Instruction Booklet
1MRA588372–MIB

Issue D December 2001 (IB 7.11.1.7-5)
Supersedes Issue C

Note: Pages with the symbol # in the footer secton have been modified.

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Addendum to IB 7.11.1.7- 5 – CPU Firmware V2.60 Instructions

The following features have been modified or added and are available in the two-winding TPU2000R CPU flash firmware version V2.60. This will serve as in interim addendum to the Instruction Booklet 1MRA588372-MIB, Issue D, December 2001 (IB 7.11.1. 7-5). Any questions regarding the availability of these features in a particular TPU2000R, contact your local Regional Technical Manager or call our Customer Support department at 800-634-6005 or 610-395-7333.

TPU 2000R Transformer Protection Unit:
New features and functionalities in V2.60 firmware release:

1. **Differential protection slope characteristics:** The differential protection algorithm security has been enhanced by the following measures:
   - The restraint current for the Percent Slope Curve in the new firmware is the average of the incoming and outgoing restraint currents against the minimum current used earlier.
   - Instead of one slope for the Percent Slope characteristics, a set of maximum of three slopes are possible – the low level slope (default 40%) up to a low level of average of restrain current (default 2 pu), medium slope (default 60%) up to medium level of average restrain current (default value 5pu) and high slope of 120% for higher levels of average restraint currents. User has the option of selecting one or two slopes only if they desire. The settings of each of the three slopes are adjustable between 20 and 160%. Default setting of 120% corresponds to 50 °. In comparison with the earlier characteristics using minimum current, the maximum slope setting was 45°.

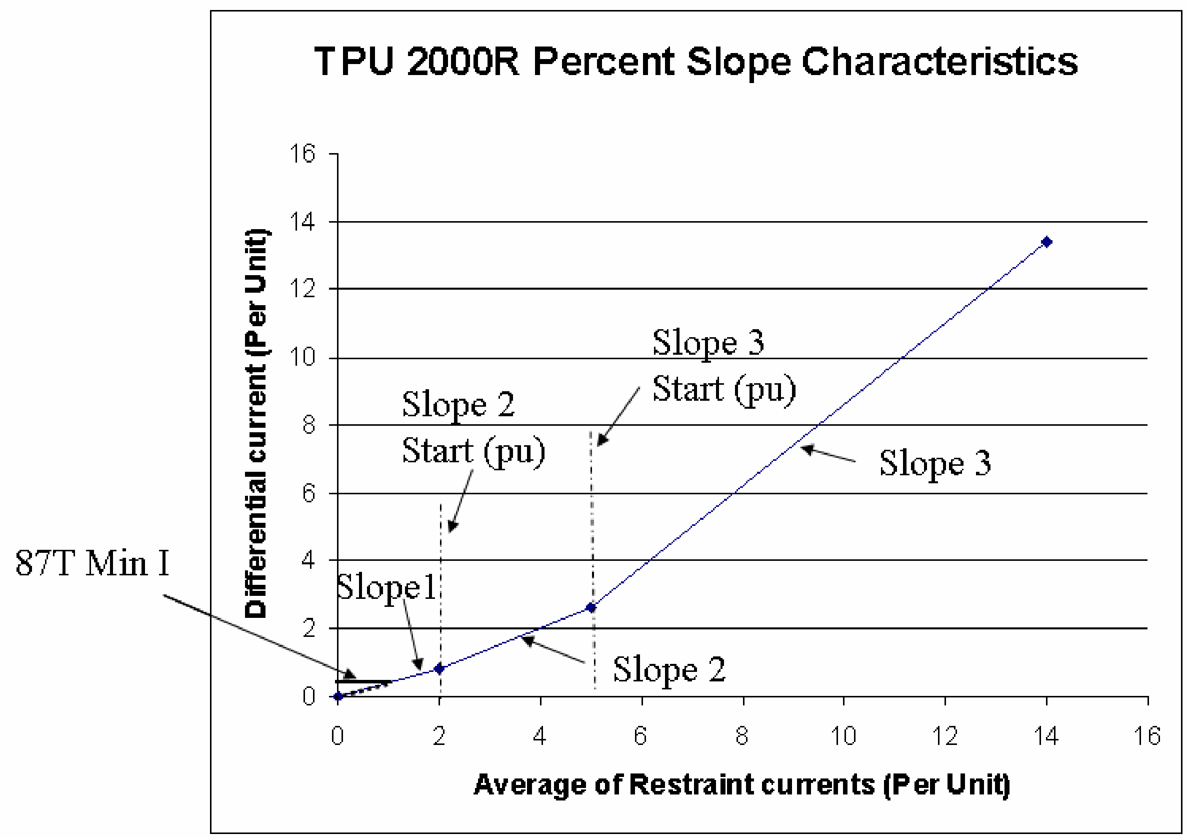

Figure A-1: Differential characteristics

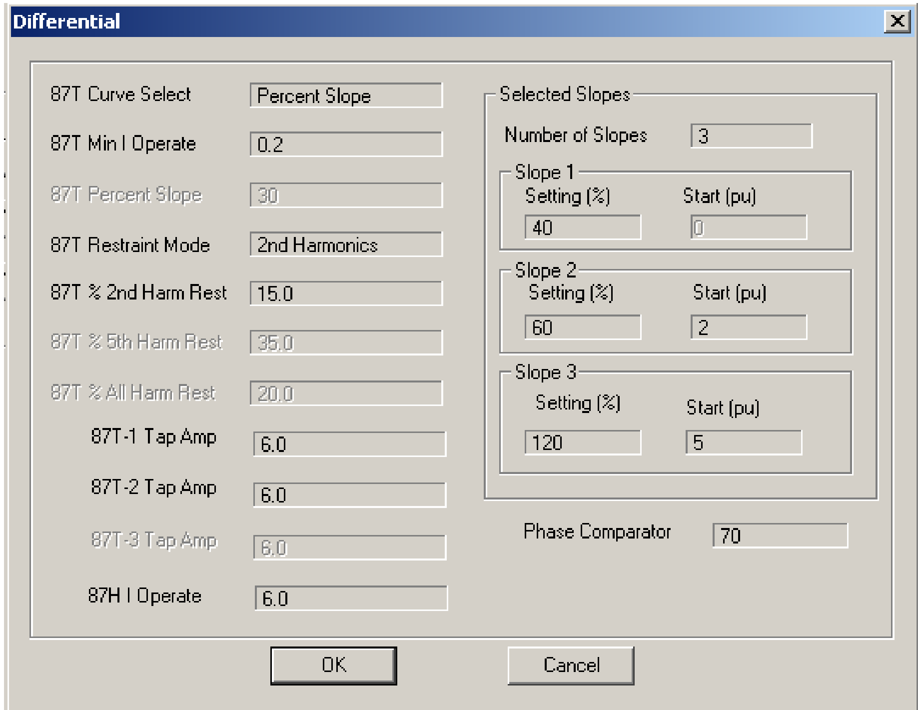

Figure A-2: Differential setting menu when three slopes are selected for 87T percent slope curve

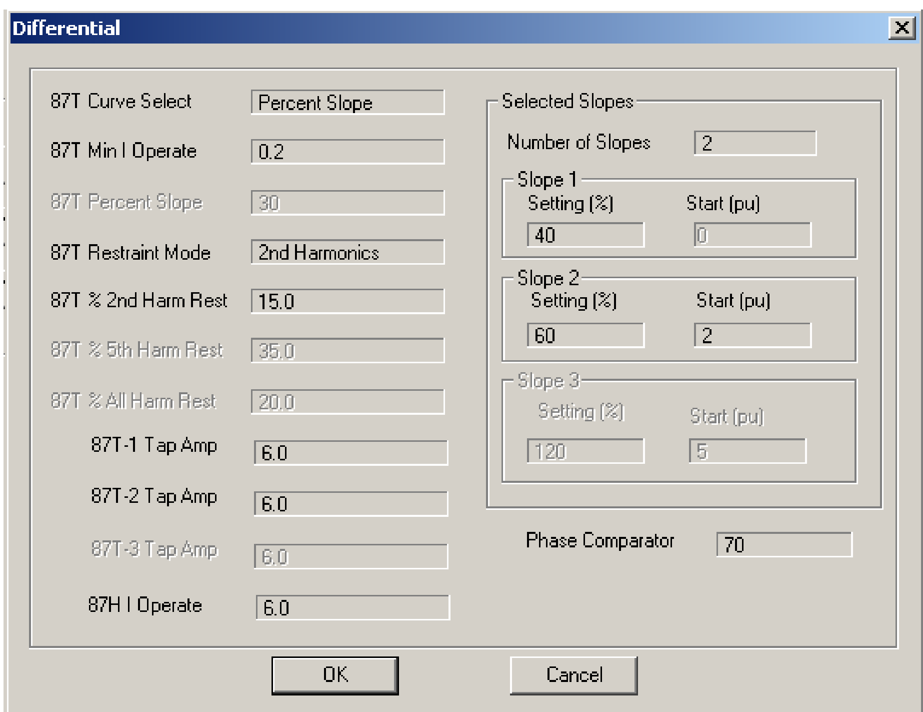

Figure A-3: Differential setting menu when two slopes are selected for 87T percent slope curve

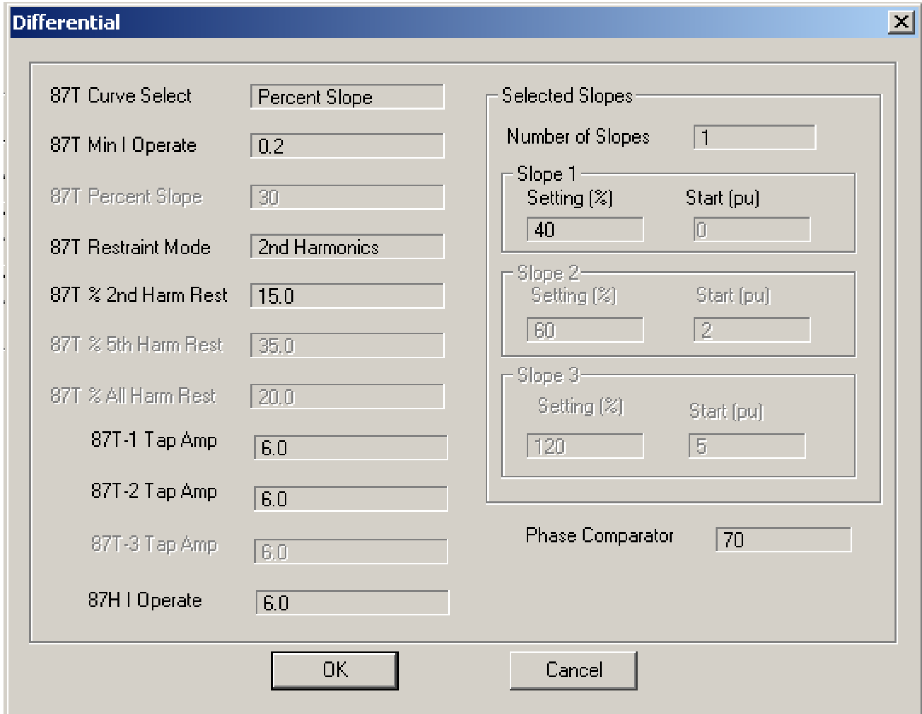

Figure A-4: Differential setting menu when one slope is selected for 87T percent slope curve

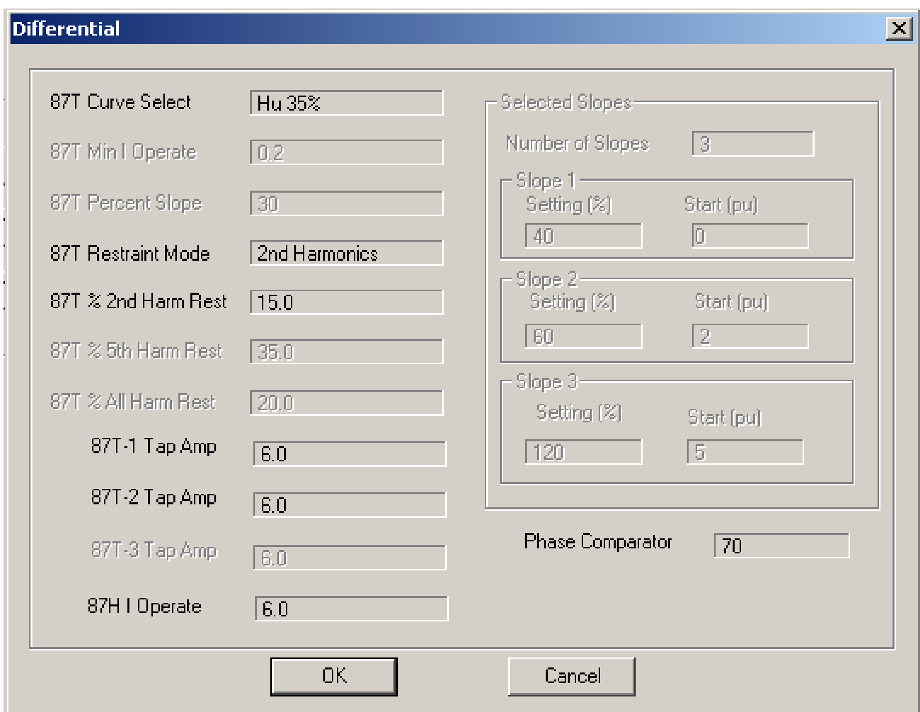

Figure A-5: Differential setting menu when HU 35% is selected as 87T curve

- The cross blocking mode is defaulted to Enable in the configuration menu. This can be disabled if desired.

- The through fault stability of the differential protection 87T has been enhanced by the addition of a through fault detection mechanism

2. **Through Fault Detection:** A new through fault detection logic, called **phase comparator**, has been added. This can be disabled or set between 45 ° and 135 °. Default setting is 70 °. The through fault detection logic works by comparing the phase angle between the two restraint signals. When the angles between the two restraint signals are beyond the set angle, the conditions are considered as through fault and tripping is blocked for some time. This feature allows the relay to restrain even with CT saturation conditions on one of the CTs. During CT saturation for through faults, angular relationship between the restraints is expected to fall outside the set angular separation. If the angles between the two restraints are within the set value, the conditions possibly correspond to an internal fault. Further check as to differentiate between internal and external fault is done by the conventional biased differential algorithm.

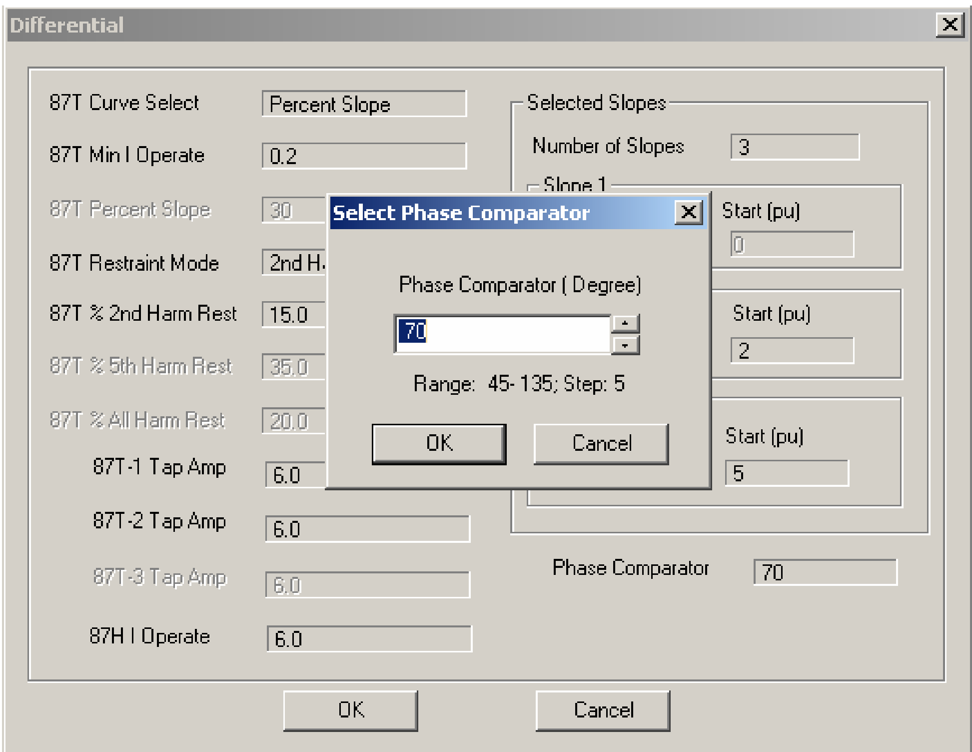

Figure A-6: Phase Comparator setting

The through fault detection logic is enabled when the both restraint currents exceed 1.25 Per Unit. In order to speed up the operation for marginal fault currents just exceeding the above threshold an additional change detector logic is provided. This logic brings in the through fault logic with sudden changes in both through fault currents without corresponding change in differential current.

Once the through fault detection takes place, the condition is sealed in till the phase angle criterion is met, held on for at least 4 cycles, allowing sufficient time for any saturated CT to come out of saturation. The biased differential protection is blocked during this condition. Once the conditions are released, the slope of the bias characteristics are held very high for the next 4 cycles before normal operation is restored.

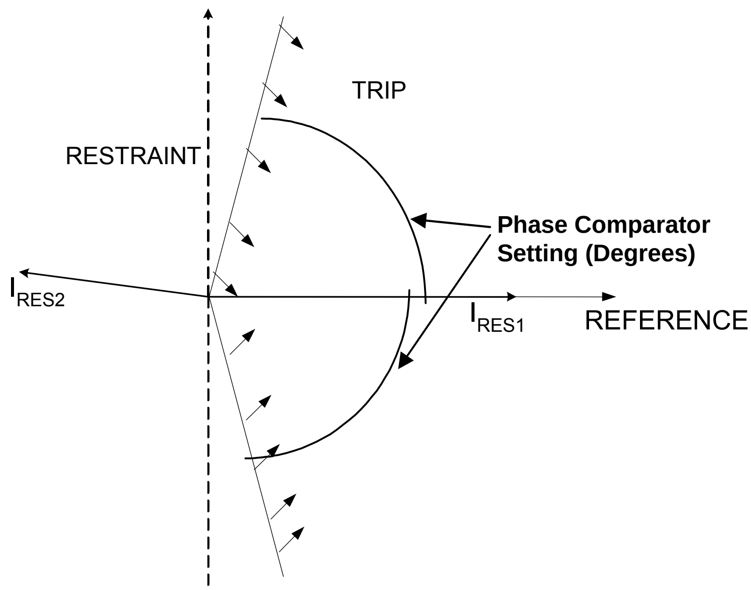

Figure A-7: Restraint Region of Phase Comparator in TPU2000R

Note: The above characteristics cannot be directly plotted on the conventional differential slope characteristics plane with bias current on X axis and differential current on Y axis because of the number of variables involved. Note also that since the final operation of the differential relay is a combination of the phase comparator and the biased differential slope characteristics, the relay would follow a combination of both the characteristics. **While testing the bias characteristics, it is thus necessary to disable the through fault detector.**

The existing through fault detection using disturbance setting is used only for providing alarm and generating operation records (Only one operation record will be written for each through fault detected either by the phase comparator or by the disturbance detector). The disturbance detector will not block the differential protection.

