed.

Parallel Phases

Parallel phases can also be simulated on the Load-Trainer Transformer Simulator. It is quite possible for a bank connected Wye (one leg out)-Open Delta (see Example 10) to become energized from the same phase. In most instances a jumper on a vertical corner burning into and falling down on the phase below has caused this. If the bank is connected between these phases this results in the input windings being in parallel and the output windings still connected in series. Using normal procedures this produces a situation that is difficult to troubleshoot. This situation can be duplicated with the use of toggle switches #1 or #2 or both (see Simulator Description). Do not measure voltages on the system supply phases. It would be rare for a trouble-shooter to have the equipment to measure the phase voltage.

Polarity

When single-phase transformers are connected together to make a three-phase transformer bank, the EMF (electromotive force) will effect the systems Polarity. The direction of both the high and low voltage coil windings of a transformer and the numbering of it’s corresponding leads will determine if polarity is additive or subtractive. A physical phenomenon caused by the magnetomotive forces in a transformer’s core and coil becomes evident when the low voltage windings are reversed.

Let’s use a single-phase transformer as an example. If the direction of the high voltage windings (H1-H2) are the same as the low voltage windings (X1-X4), the load currents in the primary and secondary are opposed. This is called Subtractive Polarity. Conversely, if the secondary windings of the transformer are reversed (X4-X1) and going in the opposite direction of the high voltage windings, then the load currents would be the same. This is called Additive Polarity. See Figure 2.
Polarity Example

A practical example of additive and subtractive polarity can be demonstrated in a Delta-Delta transformer (see Example 5). Set up the transformer connections as illustrated and measure voltage across L1 and L2. Move the position of the Additive/Subtractive switch #4 from Up to Down and observe the voltmeter and the lamps on the system voltage lines A, B, and C. What happened? Turn off power. The voltmeter drops to zero and the lamps on phase A and B glow very dimly.

Now reverse the leads on X1 and X2 for transformer #1 only, turn on the power and observe the voltmeter. What happens? Turn off power. The voltage is restored and the lamps glow normally. This is caused by a backfed EMF (electromotive force) induced across both A and B phases and L1 and L2 from the other two transformers (#2 and #3).

Now let's try another example. Confirm all switches are up, connections are made properly according to Example 5 and measure voltage across L1 and L2. This time change the position of two Additive/Subtractive switches #6 and 8 from Up to Down simultaneously. What happens? Why? Turn off power. The results are the same as if we changed only switch #4. The reason is the same.

Now without doing anything else move switch #4 from Up to Down. Turn on the power and observe the voltmeter. What happens? It would appear as if everything is back to “Normal.” Why, because the electromotive force of all three single-phase transformers are going in the same direction. The direction of the EMF is the same for all transformers, but opposite from the original configuration. This would need to be corrected in the real world or else three-phase motors would rotate in the opposite direction and customers would not be happy.

A more detailed discussion of Polarity is beyond the scope of this manual.

Warranty

Utility Solutions, Inc. warrants the Load-Trainer for any defects in manufacturing for the period of one year. If the tool is returned within that time period, Utility Solutions, Inc. will replace or repair the tool free of charge.