3. **Change in Menu setting name**: "Phase Comp" in the configuration menu settings has been renamed as "Phase Shift" to reflect the actual input used. Similarly, the harmonic restraint feature in the Primary setting has been renamed as "2nd **or** 5th Harmonic" instead of the earlier "2nd **and** 5th" to reflect the actual logic used.

4. **Fault record**: The digital fault recording has been modified. Default setting and trigger positions (15) have been modified to have a minimum pre-fault value of 4 cycles for all records. The relay will have default waveform capture settings as follows:

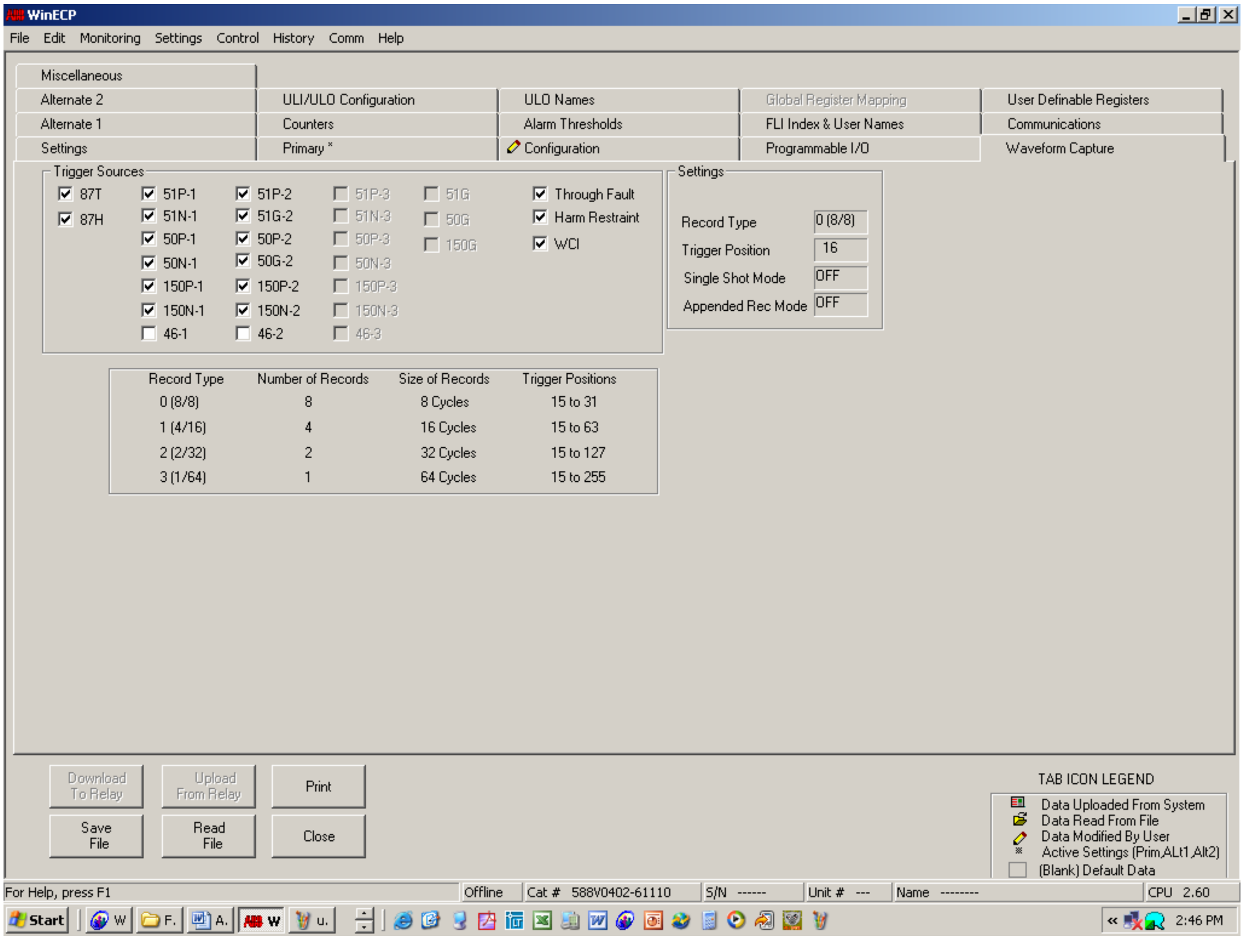

Figure A-8: Default setting of waveform capture

Waveform capture feature is usually always ON and cannot be disabled by the user. However, due to inadvertent termination of the communication session, it may be turned OFF. It shall be ensured that the waveform capture is turned ON before logging off from any communication session. (The capture can be turned ON manually using WinECP.)

5. **VT connection**: The latest firmware allows the user to select NONE as an option under "VT Connection" when no VT input is connected. The current values in A phase in Winding 1 will be taken as a reference and other currents will have angles with reference to the above current. All voltages, power and energy values will be displayed as zero.

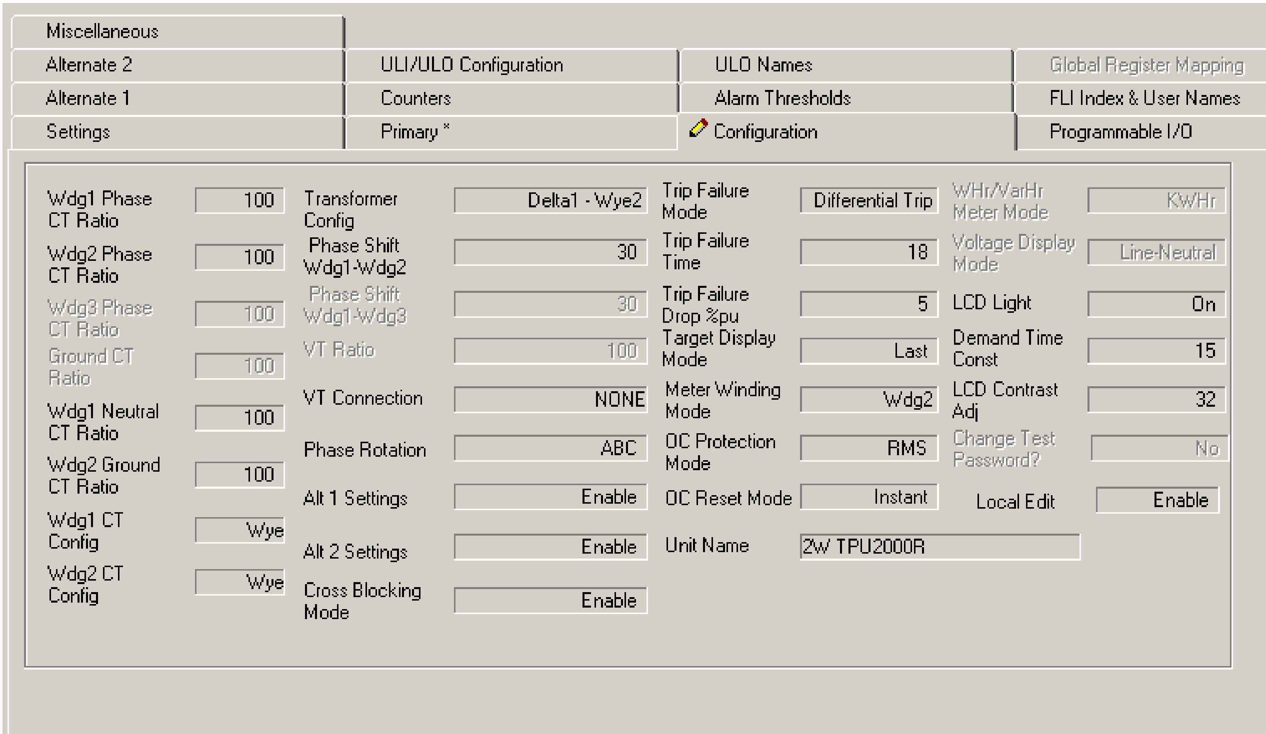

Figure A-9: Configuration Menu with VT Connection set as NONE

6. **Harmonic Blocking**: Harmonic restraint blocking will be stretched for 12.5% of the harmonic restraint pickup time with a minimum stretching of 2 cycles (with a pickup delay of 2 cycles) and maximum stretching of 20 cycles, instead of immediate reset as earlier. This makes the blocking more secure.

7. **Star/Star transformer**: With Star/Star connected transformer setting is chosen, internally the relay calculates the delta currents, which introduces a factor of √3. The tap setting is to be suitably adjusted for this.

<u>SOFTWARE TOOL COMPATIBILITY with CPU V2.60</u>

Interface Software: **Win ECP V4.70 Build 12** or higher
DFR viewing Software: **WaveWin VB.X** or higher (Installed with WinECP V4.70 installation)
Programmable Curves Software: **CurveGen: V1.0** or higher (Installed with WinECP V4.70 installation)
Flash programming Software: **WinFPI V1.05 Build 1** or higher (Installed with WinECP V4.70 installation)

TESTING THE NEW MULTISLOPE CHARACTERISTICS

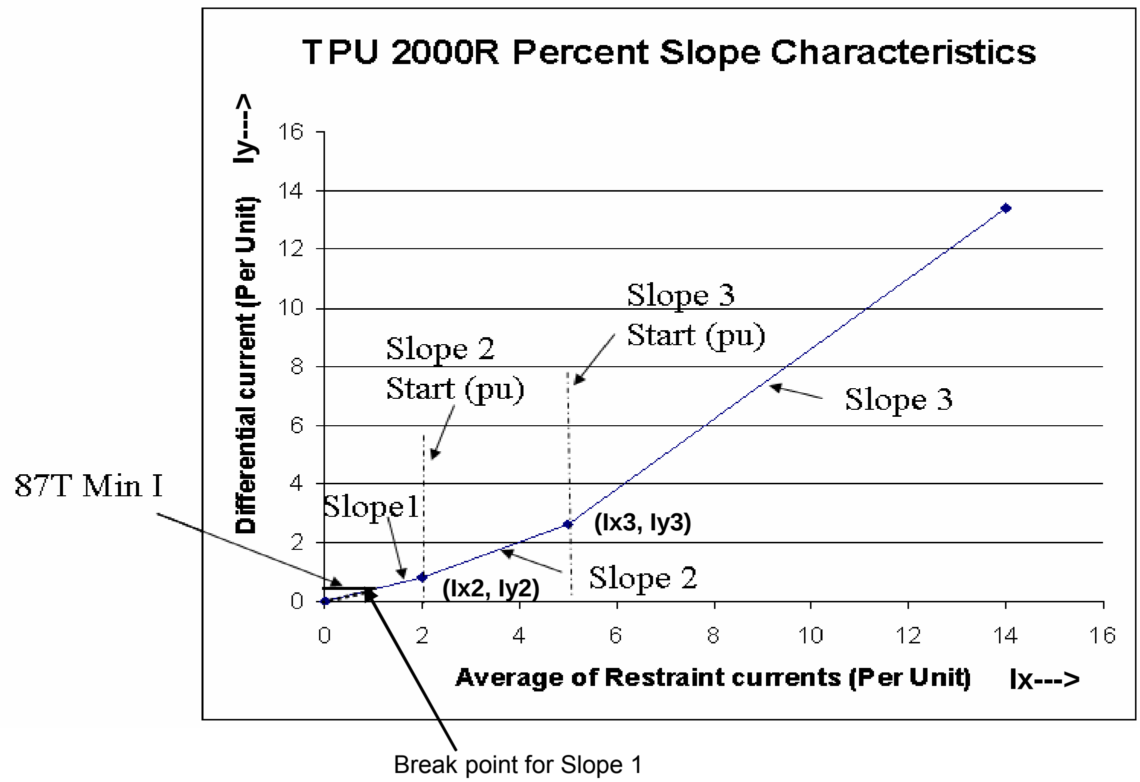

Figure A10: Differential Characteristics

Settings:

Assume the transformer is Delta/Delta, with 0 degree between HV and LV
The current transformers are considered Wye connected.
Assume the tap setting is 2A both on the HV and LV side.
The above are set in the **configuration setting** of the relay

Under Differential setting, **Disable** the **phase comparator**
Select number of slopes as **3**, the following default settings are applicable:

87T Min I	Slope 1	Slope2		Slope 3	
PU	Slope %	Slope%	Start (PU)	%	Start (PU)
0.3	40	60	2	120	5

Define

Define currents I1 and I2 as the two currents injected
into the high and low winding inputs of the relay

The angles are typically set at 180 °

CAUTION: While doing all these tests, ensure that higher currents
are not injected long. This may thermally stress the relay.

Notes:

On the X axis, the current is the average of the "magnitude" of currents

Ix = { |I1| + |I2| } / 2

On the Y axis, the current is the differential current which is the "vectorial" sum of the currents

Iy = **I1** + **I2**

If I2 is at an angle Φ with respect to I1,

Iy =|I1+I2cos(Φ) + j I2sin(Φ)|

Define

a =|I1+I2cos(Φ) |
b =| I2sin(Φ)|

So Iy =? $(a^2 + b^2)$

While testing the differential currents it is usual to keep the angles **between the vectors at 180°**

In such cases, if we use I1 and I2 to indicate the magnitudes'

Ix = { |I1| + |I2| } / 2

Ix =(I1+I2) / 2

Iy =|I1+I2cos(Φ) + j I2sin(Φ)|

Iy =I1-I2

Test procedure:

Note: The following tests involve all three phase currents.

Thus if we mention I1=3A, I2 = 5A the test kit is set as follows:

	Winding 1	**Winding 2**
Ia	3A ∠ 0°	5A ∠ 180°
Ib	3A ∠ 240°	5A ∠ 60°
Ic	3A ∠ 120°	5A ∠ 300°

Testing can be done at any portion of the characteristics by dividing it into various portions as follows.

1. Minimum Pickup:

Keep I2 =0 A, inject I1 current up to 87T Min I level.
I1 = 87T Min Ilevel (PU) = 0.3PU = 0.3 *Tap setting = 0.3*0.2=**0.6**A
The relay should trip for all higher currents.

2. Slope 1:

This is applicable from Ix level indicated as break point for Slope 1 up to Ix level of Slope 2 Start, indicated as Ix2

The break point for Slope 1 = 87T Min I / Slope1
= 0.3PU/40%
=0.3/0.4 = 0.75 PU
= 0.75 * 2 = 1.5 A

For any point in this characteristics,

Iy=Slope1. Ix=I1-I2
Ix = (I1+I2)/2

Solving for I1, I2

I1 = Ix (1+Slope1/2)
I2 =Ix (1-Slope1/2)

For example if the characteristicsis to be tested at 1PU along the X axis,
Ix = 1 PU at a slope of 40% (=0.4)
Substituting the values

I1 = 1.2 PU = 1.2*2 = 2.4A
I2= 0.8 PU =0.8 *2 = 1.6A

Keep a steady current of 0.8PU(1.6A) on both the inputs but at 180° to check the stabaility.
Increse the second current. The relay should trip when the second current exceeds 1.2 PU (2.4A)

3. Slope 2 :

This is applicable from Ix level indicated as Slope 2 Start upto Ix level of Slope 3 Start

Note that at Slope 2 Start,
Ix2 = Slope 2 Start
Iy2 = The differential current corresponding to Ix2

For any point in this portion of the characteristics,

Iy=Slope2.(Ix-Ix2) + Iy2 =I1-I2
Ix =(I1+I2)/2

Solving for I1, I2

I1 = Ix(1+Slope2/2) - Ix2 (Slope2-Slope1)/2
I2 = Ix(1-Slope2/2) + Ix2 (Slope2-Slope1)/2

Suppose one wants to test the characteristics at 4PU along the X axis,
Ix = 4 PU at a slope of 60% (=0.6)
Ix2 = 2 PU
Slope1 =0.4, Slope2=0.6

Substituting the values

I1 = 5 PU = 5x2 = 10A
I2=3 PU = 3x 2 = 6A

Slope 2 onwards may involve very large currents stressing the thermal limits
Momentarily apply 6A in both winding to check stabiity.
Apply these currents in the two windings momentarily:
Application of 6A and 9.6A should not cause trip.
Application of 6A and 10.4A should cause trip.

4. Slope 3 :

This is applicable from Ix level indicated as Slope 3 Start and beyond

Note that at Slope 3 Start,
Ix3 = Slope 3 Start
Iy3 = The differential current corresponding to the above

For any point in this portion of the characteristics,

Iy=Slope3.(Ix-Ix3) + Iy3 =I1-I2
Ix =(I1+I2)/2

Solving for I1, I2

I1 = Ix(1+Slope3 /2) - Ix3 (Slope 3 -Slope2)/2-Ix2(Slope2-Slope1)/2
I2 = Ix(1-Slope3 /2) + Ix3 (Slope3-Slope2/2+Ix2(Slope2-Slope1)/2

Suppose one wants to test the characteristics at 6PU along the X axis,
Ix = 6 at a slope of 120% (=1.2)
Ix2 = 2PU, Ix3 = 5PU
Slope1= 0.4, Slope2=0.6, Slope3=1.2

Substituting the values

I1 = 4.1PU = 4.1 x 2 = 8.2A
I2= 7.9 PU = 7.9 x 2 = 15.8A

Slope 3 testing may again involve very large currents stressing thermal limits.
Momentarily apply 8.2A in both windings to check stabiity.

Apply these currents in the two windings momentarily:
Application of 8.2A and 15A in respective windings should not cause trip.
Application of 8.2A and 16.5A should cause trip.

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Precautions

Take the following precautions when using the ABB Transformer Protection Unit 2000R:

1. Incorrect wiring may result in damage. Be sure wiring agrees with connection diagram before energizing.

2. Apply only the rated control voltage marked on the unit.

3. High-potential tests are not recommended. If a control wire insulation test is required, fully withdraw the TPU-2000R from its case and perform only a DC high-potential test. **Surge capacitors installed in the unit do not allow AC high-potential testing.**

4. Follow test procedures to verify proper operation. To avoid personal shock, use caution when working with energized equipment. Only competent technicians familiar with good safety practices should service these devices.

5. In the event the self-checking function detects a system failure, the protective functions are disabled and the alarm contacts are actuated. Replace the unit as soon as possible.

Password

6. A correct password is required to make changes to the relay settings and to test the output contacts. **The preset factory password is four blank spaces**. Once you have chosen a new password and entered it into the system, access will be denied if the password is forgotten. If you forget the password, contact the factory.

WARNING: **Removal of the relay from the case exposes the user to dangerous voltages. Use extreme care. Do not insert hands or other foreign objects into the case.**

This instruction booklet contains the information to properly install, operate and test the TPU-2000R, but does not purport to cover all details or variations in equipment, nor to provide for every possible contingency to be met in conjunction with installation, operation or maintenance. Should particular problems arise which are not sufficiently covered for the purchaser's purposes, please contact ABB Power T&D Company Inc.

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Tables

Introduction

The Transformer Protection Unit 2000R (TPU-2000R) is a microprocessor-based relay that protects three-phase, two or three winding transmission and distribution power transformers. Available for 5 amp, 1 amp, or 0.1 amp secondary current transformers (CTs), the TPU-2000R provides sensitive high-speed differential protection for internal phase and ground faults, as well as backup overcurrent protection for through-faults. Harmonic restraint prevents operation on magnetizing inrush and overexcitation.

The TPU-2000R is packaged in a metal case suitable for conventional flush mounting on a rack panel. The TPU-2000R can be totally withdrawn from its case with the exception of the input transformers. All connections to the TPU-2000R are made at clearly identified terminals on the rear of the unit.

Because of its microprocessor capability, the TPU-2000R provides the following protection, control and monitoring functions in one integrated package:

- Isolated communication ports for superior noise-free communications
- Password protected settings and controls
- Expanded operating temperature range, from -40° C to +70° C
- 32 samples per cycle for all functions including Protection, Metering and Oscillographics
- Three-phase, two or three winding transformer percentage and instantaneous differential protection: 87T/87H
- Winding 1 phase time and instantaneous overcurrent protection: 51P-1, 50P-1, 150P-1
- Winding 2 phase time and instantaneous overcurrent protection: 51P-2, 50P-2, 150P-2
- #Winding 3 phase time and instantaneous overcurrent protection: 51P-3, 50P-3, 150P-3
- Winding 1 residual neutral time and instantaneous overcurrent protection: 51N-1, 50N-1, 150N-1
- Winding 2 ground time and instantaneous overcurrent protection: 51G-2, 50G-2, 150G-2 (#51N-2, #50N-2, #150N-2)
- #Winding 3 residual neutral time and instantaneous overcurrent protection: 51N-3, 50N-3, 150N-3
- #Ground time and instantaneous overcurrent protection: 51G, 50G, 150G
- Winding 1 negative sequence time overcurrent protection: 46-1
- Winding 2 negative sequence time overcurrent protection: 46-2
- #Winding 3 negative sequence time overcurrent protection: 46-3
- Winding 1, 2 and #3 level detectors for local or upstream switch/breaker tripping decisions
- Metering of Winding 1, 2 and #3 phase and neutral/ground currents
- Metering of restraint currents, operate-currents and percentage of 2nd, 5th and all harmonics
- Optional metering of: voltages, watts, VARs, watt-hours and VAR hours, powerfactor and frequency
- Demand currents and peak demand currents with time stamp for winding 1, 2 or #3
- Optional demand watts and VARs with time stamp for winding 1, 2 or #3
- Detailed differential fault records for last 32 trips
- Detailed harmonic restraint record for last 32 restraints
- Detailed through-fault records for last 32 overcurrent trips or disturbances
- Operations (sequence of events) record for last 128 operations
- Eight (8) binary (contact) inputs: eight (8) user-programmable
- Seven (7) output contacts: six (6) user-programmable
- Three selectable settings tables: Primary, Alternate 1 and Alternate 2
- Summation of through-fault kiloamperes and duration of faults in cycles
- Battery backed-up clock maintains date and time during control power interruptions
- Continuous self-diagnostics on power supply, memory elements and microprocessors
- Front RS-232 port and a variety of rear communication port options such as RS-232, RS-485 and Modbus®
- Optional load profile capability: four currents for 40 days at 15-minute intervals
- Stores Watts, Vars and phase voltages with optional voltage inputs
- Optional user-programmable time overcurrent curves and differential restraint curves
- Optional oscillographic data storage for last eight (8) faults
- Multiple communications protocols support 10 byte ASCII, IEC870.5 (DNP 3.0), SPACOM, MODBUS®, MODBUS PLUS™ and PG&E

 # Denotes 3 Winding Relay only

Protective Functions

The TPU-2000R contains many protective relay functions. Three settings tables (Primary, Alternate 1 and Alternate 2) provide the flexibility to quickly change parameters. In addition, the TPU-2000R has programmable logic capabilities and expanded metering.

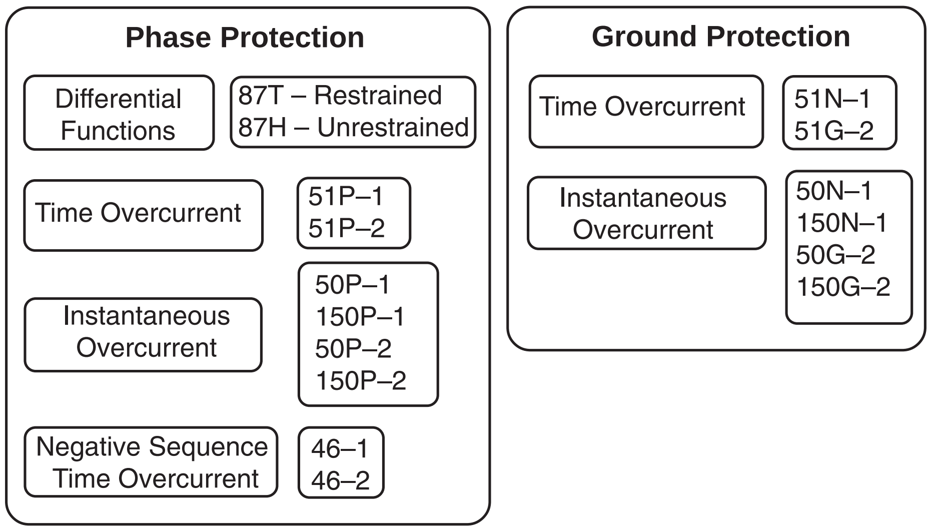


Figure 1-1. Protective Functions for the Two Winding Relay

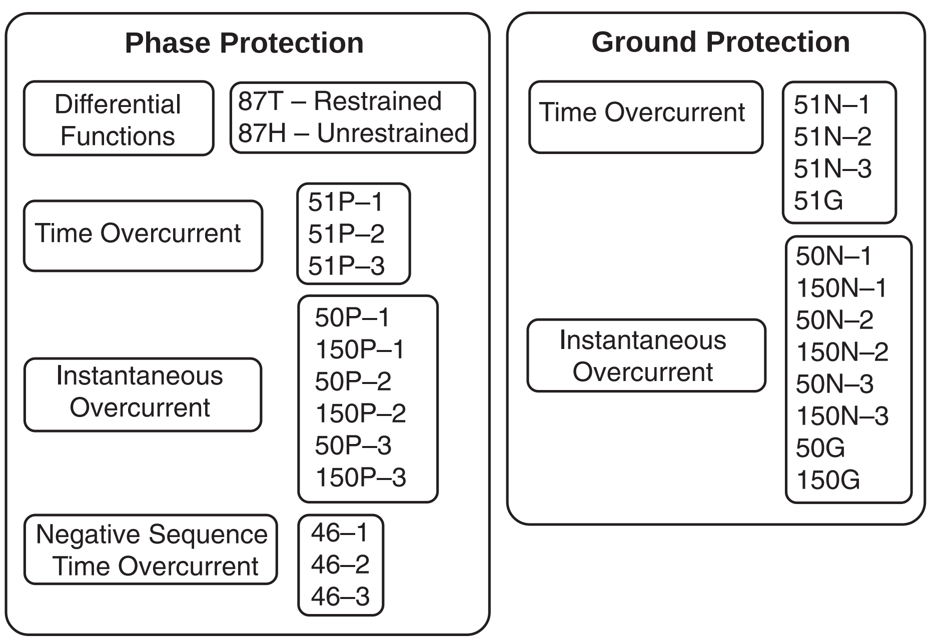


Figure 1-2. Protective Functions for the Three Winding Relay

Harmonic Restrained Percentage Differential Function 87T

87T Parameter	Range	Increment
Winding 1 and 2 differential tap settings		
5-A CTs	2 to 9 A	0.1 A
1-A CTs	0.4 to 1.8 A	0.02 A
0.1 A CTs (for use with ABB Optical CTs)	0.04 to 0.18 A	0.002 A
Harmonic restraint setting		
2nd harmonic	7.5 to 25% of the fundamental frequency	2.5%
5th harmonic	15 to 40% of the fundamental frequency	2.5%
All harmonics	15 to 40% of the fundamental frequency	2.5%

The 87T differential function provides high-speed phase and ground protection for two and three winding power transformers. It allows CT ratio matching between the two or three windings of a power transformer. Enable or disable the 87T function in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program. By using the harmonic restraint mode, you can select to restrain on 2nd, 2nd and 5th or all harmonics (2nd through 11th) during transformer inrush and overexcitation. Harmonic restraint occurs in a phase winding when the harmonic restraint setting and the operating current are exceeded in that phase.

The winding 1, 2 and 3 (if applicable) restraint currents are normalized in per unit based on the 87T-1, 87T-2 and 87T-3 (if applicable) tap settings, respectively. The restraint current is the current in per unit of tap that flows through the restraint winding. This current is derived according to the phase angle compensation chosen and the CT connections used. The operate-current is the vectorial summation of the per-unit winding 1, 2 and 3 (if applicable) restraint currents.

Until the differential current is greater than a certain percentage of the through-current, the percentage differential operating characteristic prevents operation. This characteristic accommodates CT errors, particularly those resulting from CT saturation at high current faults external to the protected zone. The percentage characteristic (the slope) is adjustable and allows tailoring of the operating characteristic to handle load tap changer variations.

The percentage differential characteristic curves include:

- an adjustable linear % slope with an adjustable minimum operate-current
- an HU 30% variable slope with a fixed minimum operate-current
- an HU 35% variable slope with a fixed minimum operate-current
- a variable slope at 15%, 25% or 40% tap with a fixed minimum operate-current Phase Angle Compensation

Percentage Differential Curve	Percent Slope	Percent Slope Increment	Minimum Operating Current	Increment
Adjustable linear % slope	15 to 60%	5%	0.2 to 1.0 per unit tap	0.1
HU 30% variable slope	–	–	Fixed at 0.3 per unit tap	–
HU 35% variable slope	–	–	Fixed at 0.35 per unit tap	–
Variable slope at 15%, 25%, or 40% tap	–	–	Fixed at 0.3 per unit tap	–

For the two or three winding relay, the operate point for the HU30% and HU35% characteristic occurs when the vectorial sum of the restraint currents, expressed as a percentage of the largest restraint current, exceeds the selected HU characteristic curve (see Figure 1-3).

For the two winding relay, the operate point for the 15%, 25% and 40% tap characteristic occurs when the difference between the two restraint currents, expressed as a percentage of the smaller restraint current, exceeds the selected % tap characteristic curve (see Figure 1-4).

For the two winding relay, the operate point for the adjustable % slope occurs when the difference between the two restraint currents, expressed as a percentage of the smaller restraint current, exceeds the % slope setting (see Figure 1-5).

For the three winding relay, when using the Constant % Differential Characteristic (Figure 1-4) or the Adjustable Constant % Differential Characteristic (Figure 1-5), the smaller restraint current in per unit of tap is defined as follows:

Assume three levels of restraint current magnitude for each phase:

Imax = Highest restraint current in per unit of tap

Imin = Smallest restraint current in per unit of tap

Imid = Middle restraint current in per unit of tap

Then the smaller restraint current for figures 1-4 and 1-5 is the following:

If **I**mid + **I**min < **I**max *then* **I** smaller = **I**mid + **I**min

If **I**mid + **I**min > **I**max *then* **I** smaller = 3**I**min - **I**mid

Figure 1-3. Variable % Differential (HU) Characteristic

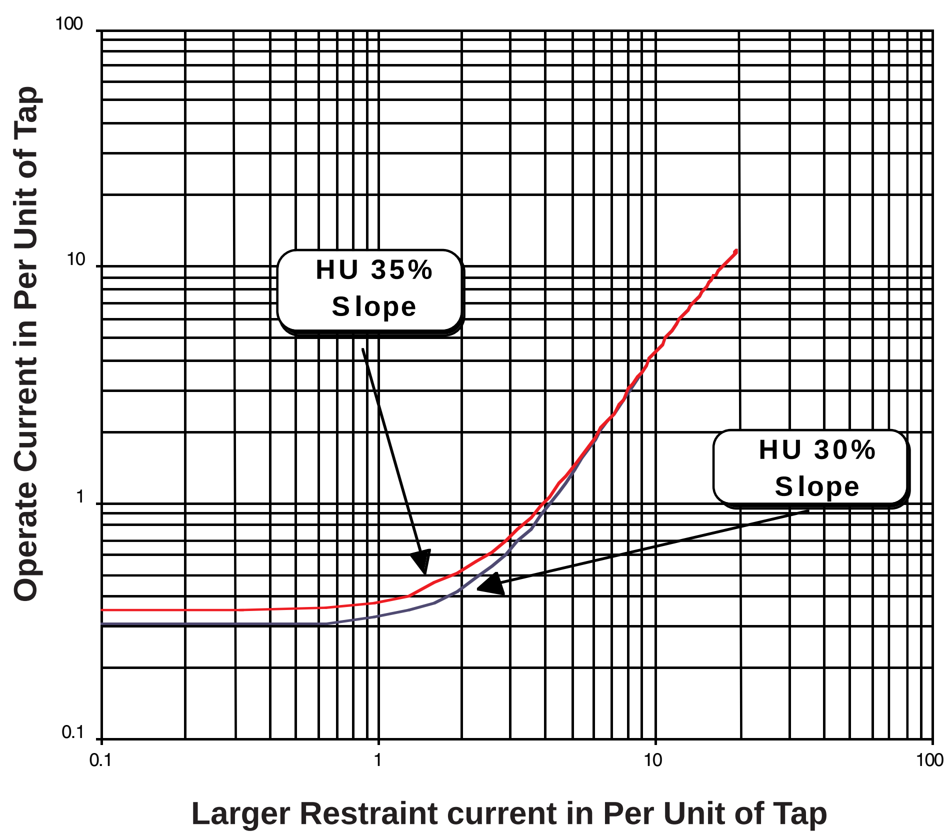


Figure 1-4. Constant % Differential Characteristic

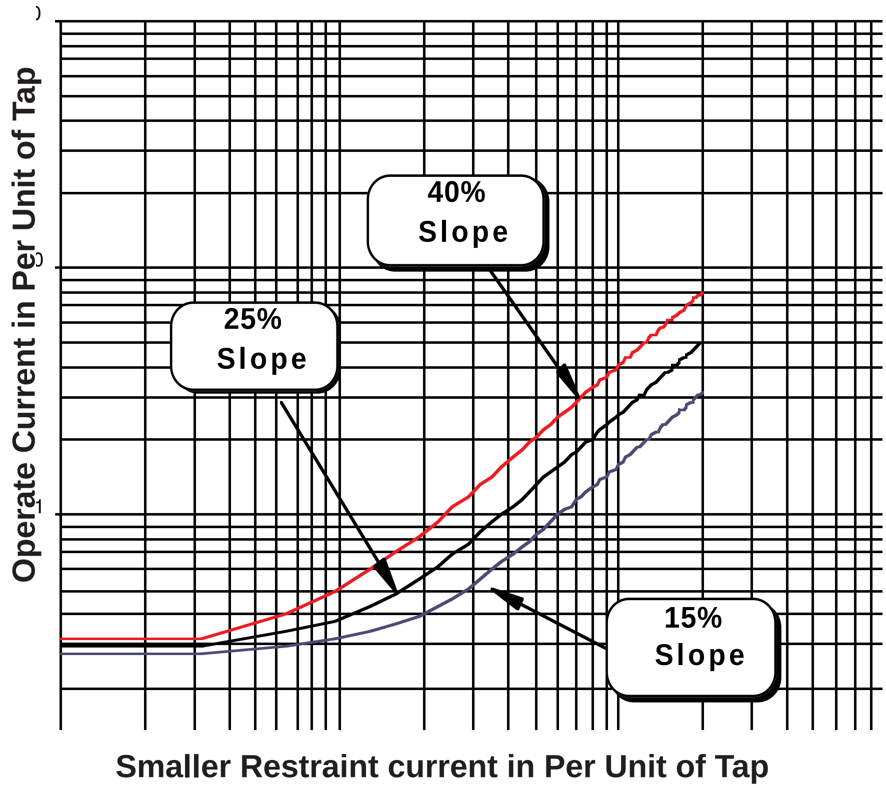
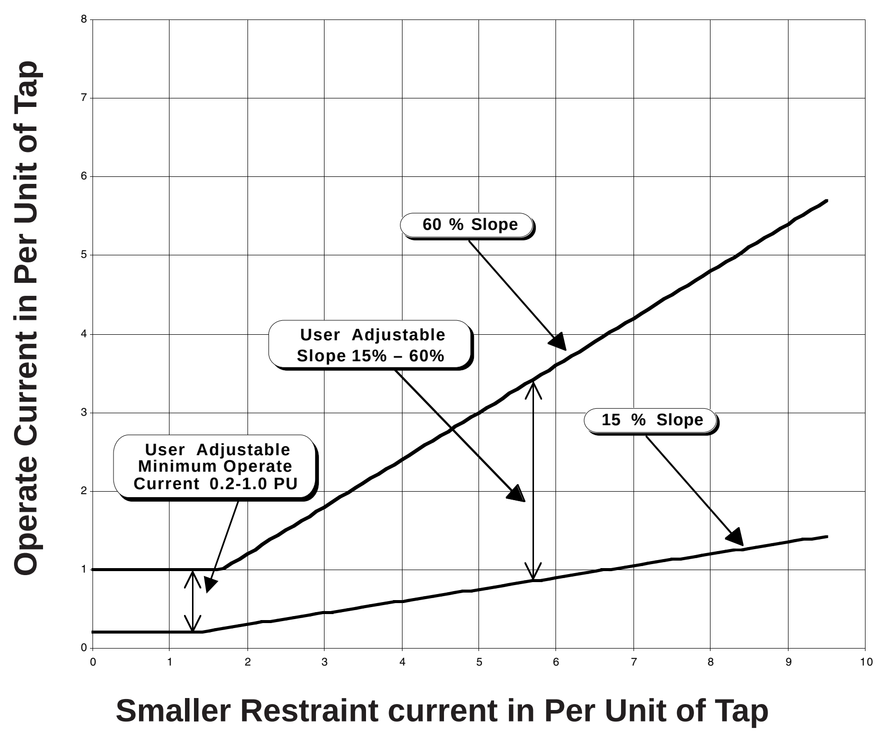


Figure 1-5. Adjustable Constant % Differential Characteristic



Unrestrained High Set Instantaneous Differential Function 87H

Function	Range	Increment
87H	6 to 20 multiples of operate current per unit	0.1

The 87H unrestrained high set instantaneous differential function operates directly on the magnitude of the operate-current with no intentional delay. The operate-current is the vectorial summation of the per-unit winding 1, winding 2 and winding 3 (if applicable) restraint currents. The pickup setting of the 87H function is in MULTIPLES of the per-unit operate-current. For internal faults the CT secondary fault current required to trip the 87H function varies depending on the winding source:

- If source is on winding 1, CT fault current = 87H pickup setting x 87T-1 tap setting.
- If source is on winding 2, CT fault current = 87H pickup setting x 87T-2 tap setting.
- If source is on winding 3, CT fault current = 87H pickup setting x 87T-3 tap setting.

Enable or disable the 87H function in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

Phase Time Overcurrent Functions 51P-1/51P-2/51P-3

51P-1/51P-2/51P-3 Parameter	Range	Increment
Pickup setting, 5 amp CT	1 to 12 A	0.1 A
Pickup setting, 1 amp CT	0.2 to 2.4 A	0.02 A
Pickup setting, 0.1 amp CT for use with ABB Optical CTs	0.02 to 0.24 A	0.002 A

The 51P-1, 51P-2 and 51P-3 (if applicable) functions protect the transformer from fault level currents. The breaker is tripped on a programmable time-delay basis when the 51P pickup setting threshold has been exceeded. Depending on the timing requirements, any one of nine 51P time overcurrent characteristic timing curves can be programmed into the TPU-2000R (see Table 1-1 on page 16). Enable or disable the 51P-1, 51P-2 and 51P-3 functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

Two reset modes are available for the 51P functions. In the instantaneous reset mode, the function resets immediately when the current drops below the pickup setting for one half of a cycle. In the delayed reset mode, the function follows a slow reset characteristic that depends on the duration of the overcurrent condition and the amount of load current after the overcurrent condition.

If the CTs are configured in Delta, the pickup values should be set as if the CTs were wired in Wye. The line currents should be used for pickup calculations and <u>**NOT**</u> currents seen at the inputs of the relay..

In the three winding TPU, the CTs **must** be configured in Wye.

1st Phase Instantaneous Overcurrent Functions 50P-1/50P-2/50P-3

50P-1/50P-2/50P-3 Parameter	Range	Increment
Pickup setting	0.5 to 20 times	0.1 times
Curves:		
Instantaneous Curve	No delay	
Inverse Instantaneous, Short Time Inverse, and Short Time Extremely Inverse Curves	1 to 10 time dial	0.1
Definite Time Curve	0 to 9.99 seconds	0.01 seconds

The winding 1, 2 and 3 (if applicable) instantaneous overcurrent 50P-1, 50P-2, 50P-3 pickup settings are in MULTIPLES of the 51P-1, 51P-2 and 51P-3 time overcurrent pickup settings, respectively. Depending on your timing requirements, you can select any one of the five instantaneous overcurrent characteristic timing curves programmed into the TPU-2000R (see Table 1-2 on page 16). Enable or disable the 50P-1, 50P-2 and 50P-3 functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

2nd Phase Instantaneous Overcurrent Functions 150P-1/150P-2/150P-3

150P-1/150P-2/150P-3 Parameter	Range	Increment
Pickup setting	0.5 to 20 times	0.1 times
Definite time curve	0 to 9.99 seconds	0.01 seconds

The winding 1, 2 and 3 (if applicable) instantaneous overcurrent 150P-1, 150P-2 and 150P-3 pickup settings are in MULTIPLES of the 51P-1, 51P-2 and 51P-3 time overcurrent pickup settings, respectively. Enable or disable the 150P-1, 150P-2 and 150P-3 functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

Ground Time Overcurrent Functions 51N-1/51G-2 (2 Winding Relay) 51N-1/51N-2/51N-3 (3 Winding Relay)

2 Winding Relay

51N-1/51G-2 (2w) Parameter 51N-1/51N-2/51N-3/51G (3w) Parameter	Range	Increment
Pickup setting (5A CT)	1 to 12 A	0.1 A
Pickup setting (1A CT)	0.2 to 2.4 A	0.02
Pickup setting (0.1A CT) for use with ABB Optical CTs	0.02 to 0.24 A	0.002 A
Curves:		
Inverse Type Curves	0 to 10 time dial	0.1
Definite time curve	0 to 10 seconds	0.1 seconds

For the 2 winding relay, you can connect the TPU-2000R's winding 1 and 2 ground current inputs for residual or zero sequence applications. Depending on timing requirements, any one of nine time overcurrent characteristic timing curves can be programmed into the TPU-2000R (see Table 1-1). Enable or disable the 51N and 51G functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

3 Winding Relay

For the 3 winding relay, the neutral currents are calculated internally by the relay. These give the base currents needed for the 51N-1, 51N-2 and 51N-3 functions, respectively. For example, the winding 1 neutral current is simply the vectorial sum of IA-1, IB-1 and IC-1 currents. Depending on your timing requirements, you can select any one of nine time overcurrent characteristic timing curves programmed into the TPU-2000R (see Table 1-1), or you can program time delay selection for the Definite Time Curve. Enable or disable the 51N-1, 51N-2 and 51N-3 functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Input screen of the External Communications Program.

Floating Ground Time Overcurrent Function 51G (3 Winding Relay only)

A separate CT input is available on the three winding relay. This input gives the base current needed for the 51G function. Depending on the timing requirements, select any one of nine time over current characteristic timing curves programmed into the TPU 2000R (see table 1-1), or program the time delay selection for the Definite Time Curve. Enable or disable the 51G function in the primary, Alternate 1 and Alternate 2 settings. When a function is enabled in the settings table, that function can be remotely enabled or disabled by mapping it to a programmable contact input in the programmable input screen of the External Communications Program.

Two reset modes are available for the above functions in both the 2 and 3 winding relays. In the instantaneous reset mode, the function resets immediately when the current drops below the pickup setting for one half of a cycle. In the delayed reset mode, the function follows a slow reset characteristic that depends on the duration of the overcurrent condition and the amount of load current after the overcurrent condition. See Reset Time Equation above Table 1-3.

1st Ground Instantaneous Overcurrent Functions 50N-1/50G-2 (2 Winding Relay) and 50N-1/50N-2/50N-3/50G (3 Winding Relay)

50N-1/50G-2 (2w) Parameter 50N-1/50N-2/50N-3/50G (3w) Parameter	Range	Increment
Pickup setting	1 to 12 A	0.1 A
Curves:		
Instantaneous Curve	No delay	
Inverse Instantaneous, Short Time Inverse, and Short Time Extremely Inverse Curves	0 to 10 time dial	0.1
Definite Time Curve	0 to 9.99 seconds	0.01 seconds

For the 2 winding relay, the winding 1 and 2 instantaneous overcurrent 50N-1 and 50G-2 pickup settings are in MULTIPLES of the 51N-1 and 51G-2 time overcurrent pickup settings, respectively. For the 3 winding relay, the instantaneous overcurrent 50N-1, 50N-2, 50N-3 and 50G pickup settings are in MULTIPLES of the 51N-1, 51N-2, 51N-3 and 51G time overcurrent pickup settings, respectively. Depending on your timing requirements, you can select any one of the five instantaneous overcurrent characteristic timing curves programmed into the TPU-2000R (see Table 1-2 on page 16). Enable or disable any of the above functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

2nd Ground Instantaneous Overcurrent Functions 150N-1/150G-2 (2 Winding Relay) and 150N-1/150N-2/150N-3/150G (3 Winding Relay)

150N-1/150G-2 (2w) Parameter 150N-1/150G-2/150N-3/150G (3w) Parameter	Range	Increment
Pickup setting	0.5 to 20 times	0.1 times
Definite time curve	0 to 9.99 seconds	0.01 seconds

For the 2 Winding Relay, the winding 1 and 2 instantaneous overcurrent 150N-1 and 150G-2 pickup settings are in MULTIPLES of the 51N-1 and 51G-2 time overcurrent pickup settings, respectively. For the 3 Winding Relay, the instantaneous overcurrent functions 150N-1, 150N-2, 150N-3 and 150G are multiples of 51N-1, 51N-2, 51N-3 and 51G respectively. Enable or disable any of the above functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

Negative Sequence Time Overcurrent Functions 46-1/46-2/46-3

46-1/46-2/46-3 Parameter	Range	Increment
Pickup setting, 5 ampere CT	1 to 12A	0.1A
Pickup setting, 1 ampere CT	0.2 to 2.4A	0.02A
Pickup setting, 0.1 ampere MOCT	0.02 to 0.24A	0.002A

The negative sequence time overcurrent function provides increased sensitivity on phase-to-phase faults. The 46 functions have the same pickup range, curve selections and time dial range as the 51P selections. Enable or disable the winding 1, 2 and 3 (if applicable) 46 functions in the Primary, Alternate 1 and Alternate 2 settings. When the function is enabled in the settings table, you can remotely enable or disable that function by mapping it to a programmable contact input in the Programmable Inputs screen of the External Communications Program.

The negative sequence function can be set below load current because normal, balanced load currents do not generate negative sequence current. Increased sensitivity for phase-to-phase faults can be gained. For a phase-to-phase fault where Ia = Ib and Ic = 0, the negative sequence current I_2 equals 58% of Ia.

Two reset modes are available for the 46 functions. In the instantaneous reset mode, the function resets immediately when the current drops below the pickup setting for one half of a cycle. In the delayed reset mode, the function follows a slow reset characteristic that depends on the duration of the overcurrent condition and the amount of load current after the overcurrent condition.

Table 1-1. Time Overcurrent Curves (51/46)*

Curve	Time Dial/Delay
Extremely Inverse	1.0 to 10
Very Inverse	1.0 to 10
Inverse	1.0 to 10
Short Time Inverse	1.0 to 10
Definite Time	0.0 to 10.0 seconds
Long Time Extremely Inverse	1.0 to 10
Long Time Very Inverse	1.0 to 10
Long Time Inverse	1.0 to 10
Recloser Curve #8	1.0 to 10
User Prog 1 †	–
User Prog 2 †	–
User Prog 3 †	–

Table 1-2. Instantaneous Overcurrent Curves (50)

Curve	Time Dial/Delay
Standard	Instantaneous
Inverse	1.0 to 10
Definite Time	0 to 9.99 seconds
Short Time Inverse	1.0 to 10
Short Time Extremely Inverse	1.0 to 10
User Prog 1 †	–
User Prog 2 †	–
User Prog 3 †	–

*Time overcurrent curves are also available as transparencies
†Only available with the user-programmable curves option.
Refer to section 10 (Optional Features).

Timing Curves

Time Overcurrent Curve Equation

ANSI

$$\text{Trip Time} = \left(\frac{A}{M^p - C} + B\right) \times \left(\frac{14n-5}{9}\right)$$

$$\text{Reset Time} = \left(\frac{D}{|1-EM|}\right) \times \left(\frac{14n-5}{9}\right)$$

M = Multiples of pickup current (I/Ipu)

n = Time Dial setting (range 1 to 10 in steps of 0.1)

Table 1-3. Constants for Time Overcurrent Characteristics

Curve	A	B	C	P	D	E
Extremely Inverse	6.407	0.025	1	2.0	3	0.998
Very Inverse	2.855	0.0712	1	2.0	1.346	0.998
Inverse	0.0086	0.0185	1	0.02	0.46	0.998
Short Time Inverse	0.00172	0.0037	1	0.02	0.092	0.998
Short Time Ext. Inv.	1.281	0.005	1	2.0	0.6	0.998
Long Time Ext. Inv.	64.07	0.250	1	2.0	30	0.998
Long Time Very Inv.	28.55	0.712	1	2.0	13.46	0.998
Long Time Inverse	0.086	0.185	1	0.02	4.6	0.998
Recloser Curve #8	4.211	0.013	0.35	1.8	3.29	1.5

Notes:

- The time in seconds for the Long Time Extremely Inverse Curve is 10 times that of the Extremely Inverse Curve.
- The time in seconds for the Long Time Very Inverse Curve is 10 times that of the Very Inverse Curve.
- The time in seconds for the Long Time Inverse Curve is 10 times that of the Inverse Curve.
- The time in seconds for the Short Time Inverse Curve is 1/5 times that of the Inverse Curve.
- The time in seconds for the Short Time Extremely Inverse Curve is 1/5 times that of the Extremely Inverse Curve.

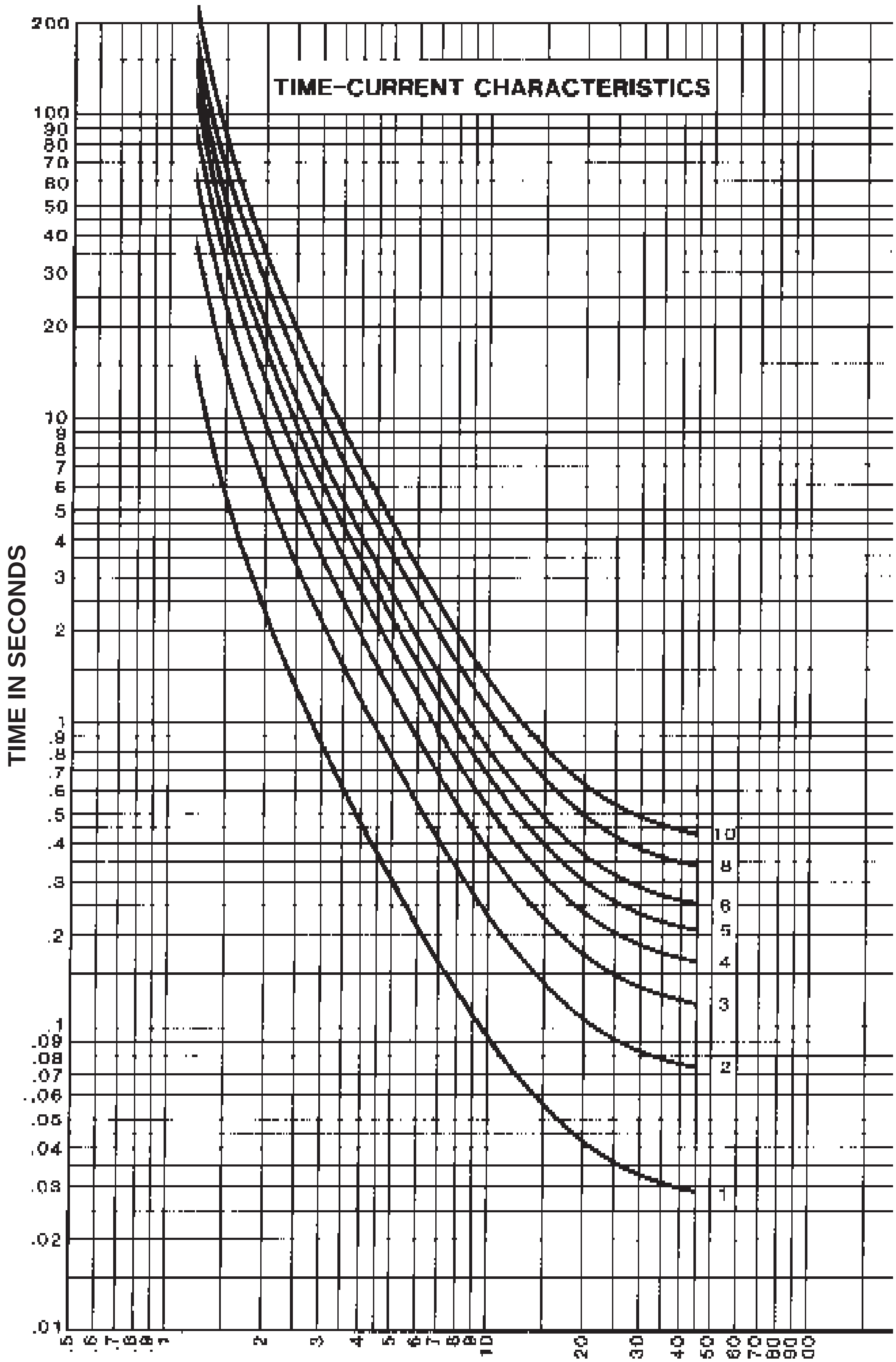


Figure 1-6. Extremely Inverse Curve

DWG. NO. 605842 Rev. 2

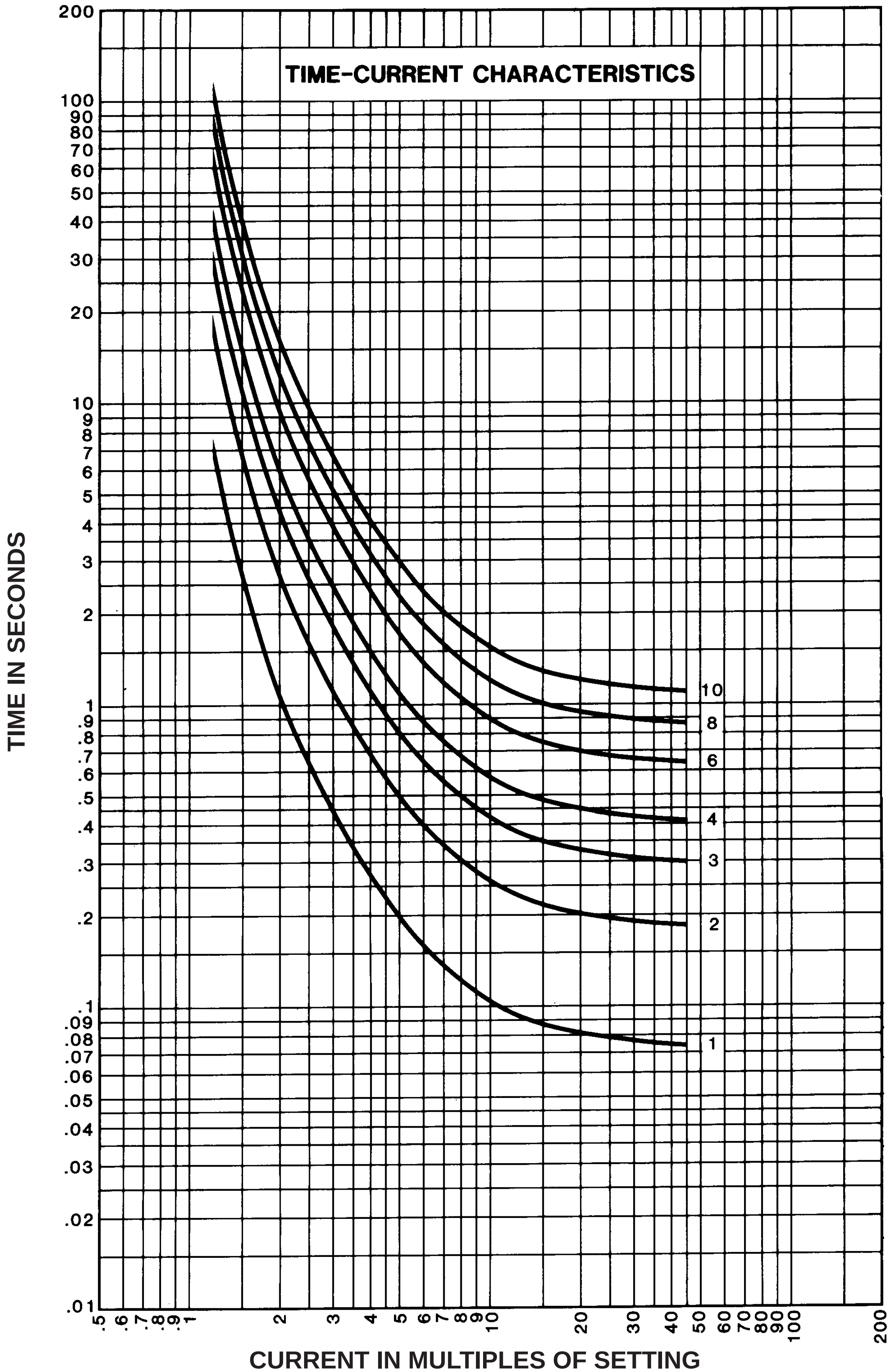
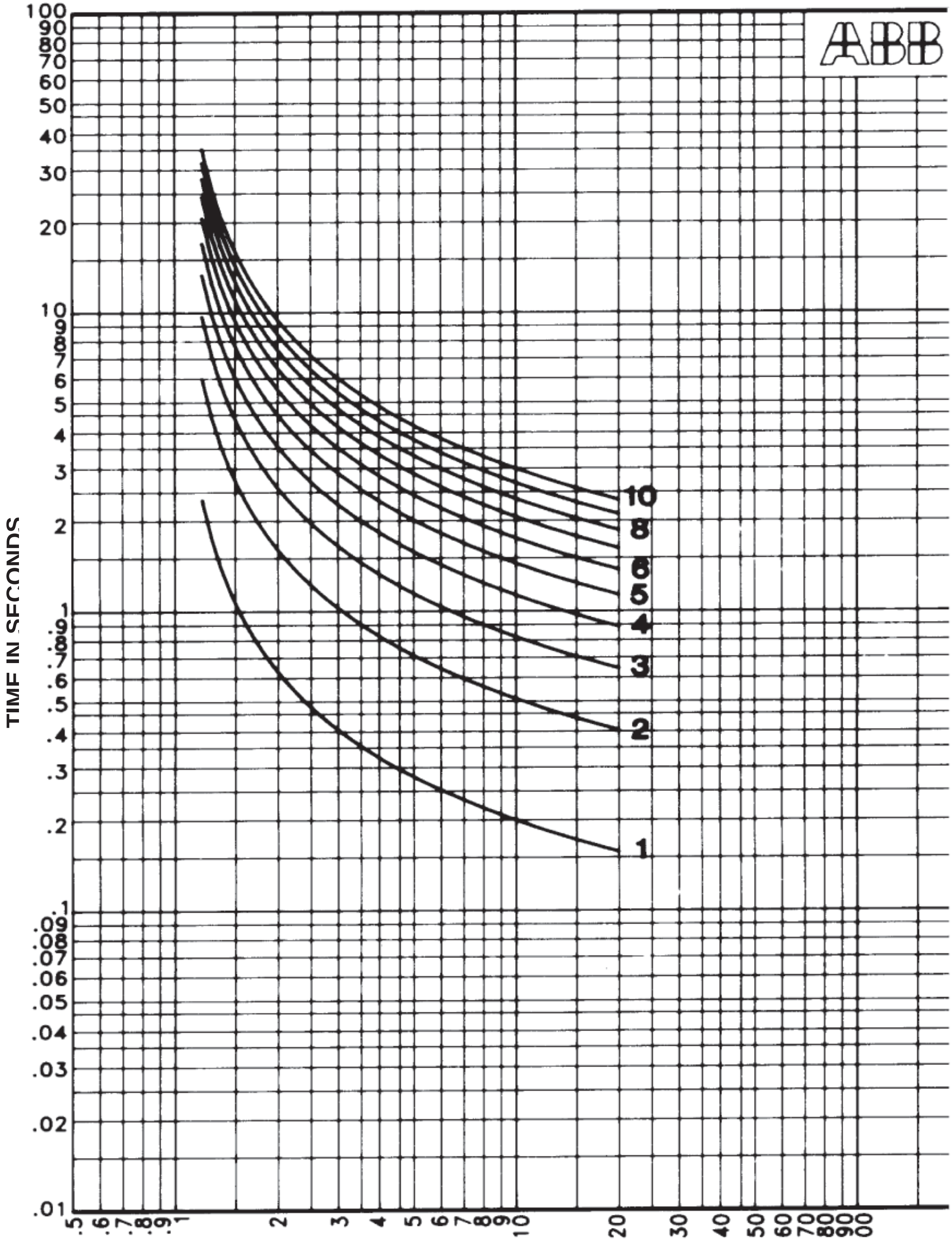


Figure 1-7. Very Inverse Curve

DWG. NO. 605841 Rev. 2



CURRENT IN MULTIPLES OF SETTING

Figure 1-8. Inverse Curve

DWG. NO. 605854 Rev. 0

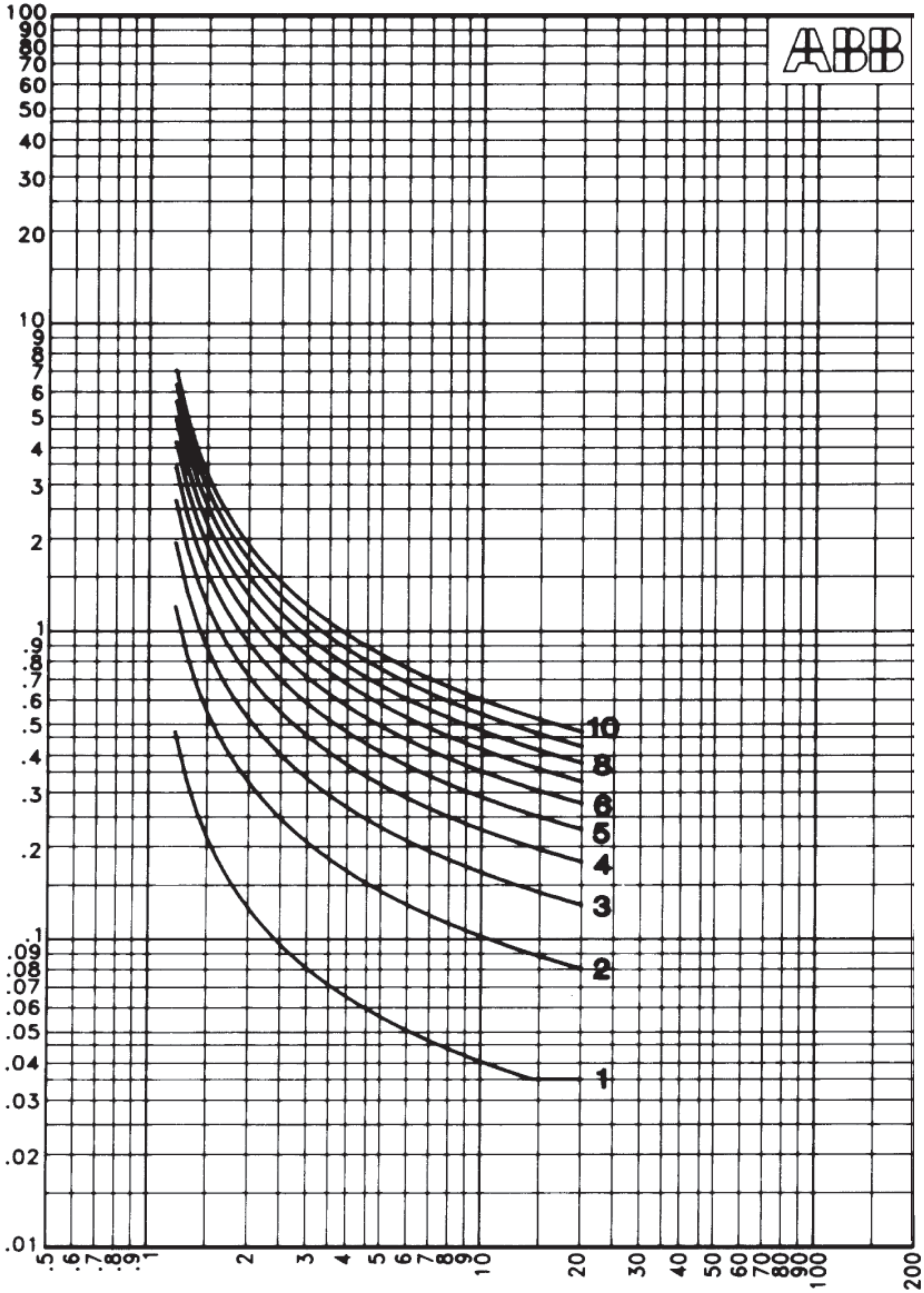


Figure 1-9. Short Time Inverse Curve

DWG. NO. 605855 Rev. 0

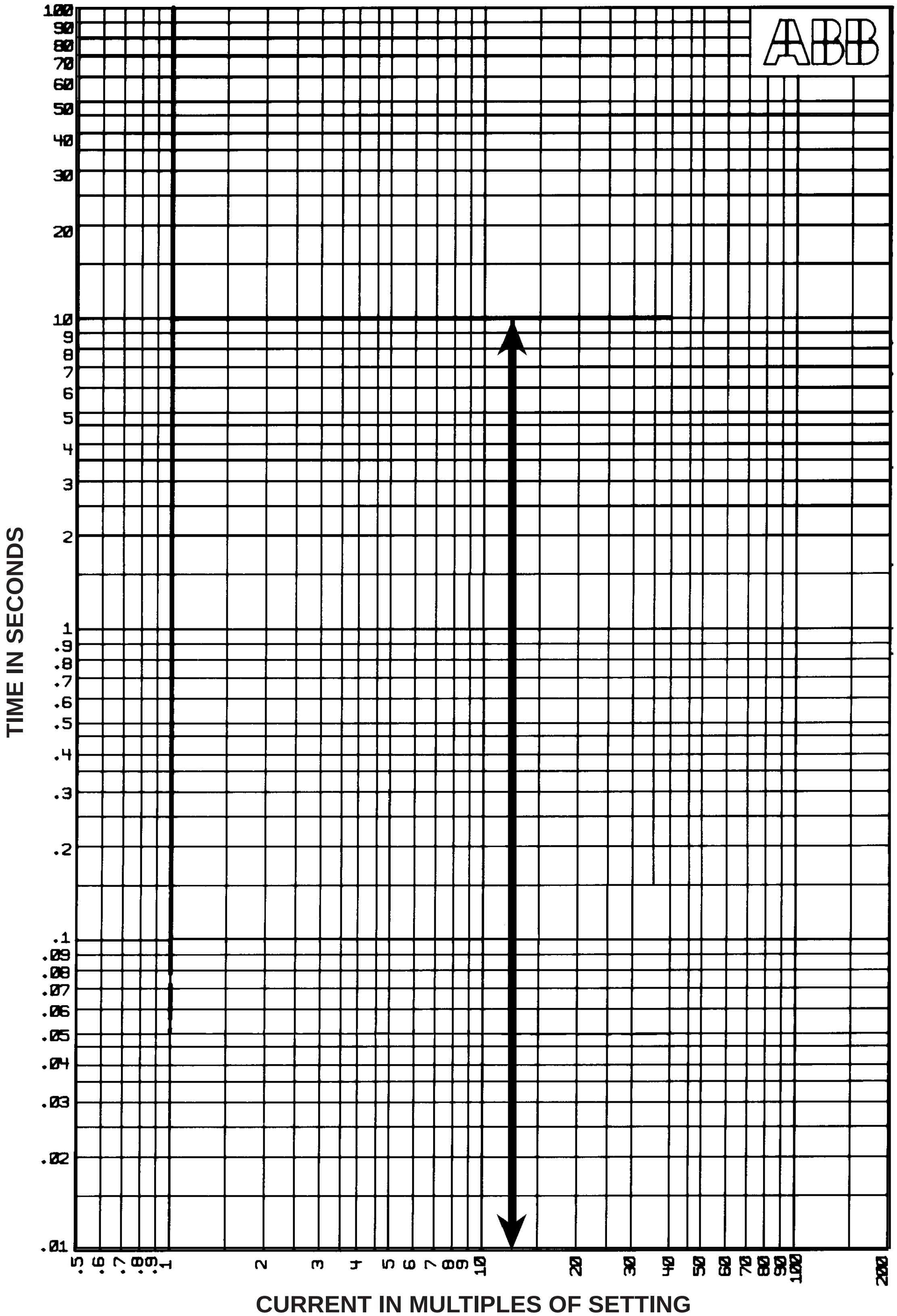


Figure 1-10. Definite Time Curve

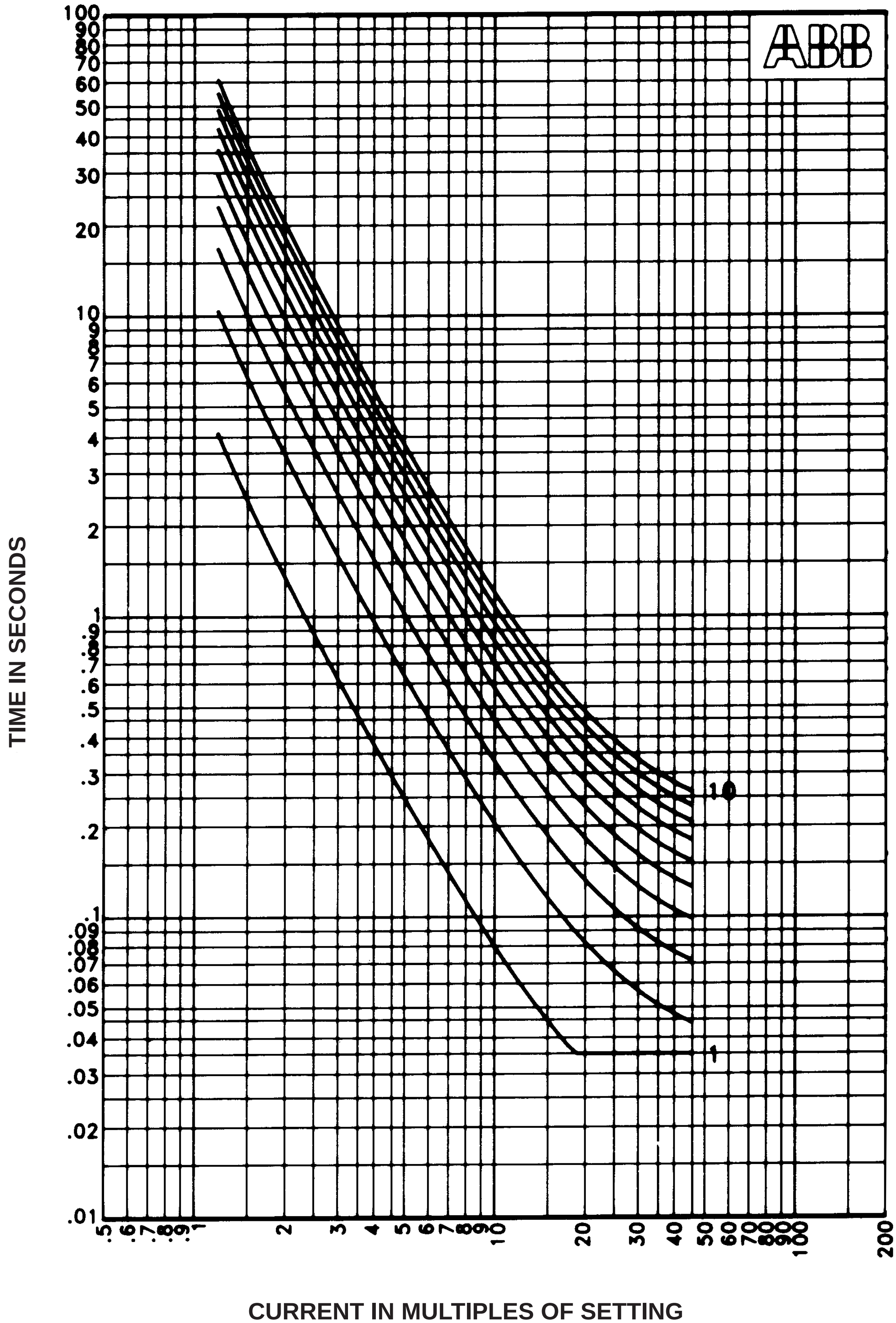


Figure 1-11. Recloser Curve #8

DWG. NO. 605856 Rev. 0

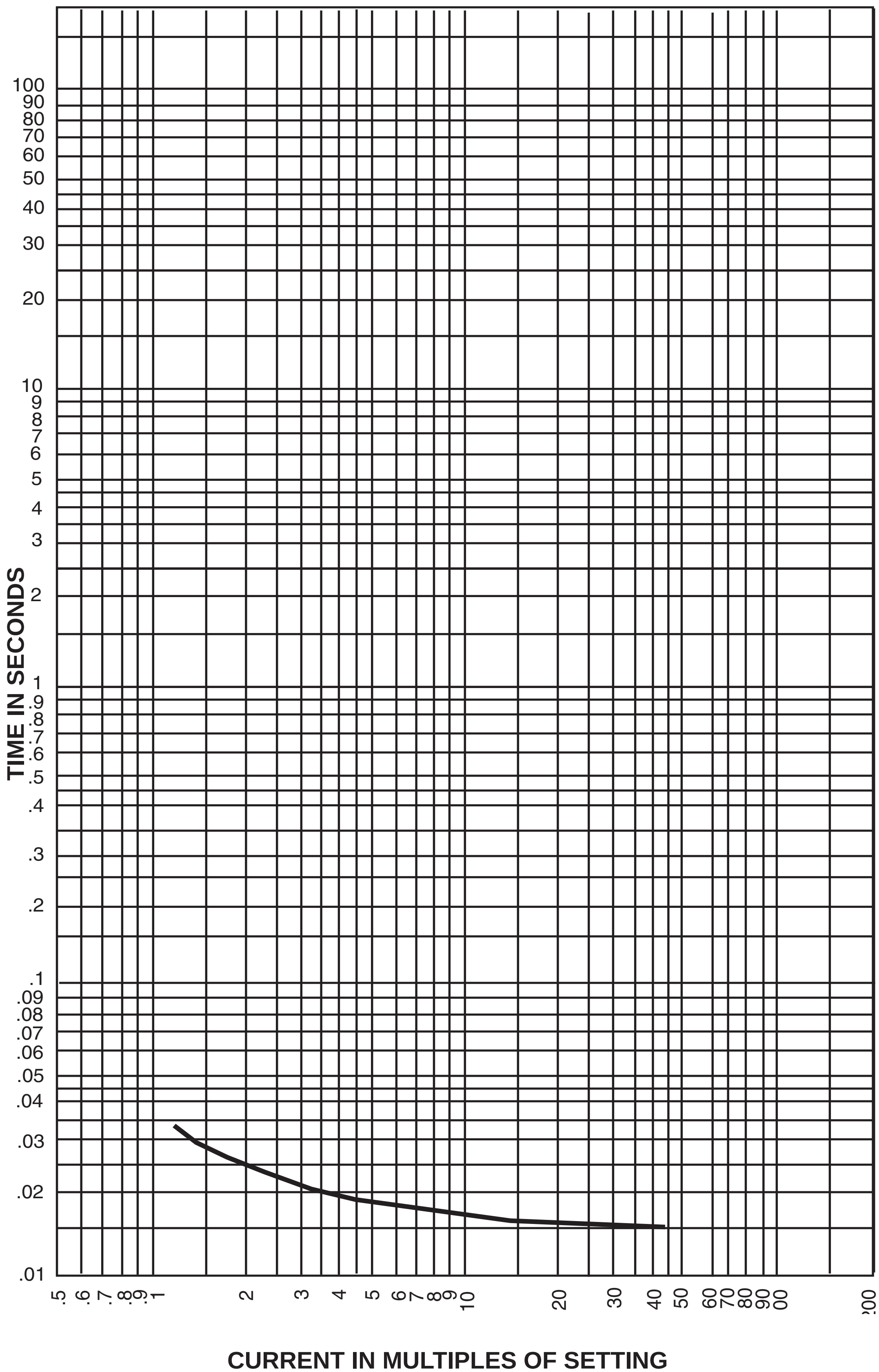


Figure 1-12. Standard Instantaneous Curve

DWG. NO. 605845 Rev. 2

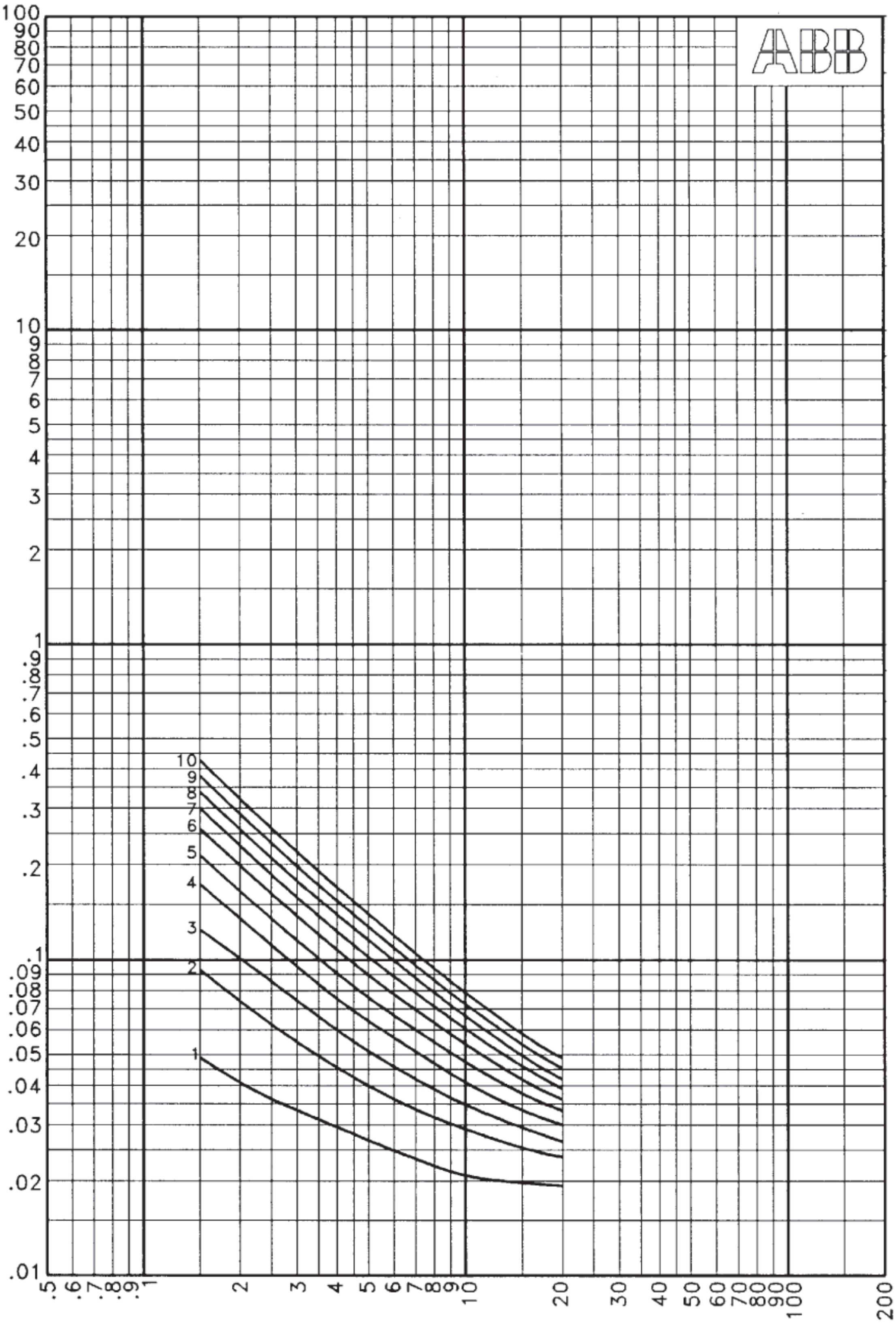


Figure 1-13. Inverse Instantaneous Curve DWG. NO. 604916 Rev. 0

“Self-Cooled” Rating “OA-1/OA-2/OA-3 Rating Amp”

The self-cooled rating settings are found in the Primary, Alternate 1 and Alternate 2 change settings menus. When the
winding 1 time overcurrent function Curve Select setting (51P-1 Curve Sel) is set to disable, the OA-1 Rating setting appears. When the winding 2 time overcurrent function Curve Select setting (51P-2) is set to disable, the OA-2 Rating setting appears. If a 3 winding TPU2000R is used and the 51P-3 curve select setting is set to disable, the OA-3 Rating setting appears. Because the time overcurrent function settings are not displayed in the disabled state, the OA-1/OA-2/OA-3 Rating settings become reference settings for other elements of the relay, namely, the Disturbance Functions, Level Detectors and metering accuracy calculations. You should set it as though you would set the 51P settings. Note that the instantaneous functions are also disabled whenever the time overcurrent, 51P, is disabled. Any function in the settings table normally set as a multiple of the 51P pickup setting, should now be set as a multiple of the OA pickup setting. For example, when the 51P-2 is disabled, the Disturbance-2 element pick-up is set as a multiple of the OA-2 setting. In the 3 winding relay, the Disturbance-3 element pick-up is set as a multiple of the OA-3 setting. Please note that the relay does NOT TRIP on the OA settings.

Disturbance - 2/Disturbance - 3 Functions

For the two winding relay, the Disturbance - 2 function is a sensitive overcurrent element that is set as a multiple of the 51P-2 setting and corresponds to the logical output “THRUFA.” For the 3 winding relay, the Disturbance - 3 function is a sensitive overcurrent element that is set as a multiple of the 51P-3 setting where the logical output “THRUFA” is the output of the Disturbance - 2 OR the Disturbance - 3 function. This output can be mapped to a physical output contact to initiate a fault recorder or other device. In the 2 winding relay, when the Disturbance - 2 element detects a fault, it logs that fault in the Through-Fault Record as “Disturbance.” In the 3 winding relay, when one of the disturbance elements detects a fault, it logs that fault in the Through-Fault record as “Disturbance-2” or “Disturbance-3.” If the TPU-2000R trips on any overcurrent element for the same fault, the overcurrent trip element is logged in place of “Disturbance.”

Important:

The Disturbance functions internally “race” with the instantaneous overcurrent functions. Be sure that the Disturbance pickup settings are below the lowest PHASE instantaneous pickup setting. To avoid any race conditions with the GROUND instantaneous functions, set the GROUND instantaneous functions with a time delay of at least 0.03 seconds.

Level Detector - 1/ - 2/ - 3

Current-level detectors, LDA - 1 for winding 1, LDA - 2 for winding 2 and LDA-3 (if a 3 winding relay is used) are used to sense high and low level faults based on a set threshold. The LDA-1, LDA-2 and LDA-3 (if applicable) threshold is set based on a multiple of the 51P-1, 51P-2 and 51P-3 pick-up settings, respectively. Its output, HLDA (High Level Detect) can be mapped to an output contact to trip an upstream breaker if the fault current exceeds the break rating of the downstream tripping device. LLDA (Low Level Detect), can be mapped to another contact to trip the local tripping device if the fault current is within the break rating of that device. Refer to Figure 1-14. LLDA is always asserted when HLDA is not asserted and vice versa.

WARNING:

The LDA functions internally “race” with the instantaneous overcurrent functions if the LDA pickup is set above any of the instantaneous pickup settings. To avoid any race conditions with any of the instantaneous functions, set the instantaneous functions with a time delay of at least 0.03 seconds.

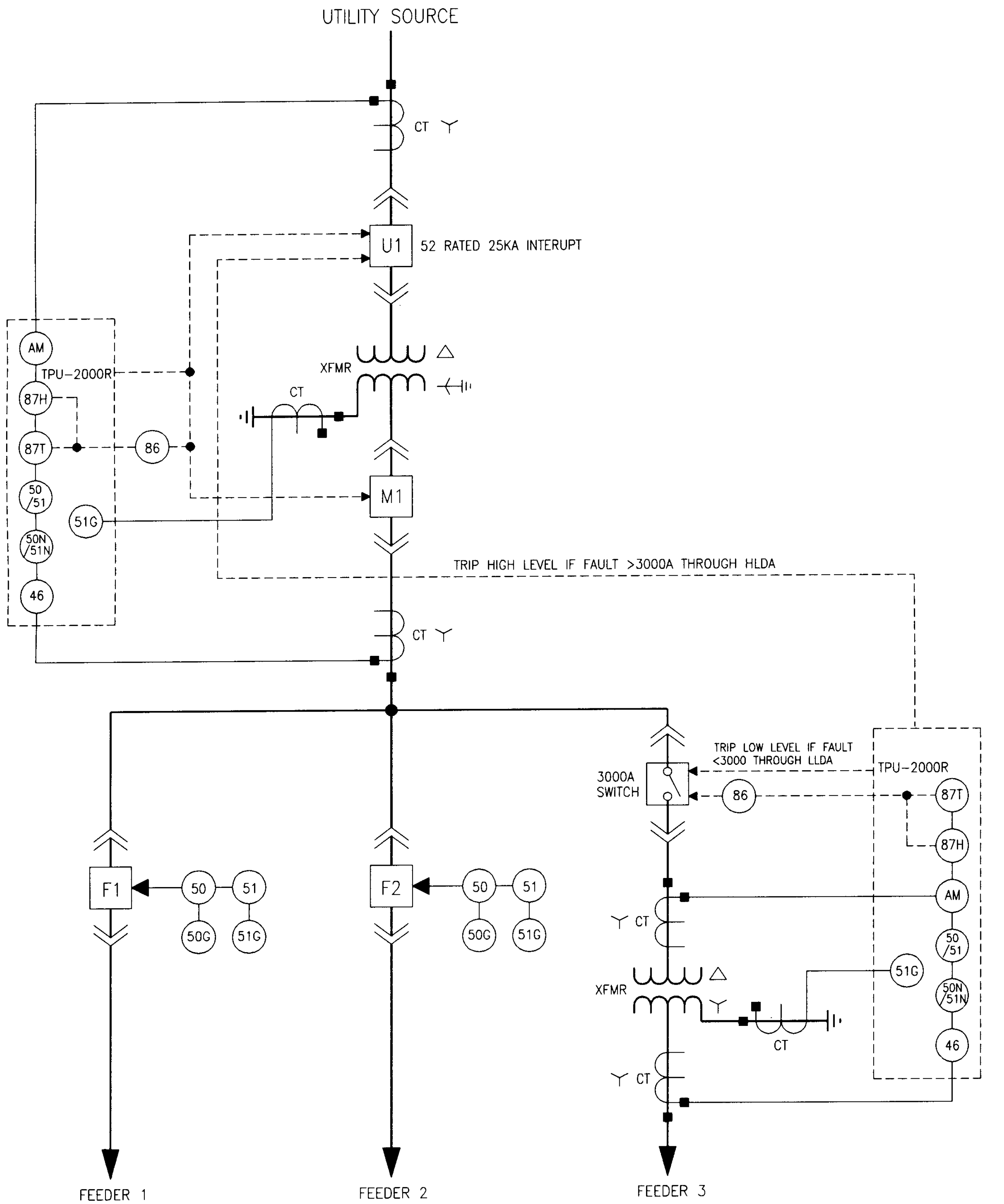


Figure 1-14. Level Detector -1/-2 Application

Configuration Settings

Cross Blocking Mode

When the Cross Blocking Mode is enabled in the Configuration Settings, harmonic restraint occurs in all three phase windings when the harmonic restraint setting and the operate-current are exceeded in any one or more phase windings. When the Cross Blocking Mode is disabled, harmonic restraint occurs on a per-phase basis. In other words, harmonic restraint in one phase does not restrain another phase from tripping when the Cross Blocking Mode is disabled.

Phase Angle Compensation for a 2 Winding TPU2000R

The Phase Compensation Setting is the phase shift across the two sides of the power transformer and is applicable to the 87T and 87H differential elements only. This setting should not include the effect of the CT secondary connections. The winding 1 and winding 2 CT configuration settings compensate for any shift due to CT wiring. It is in this regard that this setting is the angle by which the winding 1 primary currents **lead** the winding 2 primary currents.

Function	Range	Increment
Phase Angle Compensation	0 to 330°	30°

Example:

The power transformer high side is configured Delta (A–B) and is assigned to the TPU-2000R winding 1 input. The low side is configured Wye and is assigned to the TPU-2000R winding 2 input. Since the transformer high side (TPU-2000R winding 1) leads the low side (TPU-2000R winding 2) by 30 degrees, the Phase Angle Compensation setting should be 30 degrees. If the assigned windings are reversed in this example (high side winding 2, low side winding 1) the setting would be 330 degrees because winding 1 now **lags** winding 2 by 30 degrees.

IMPORTANT NOTE: Prior to completing commissioning, always verify that the TPU2000R differential metering values are correct and acceptable using the front panel MMI or the interface software WinECP. For the 2-Winding unit, on a per-phase basis, the restraint magnitudes should be equal and their angles 180 degrees apart. If the magnitudes are unequal, then the tap setting are incorrect; see page 7-1. If the angles are not 180 degrees apart, the Phase Compensation Angle is incorrect; see page 2-1.

Phase Angle Compensation for a 3 Winding TPU2000R

For a three winding transfomer, two phase compensation settings are required. The phase shift from the high side winding (winding 1) to the low side winding (winding 2) of the power transformer is phase compensation 1-2. The phase shift from the high side winding to the tertiary winding (winding 3) is phase compensation 1-3. **For the three winding relay, it is required that the current transformers are wired in wye.**

Example:

The power transfomer high side (winding 1) is configured Delta (A–C), low side (winding 2) is configured Wye and the tertiary (winding 3) is Delta (A–C). With an ABC phase rotation, the phase compensation 1-2 setting is 330 degrees and the phase compensation 1-3 setting is 0 degrees. See Section 7 for a method to determine the correct phase compensation setting. Please see the drawings in the section 11 for further examples.

IMPORTANT NOTE: Prior to completing commissioning, always verify that the TPU2000R differential metering values are correct and acceptable using the front panel MMI or the interface software WinECP. For the 3-Winding unit, on a per-phase basis, the two smaller restraint magnitudes should add to the larger restraint magnitude and the two smaller restraint currents' angels should be 180 degrees apart from the larger restraint current's angle. IF the two magnitudes do not add to the third, then then tap settings are incorrect; see page 7-3. If the two angles are not 180 degrees apart from the third angle, the Phase Compensation is incorrect; see page 2-1.

Trip Failure Dropout Time

The Trip Failure Dropout Time is the allotted time for the system to clear a fault once a trip signal has been issued. The timer, which is adjustable from 5 to 60 cycles, starts when any function goes into a trip state and stops when the conditions described below are satisfied. The logical output for the Trip Failure alarm “TFA” can be mapped to an output contact for external tripping or monitoring purposes.

This setting has two functions. The **Trip Failure Mode** setting defines how overcurrent functions drop out as well as when the DIFF function drops out. This setting also tells the TPU-2000R which protective elements to look at for a trip failure. The **Trip Failure Dropout** setting defines the actual drop out points of the protective functions. The various combinations and effects of these two settings are shown in the table below:

Trip Failure Mode	**Overcurrent Function Dropout**	**DIFF Function Dropout**
DIFF	98% of Pickup	Fault Cleared Condition
DIFF and OC	TFDO% x OC Function Pickup	Fault Cleared Condition
OC Alarm	TFDO% x OC Function Pickup	95% of Iop

In the above table, the **Fault Cleared Condition** is satisfied when **ALL** of the below conditions are satisfied:

- Winding 1 Highest phase current < TFDO% x 51P-1 pickup
- Winding 1 Highest phase current < TFDO% x OA-1 pickup (only if 51P-1 is disabled)
- Winding 1 Neutral current < TFDO% x 51N-1 pickup
- Winding 2 Highest phase current < TFDO% x 51P-2 pickup
- Winding 2 Highest phase current < TFDO% x OA-2 pickup (only if 51P-2 is disabled)
- Winding 2 neutral current < TFDO% x 51G-2 pickup

If a 3 Winding Relay is used, then the following conditions also apply:

- Winding 3 Highest phase current < TFDO% x 51P-3 pickup
- Winding 3 Highest phase current < TFDO% x OA-3 pickup (only if 51P-3 is disabled)
- Winding 3 Neutral current < TFDO% x 51N-3 pickup

CT Configuration

In the 2 winding relay, it is imperative to enter the proper CT configuration settings for winding 1 and winding 2. The options are Wye, Del (A-B), or Del (A-C).

If the CTs are configured in Delta, please note that the overcurrent pickup settings should be done as if the CTs were wired in Wye. Also, the relay will derive the **individual** phase currents for the metering display from the Delta currents and the neutral CT input.

For the 3 winding relay, the CTs **MUST** be wired in Wye.

Metering Without Optional VT Inputs

For the 2 winding TPU-2000R, the man-machine interface (MMI) continuously displays RMS per-phase current magnitudes for windings 1 and 2: Ia-1, Ib-1, Ic-1, In-1, Ia-2, Ib-2, Ic-2, Ig-2. For the MMI display to show correct primary values, you **must** enter the CT wiring configuration (Wye, Delta Ia–Ic or Delta Ia–Ib) and the ratio of the winding 1 and 2 CTs into the Configuration Settings. For CT's connected Delta, the neutral bushing CT must be connected to the TPU-2000R ground sensor input in order to measure the zero sequence current. In the Wye configuration, the current is read directly from the CTs. In the Delta configuration, the TPU-2000R derives the line currents from the CT secondary currents. The MMI will display the line currents, **NOT** the Delta currents. Make sure you have chosen the correct Delta configuration (Ia–Ic or Ia–Ib). Also, the overcurrent protection functions react according to the line currents derived from inside the Delta.

For the 3 winding TPU-2000R, the MMI continuously displays RMS per-phase current values for 2 of the 3 windings. The user selects which windings to display in the configuration settings. The default setting is winding 1 and winding 2. Please note that all of the CTs for the 3 winding TPU-2000R **must** be wye connected regardless of transformer configuration.

Use the meter menu to confirm continuity of current through each input sensor. Current IA-1 is shown at 0° phase angle and is used as a reference for the other current phase angles. The MMI also allows you to scroll through the numerous system parameters listed below.

Load Values

- Winding 1–RMS Phase currents IA-1, IB-1 and IC-1: amperes and leading degrees
- Winding 1–RMS Neutral current IN-1: amperes and leading degrees
- Winding 1–Positive, negative and zero sequence currents I_1-1, I_2-1 and I_0-1: amperes and leading degrees
- Winding 2–RMS Phase currents IA-2, IB-2 and IC-2: amperes and leading degrees
- Winding 2–RMS Ground current IG-2: amperes and leading degrees
- Winding 2–Positive, negative and zero sequence currents I_1-2, I_2-2 and I_0-2: amperes and leading degrees

For the 3 winding relay, the following values are also displayed:

- Winding 3–RMS Phase currents Ia-3, Ib-3 and Ic-3: amperes and leading degrees
- Winding 3–RMS Neutral current In-3: amperes and leading degrees
- Winding 3–Positive, negative and zero sequence currents I_1-3, I_2-3 and I_0-3: amperes and leading degrees

Demand and Maximum/Minimum Values

- Winding 1, winding 2 or winding 3 (if applicable): phase and neutral (ground) demand currents
- Winding 1, winding 2 or winding 3 (if applicable): phase and neutral (ground) peak demand currents with time stamp

The demand currents are calculated by using a $\log_{10}$ function and emulate thermal demand ammeters. You can program the Demand Meter Time Constant for 5, 15, 30 or 60 minutes.

Differential Values

The winding 1, winding 2 and winding 3 (if applicable) restraint currents metered on the differential screen are the apparent relay currents in per unit of the respective winding tap. Depending on the transformer and current transformer configuration, the relay currents may be compensated internally by the TPU-2000R. The apparent restraint currents (after internal phase and magnitude compensation have been applied) are added vectorially to determine the differential (operate) current, which is then displayed.

Example:	**Transformer:**	High side Delta, Low side Wye connected with a 30° phase shift
	Current Transformer:	Low side Wye, High side Wye connected

To compensate for the phase shift between the low side currents and the high side currents, the unit mathematically performs a delta transformation on the low side relay currents. The phase A restraint current is the vector difference of phase A and phase B relay currents ($IA_{rest} = IA_{relay} - IB_{relay}$).

- Operate Currents—Phase A, B and C: fundamental magnitude in per unit (vectorial summation of winding 1 and 2 restraint currents)
- Winding 1 Restraint Currents—A-1, B-1 and C-1: fundamental magnitude in per unit of 87T-1 tap setting and degrees
- Winding 2 Restraint Currents—A-2, B-2 and C-2; fundamental magnitude in per unit of 87T-2 tap setting and degrees
- 2nd Harmonic Restraint Currents—A-1, B-1, C-1, A-2, B-2 and C-2: in percent of fundamental current
- 5th Harmonic Restraint Currents—A-1, B-1, C-1, A-2, B-2 and C-2: in percent of fundamental current
- All Harmonics Restraint Currents—A-1, B-1, C-1, A-2, B-2 and C-2: in percent of fundamental current

In the case of the two winding relay, if CT connections and the Phase Angle Compensation setting are correct, the winding 1 and 2 restraint currents will be 180° out of phase. This check should be made when commissioning the installation.

For the 3 winding relay, the following additional data is calculated:

- Winding 3 restraint currents - A-3, B-3 and C-3: fundamental magnitude in per unit of 87T-3 tap setting and degrees
- 2nd Harmonic Restraint Currents - A-3, B-3 and C-3: in percent of fundamental current
- 5th Harmonic Restraint Currents - A-3, B-3 and C-3: in percent of fundamental current
- All Harmonic Restraint Currents - A-3, B-3 and C-3: in percent of fundamental current

In the case of the three winding relay, if CT connections and the Phase Angle Compensation settings are correct, the vectorial sum in per unit of all three restraint currents should be zero. This check should be made when commissioning the installation.

Figure 3-1. Meter Menu Displays

Examples of the metering displays for Load, Demand, Differential and Maximum/Minimum Values are shown below.

Load Values

==== Load Values ====			
Ia-1:	426	∠:	0
Ib-1:	414	∠:	234
Ic-1:	429	∠:	117↓
In-1:	102	∠:	108
I0-1:	116	∠:	102
I1-1:	421	∠:	357
I2-1:	0	∠:	0
Ia-2:	622	∠:	350
Ib-2:	624	∠:	230
Ic-2:	628	∠:	110
In-2:	0	∠:	0
I0-2:	0	∠:	0
I1-2:	624	∠:	350
I2-2:	0	∠:	120
#Ia-3:	109	∠:	120
#Ib-3:	110	∠:	0
#Ic-3:	109	∠:	120
#In-3:	0	∠:	240
#I0-3:	0	∠:	0
#I1-3:	110	∠:	0
#I2-3:	109	∠:	0
#Ig :	0	∠:	0

#Denotes 3 Winding Relay only

Max/Min Demand

=MAX/MIN DEMANDS=	
Max Ia-1:	958
95/02/09	12:30
Min Ia-1	0
95/01/01	8:58
Max Ib-1:	1000
95/02/08	12:30
Min Ib-1:	0
95/01/01	8:58
Max Ic-1:	989
95/02/08	12:30
Min Ic-1:	1
95/01/01	8:59
Max In-1:	1002
95/02/08	12:30
Min In-1:	0
95/01/01	8:58

Demand Values

==Demand Values==	
Ia-1:	172
Ib-1:	166
Ic-1:	174
In-1:	42
I0-1:	0
I1-1:	0

Deifferential Values

======DIFFER. VALUES =====		
Ioperate A:	0.21	
Ires	A-1:	1.76 ∠: 0
Ires	A-2	1.55 ∠: 180
#Ires	A-3	0.00 ∠: 0
Ioperate B:	0.30	
Ires	B-1:	1.84 ∠: 240
Ires	B-2	1.54 ∠: 60
#Ires	B-3	0.00 ∠: 0
Ioperate C:	0.26	
Ires	C-1:	1.81 ∠: 120
Ires	C-2:	1.55 ∠: 300
#Ires	C-3:	0.00 ∠: 0
2nd Harm A-1:	0.0%	
2nd Harm B-1:	0.0%	
2nd Harm C-1:	0.0%	
2nd Harm A-2:	0.0%	
2nd Harm B-2:	0.0%	
2nd Harm C-2:	0.0%	
#2nd Harm A-3:	0.0%	
#2nd Harm B-3:	0.0%	
#2nd Harm C-3:	0.0%	
5th Harm A-1:	7.0%	
5th Harm B-1:	7.0%	
5th Harm C-1:	7.0%	
5th Harm A-2:	2.5%	
5th Harm B-2:	2.5%	
5th Harm C-2:	2.5%	
#5th Harm A-3:	2.5%	
#5th Harm B-3:	2.5%	
#5th Harm C-3:	2.5%	
All Harm A-1:	8.0%	
All Harm B-1:	7.0%	
All Harm C-1:	8.0%	
All Harm A-2:	3.5%	
All Harm B-2:	3.5%	
All Harm C-2:	0.0%	
#All Harm A-3:	3.5%	
#All Harm B-3:	3.5%	
#All Harm C-3:	0.0%	

#Denotes 3 Winding Relay only

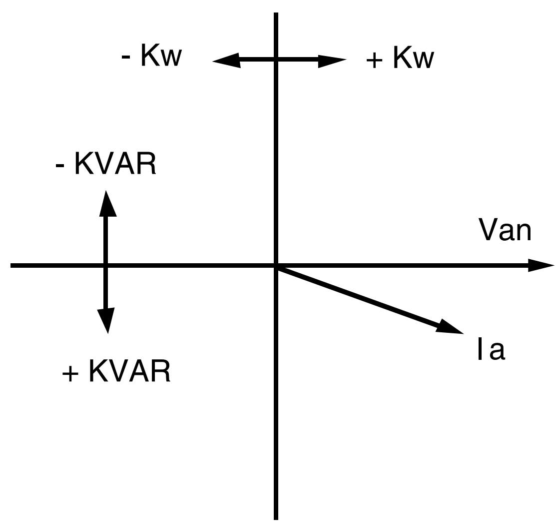
Metering With Optional VT Inputs

The man-machine interface (MMI) continuously displays RMS current magnitudes I_A, I_B, I_C and I_N for winding 1, 2 or 3 (if applicable) and RMS voltage magnitudes for Van, Vbn and Vcn (Wye-connected VTs) or for Vab, Vbc and Vca (Delta-connected VTs). For the MMI to show correct primary values, you **must** enter the ratio of the CTs and VTs and the type of VT connection (Wye phase-to-ground or Delta phase-to-phase, nominal voltage) into the Configuration Settings. Use the meter menu to confirm continuity of current and voltage through each input sensor. Voltage Van (or Vab) is shown at 0° phase angle and is used as a reference for the other voltage and current phase angles. The MMI also allows you to scroll through the numerous system parameters listed below. See Figure 3-3 for Metering Menus with Optional VTs.

The metered sequence voltage components of the TPU-2000R (V_1 and V_2) are derived form the line-to-neutral voltages, regardless if the unit is wired in a Wye or Delta configuration. If a balanced condition is assumed:

- In a Delta configuration the angle of the positive sequence voltage (V_1) leads Vab by 330°.
- In a Wye configuration the angle of the positive sequence voltage (V_1) equals Van (V_1 = Van = 0°).

Figure 3-2. TPU-2000R Metering Conventions



Selected Winding Load Values

- Phase currents Ia, Ib and Ic
  - Amperes
  - Degrees
- Ground current In
  - Amperes
  - Degrees
- Phase voltage Van, Vbn and Vcn for Wye VTs
  - Kilovolts
  - Degrees
- Phase voltage Vab, Vbc and Vca for Delta VTs
  - Kilovolts
  - Degrees
- Kilowatts per phase and 3-phase for Wye VTs and 3-phase for Delta VTs
- KiloVARs per phase and 3-phase for Wye VTs and 3-phase for Delta VTs
- Kilowatt-hours per phase and 3-phase for Wye VTs and 3-phase for Delta VTs
- KiloVAR-hours per phase and 3-phase for Wye VTs and 3-phase for Delta VTs
- Zero (I_0), positive (I_1) and negative (I_2) sequence currents
  - Amperes
  - Degrees
- Positive (V_1) and negative (V_2) sequence voltages
  - Kilovolts
  - Degrees

Demand Values

- Demand (phase and ground) currents in amperes
- Demand kilowatts
  - Per phase and 3-phase for Wye VTs
  - 3-phase for Delta VTs
- Demand KiloVARs
  - Per phase and 3-phase for Wye VTs
  - 3-phase for Delta VTs

Maximum and Minimum Values

- Maximum and minimum (phase and ground) currents in amperes
- Date and time stamp for maximum and minimum (phase and ground) currents
- Maximum and minimum kilowatts
  - Per phase and 3-phase for Wye VTs
  - 3-phase for Delta VTs
- Date and time stamp for maximum and minimum kilowatts
- Maximum and minimum KiloVARs per phase and 3-phase for Wye VTs; 3-phase for Delta VTs
- Date and time stamp for maximum and minimum KiloVARs

The demand currents are calculated by using a log 10 function and replicate thermal demand ammeters. The demand kilowatts and kiloVARs are averaged values that are calculated by using the kilowatt-hours, kiloVAR-hours and the selected Demand Meter Constant. The Demand Meter Constant is a time interval you can program for 5, 15, 30 or 60 minutes. It is found in the Configuration Settings. See Table 6-2 of this manual.

Examples of the metering displays for Load, Demand, Maximum/Minimum Values and Fault Records are shown in Figure 3-3.

Figure 3-3. Meter Menu Displays With Optional VT Inputs

Load Values

____Load Values____		
Ia-1:	320 ∠:	344
Ib-1:	318 ∠:	224
Ic-1:	320 ∠:	104 ↓
In-1:	2 ∠:	2
I0-1:	0 ∠:	0
I1-1:	320 ∠:	0
I2-1	0 ∠:	0
Ia-2:	320 ∠:	344
Ib-2:	318 ∠:	224
Ic-2:	320 ∠:	104
Ig-2/#In-2:	2 ∠:	2
I0-2:	0 ∠:	0
I1-2:	320 ∠:	0
I2-2	0 ∠:	0
#Ia-3:	320 ∠:	344
#Ib-3:	318 ∠:	224
#Ic-3:	320 ∠:	104
#In-3:	2 ∠:	2
#I0-3:	0 ∠:	0
#I1-3:	320 ∠:	0
#I2-3	0 ∠:	0
#Ig	0 ∠:	0
kVan:	7.80 ∠:	0
kVbn:	7.80 ∠:	240
kVcn:	7.80 ∠:	120
kV1:	7.80 ∠:	0
kV2:	0 ∠:	0
kW-A:		2396
kW-B:		2381
kW-C:		2396
kW-3P:		7173
kVAR-A:		699
kVAR-B:		695
kVAR-C:		699
kVAR-3P:		2093
kWHr-A:		575040
kWHr-B:		571065
kWHr-C:		576110
kWHr-3P:		1722215
kVARHr-A:		167760
kVARHr-B:		165440
kVARHr-C:		168225
kVARHr-3P:		501425
PF:	0.96	LAGGING
FREQ:		60.00

#Denotes 3 winding Relay only

Demand Values

___Demand Values___	
Ia:	305
Ib:	297
Ic:	302 ↓
In:	8
kW-A:	2283
kW-B:	2225
kW-C:	2247
kW-3P:	6750
kVAR-A:	664
kVAR-B:	655
kVAR-C:	662
kVAR-3P:	1978

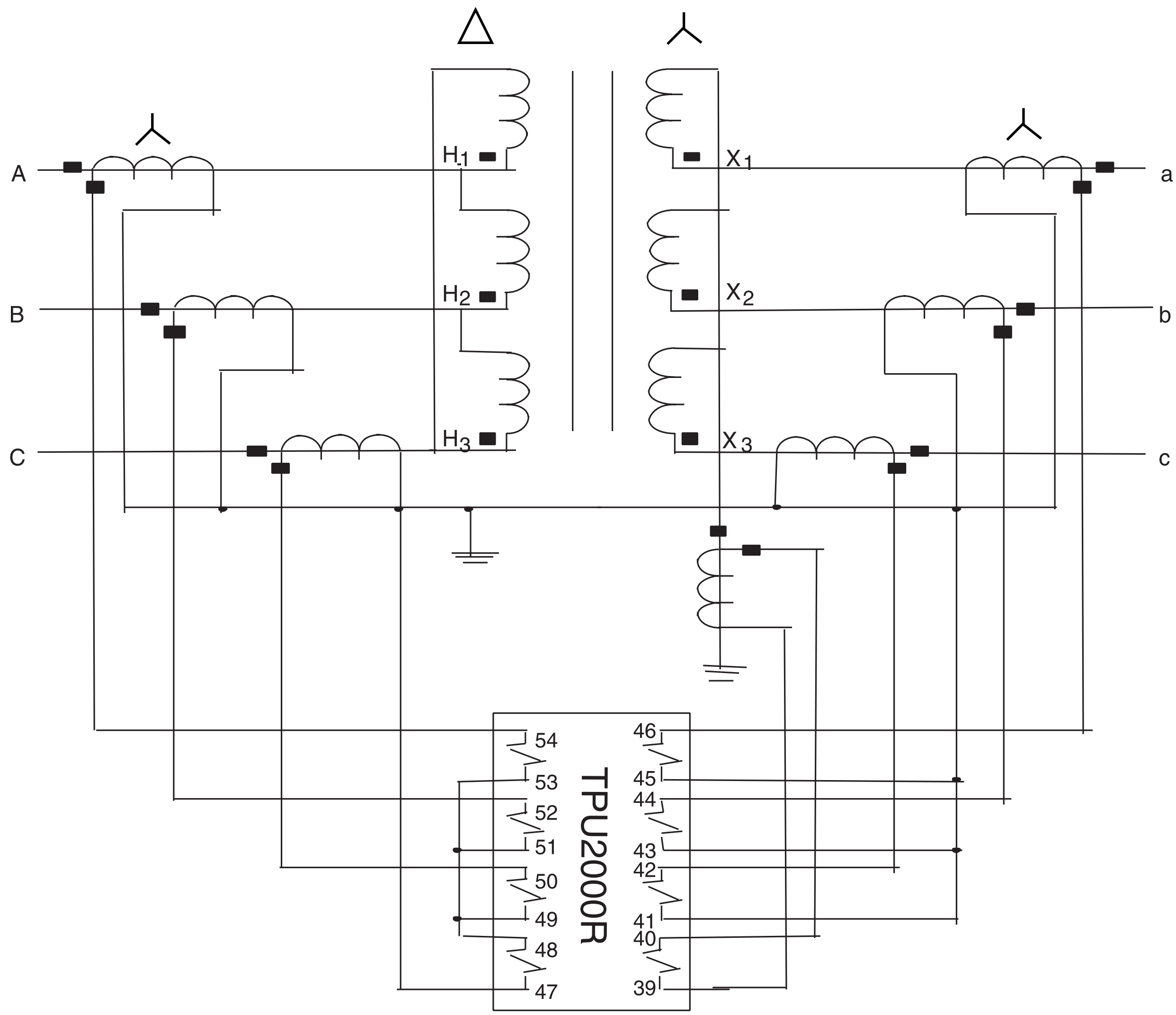
Maximum/Minimum Demand

Max Ia:	425	
	08/20/94	16:25
Min Ia:	55	
	08/03/94	04:10
Max Ib:	405	
	08/20/94	16:30
Min Ib:	46	
	08/02/94	04:22
Max Ic:	415	
	08/20/94	16:18
Min Ic:	52	
	08/03/94	03:55
Max In:	38	
	08/15/94	15:46
Min In:	0	
	08/03/94	03:17
Max kW-A	2983	
	08/20/94	16:25
Min kW-A	432	
	08/03/94	04:10
Max kW-B	2843	
	8/20/94	16:32
Min kW-B	361	
	08/02/94	04:21
Max kW-C	2913	
	08/20/94	16:19
Min kW-C	408	
	08/04/94	03:55
Max kW-3P	8885	
	08/20/94	16:23
Min kW-3P	1140	
	08/02/94	03:58
Max kVAR-A	1425	
	08/20/94	16:27
Min kVAR-A	–120	
	08/03/94	04:02
Max kVAR-B	1379	
	08/20/94	16:28
Min kVAR-B	–117	
	08/02/94	04:24
Max kVAR-C	1392	
	08/20/94	16:17
Min kVAR-C	–124	
	08/03/94	03:52
Max kVAR-3P	4160	
	08/20/94	16:19
Min kVAR-3P	–355	
	08/02/94	04:12

Metering Conventions

In considering a utility's convention of power flow into or out of a bus, on the secondary of the transformer, the metering convention shown in Figure 3-2 is achieved when the transformer secondary CT's are shown in Figure 3-4, i.e., the CT's polarity lead connected to the TPU2000R's "+" terminal. If the metering convention shown in Figure 3-5 is desicred, then use the transformer secondary CT connections shown in Figure 3-6, where the CT's polarity lead is connected to the TPU2000R "-" terminal, and add 180 degrees to the previously calcuated Phase Compensation Angle setting.

Figure 3-4. Connection for Standard Metering Convention



#

30° phase shift compensation

Figure 3-5. TPU2000R Metering Convention with Reverse Connections

#

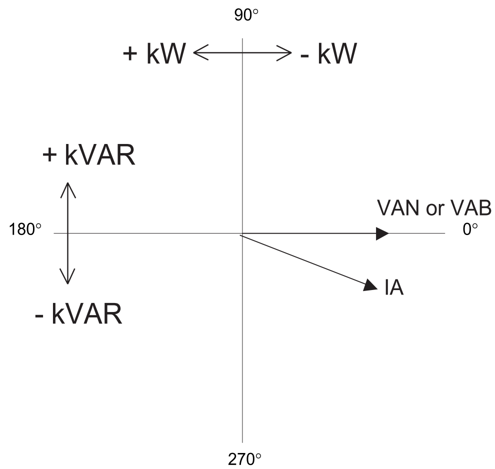
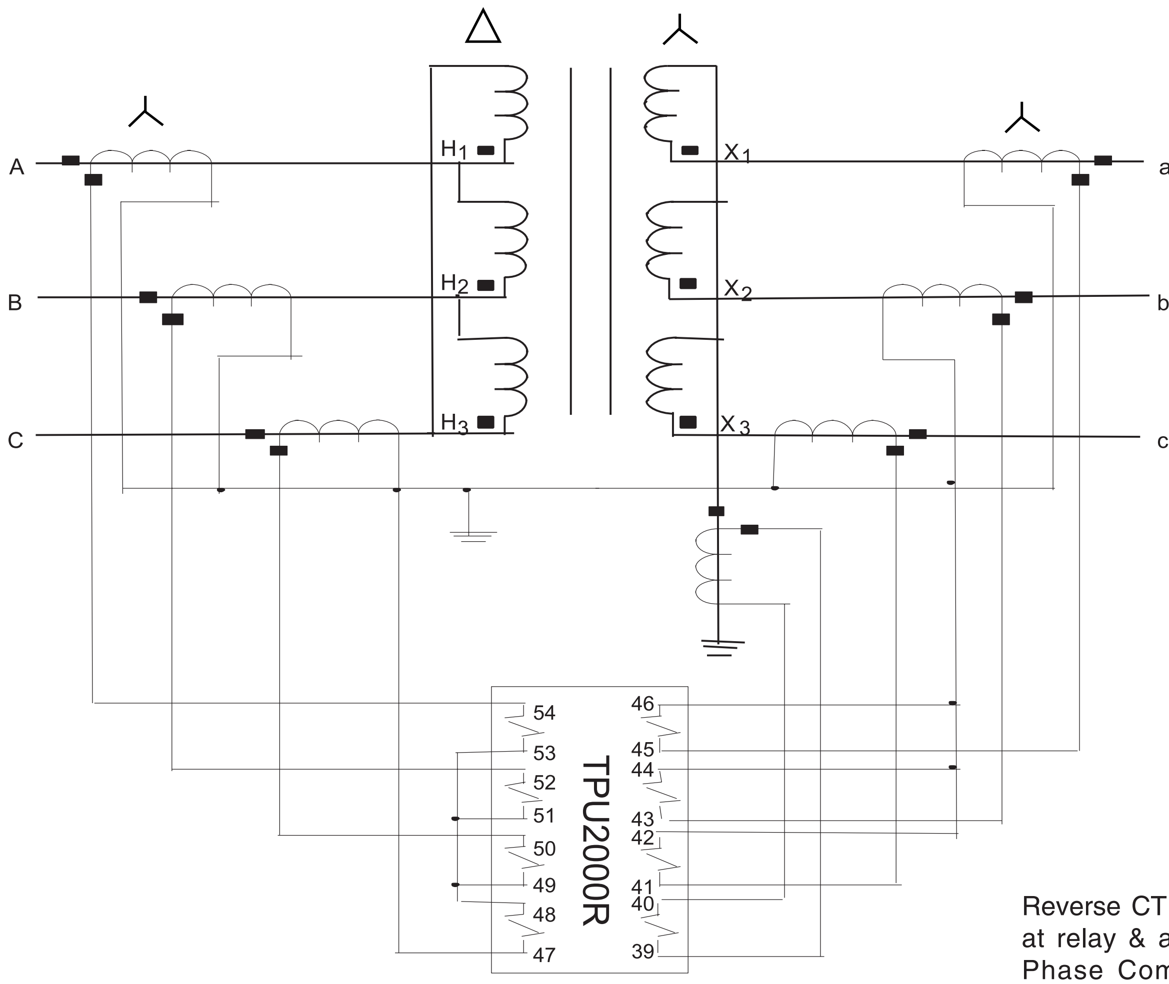


Figure 3-6. Connections to Reverse Standard Metering Convention



#

Reverse CT connection at relay & add 180º to Phase Compensation Angle

210° phase shift compensation

Internal Design

The heart of the TPU-2000R is the microprocessor. The capabilities of the microprocessor allow the TPU-2000R to perform the many protective functions. Figure 4-1 shows a block diagram of the unit.

Processor Specifications

The processing power of the TPU-2000R provides a true multitasking environment that combines protection, metering and control. The hardware components of the unit include:

- CPU—16-MHz, 32-bit 68332 Motorola microprocessor
- CPU RAM—64 K of temporary storage for CPU
- DSP—a 16-bit digital signal processor handles all analog acquisition and measurement of input parameters. It also performs all arithmetic iterations of the converted digital input signals.
- EEPROM stores all protective function settings.
- 16-bit analog-to-digital (A/D) converter
- CPU EPROM stores the CPU's programming.
- FLASH EPROM—0.5 M of memory store the DSP's operating algorithm.
- DSP RAM—16 K of memory provide temporary storage of DSP's arithmetic values.
- Real-time battery backed-up clock

Battery Backed-Up Clock

An internal clock time-tags the faults in the fault records, events in the operations record and values in the load profile record. In normal operation, this clock is powered by the TPU-2000R. When the TPU-2000R is withdrawn from its case, a battery powers the clock. As long as you turn off the battery backed-up clock during prolonged storage, the battery should last the life of the unit. Turn off the battery backed-up clock through the front man-machine interface by entering a "0" for the day.

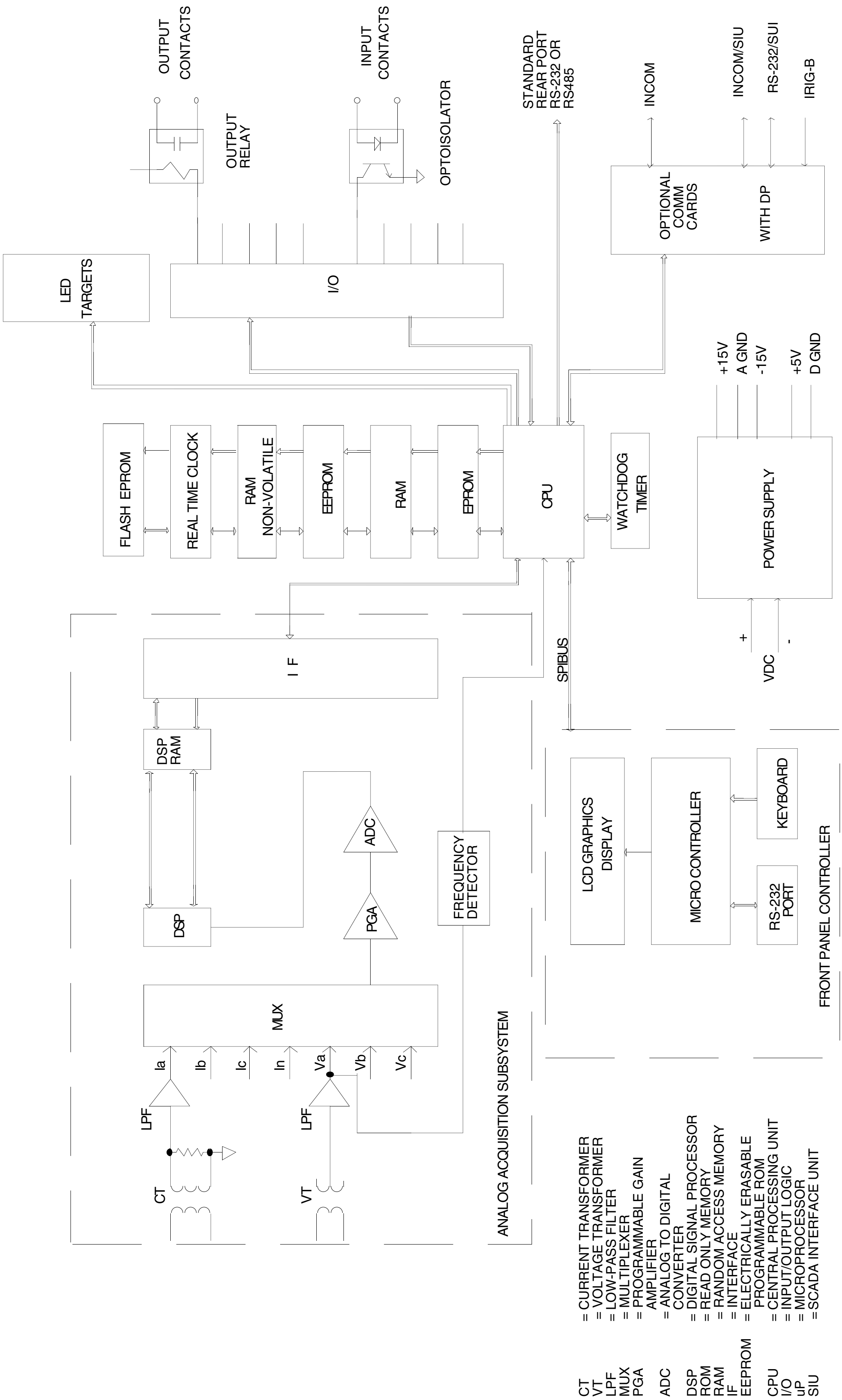


Figure 4-1. TPU-2000R Block Diagram

Ratings and Tolerances

Current Input Circuits

- 5-A input rating, 16 A continuous and 450 A for 1 second
- 1-A input rating, 3 A continuous and 100A for 1 second
- .1-A input rating, 3 A continuous and 100 A for 1 second
- Input burden at 0.245 VA at 5 A (1 - 12A range)
- Frequency 50 or 60 Hz
- Input burden at 0.014 VA at 1 A (0.2 - 2.4A range)

Contact Input Circuits Voltage Range

- 19 to 280 Vdc

Voltage Input Circuit

Voltage ratings based on the VT connection setting.

BURDEN

- 0.04VA for V(A-N) at 120 Vac

VOLTAGE

• **Wye** Connection: 160 V (L-N) continuous and 480 V (L-N) for 10 seconds
• **Delta** Connection: 260 V (L-L) continuous and 831 V (L-L) for 10 seconds

Contact Input Circuits (Input Burden)

- 2.10 VA at 220 Vdc and 250 Vdc
- 0.52 VA at 125 Vdc and 110 Vdc
- 0.08 VA at 48 Vdc
- 0.02 VA at 24 Vdc

Control Power Requirements

- 48 Vdc model, range = 38 to 58 Vdc
- 110/125/220/250 Vdc models, range = 70 to 280 Vdc
- 24 Vdc model, range = 19 to 39 Vdc

Control Power Burden

18 VA maximum over the above ranges

Output Contacts Ratings

125 Vdc	220 Vdc
• 30 A tripping	• 30 A tripping
• 6 A continuous	• 6 A continuous
• 0.25 A break inductive	• 0.1 A break inductive

Operating Temperature

- –40° to +70° C

  —Operating temperatures below –20° C may impede the LCD display contrast.

  —Operating temperatures below 0° C may impede Modbus Plus™ communications on units equipped with the Modbus Plus™ communications card (rear port options 6 and 7).

Humidity

- Per ANSI 37.90, up to 95% without condensation

Transient Immunity

- Surge withstand capability
  - SWC and fast transient tests per ANSI C37.90.1 and IEC 255-22-1 class III and 255-22-4 class IV for all connections except comm or AUX ports
  - Isolated comm ports and AUX ports per ANSI 37.90.1 using oscillatory SWC Test Wave only and per IEC 255-22-1 class III and 255-22-4 class III
  - Impulse voltage withstand test per IEC 255-5
  - EMI test per trial use standard ANSI C37.90.2 - 1995

Tolerances Over Temperature Range of -20º C to +55º C

	Function	Pickup	Dropout	Timing (whichever is greater)
#	87T	±3% of expected restraint value	95% of tap setting	< 40 ms (60Hz)/50 ms (50Hz)
	87H	±7% of tap setting	95% of tap setting	< 40 ms (60Hz)/50 ms (50Hz)
#	Harm.Restr.	±20% of percentage setting		
	51P/51N	±3% of setting	98% of setting	± 7% or ± 16 ms (60Hz)/± 20 ms (50Hz)
	50P/50N	±7% of setting	98% of setting	± 7% or ± 16 ms (60Hz)/± 20 ms (50Hz)
	46P	±3% of 51P setting	98% of setting	± 7% or ± 16 ms (60Hz)/± 20 ms (50Hz)
	Ammeter	± 1% of 51P and 51N time overcurrent pickup setting		
	Voltmeter	± 1% of VT Connection setting		
	Wattmeter	± 2% of full scale		
	VARmeter	± 2% of full scale		
	Power Meter	± 2% of I xV, 51P pickup setting x VT Connection setting		
	Frequency	± 0.01 Hz		
	Programmable Output Timers	± 4 milliseconds		

Dielectric

- 2000 Vac for 60 seconds, all circuits to ground except comm ports per IEC 255-5
- 1500 Vac for 60 seconds, for isolated communication ports
- 1000 Vac for 60 seconds, for Modbus Plus® interface

Weight *(Standard TPU-2000R unit with Voltage Inputs)*

	2 Winding	3 Winding
• Unboxed	6.40 kg (14.10lbs)	6.74 kg (14.85 lbs)
• Boxed	6.72 kg (14.81 lbs)	7.06 kg (15.56 lbs)

Installation

The TPU-2000R unit comes enclosed in a metal case. Follow the instructions and diagrams in this section to install the TPU-2000R.

Receipt of the TPU-2000R

When you receive the TPU-2000R, examine it carefully for shipping damage. If any damage or loss is evident, file a claim at once with the shipping agent and promptly notify the nearest ABB sales office.

Before installing the unit, it is suggested that the following procedures be performed:

On units equipped with an MMI

- Power up the relay. The LEDs should light and a slight clicking sound will be heard.
- Using the arrow keys, go to the Main Menu, scroll to Settings, press <E>, scroll to Unit Information, press <E>. Verify unit information against front panel nameplate.
- Press <C> to return to the Settings menu, scroll to Show Settings, press <E>. Check default settings against the tables supplied in this manual.
- After checking the default settings, press <C> twice to return to the Main menu. Scroll to Test and press <E>, at the Self Test selection, press <E>. The unit will self test.
- After performing the self test, press <C> twice to return to the Main menu. Scroll to Settings and press <E>, in the Settings menu, scroll to Change Settings and press <E>. In the Change Settings menu, scroll to Clock, and set the unit clock.
- At this point, the internal battery is now in use. If the unit is not going into service for an extended period, set the day of the month to zero (0) and the battery will not be in use. The battery will remain unused until the clock is set to a valid date.
- Press <E> to enter the correct time and return to the Change Settings menu.
- Set the PASSWORD by scrolling to Configuration and press <E>. At the Password prompt, press <E> again. Once in the Change Confi Sett menu, scroll to Relay Password and enter a password. This will be the main password for entry to the unit. Press <E> to enter the password and return to the Change Confi Sett menu. Scroll to Test Password, and enter a different password. This password allows low level entry to the Test options of the unit.

WARNING: If the password entered in the Relay Password section is lost or forgotten, the unit cannot be accessed. If this situation occurs, contact ABB Allentown immediately.

On units not equipped with an MMI, connect a PC to the RS-232 port on the front of the unit and use the ECP (External Communication Program) and follow the same process as outlined above.

Installing the TPU-2000R

The TPU-2000R is enclosed in a standard 3U (3 unit high rack), 19 x 5-inch case designed for rack mounting. Figure 4-2 shows the dimensions of the TPU-2000R. A kit for panel mounting can be ordered separately. See section 13 for details.

Dimensions are in: inches
[millimeters]

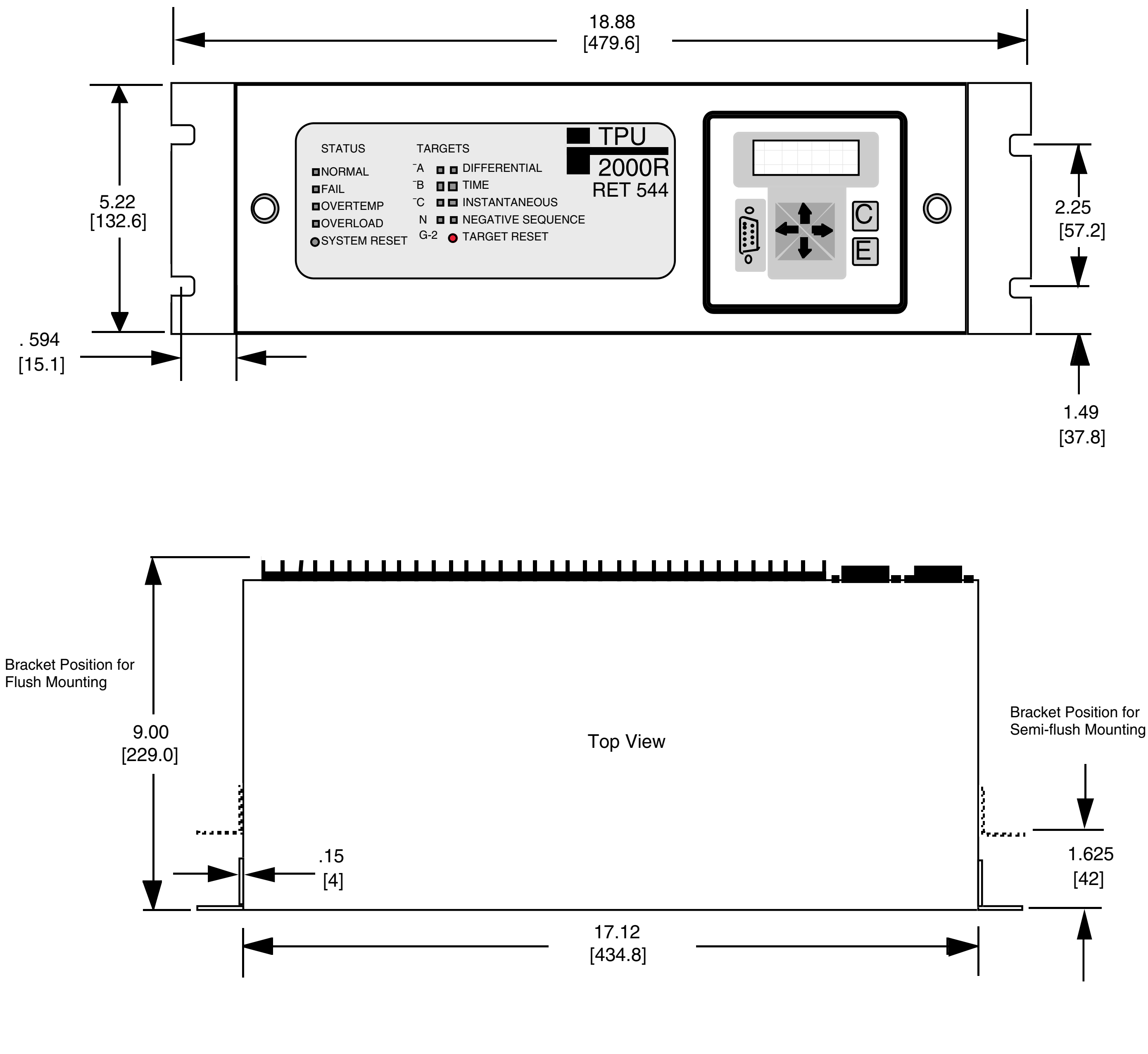


Figure 4-2. TPU-2000R Case Dimensions

Rear Terminal Block Connections

Apply only rated control voltage marked on the front panel of the unit to the positive terminal and the negative terminal. Wire the ground stud on the rear of the case to the equipment ground bus with at least #10 gauge wire. Figure 4-3 shows the rear terminal block layout and numbers.

Tables 11-1 and 11-2 lists the minimum required connections for a functioning system. Optional connections are shown on the bottom of the table. Jumper #6 is used to set the TRIP Output Contact to Normally Open or Normally Closed.

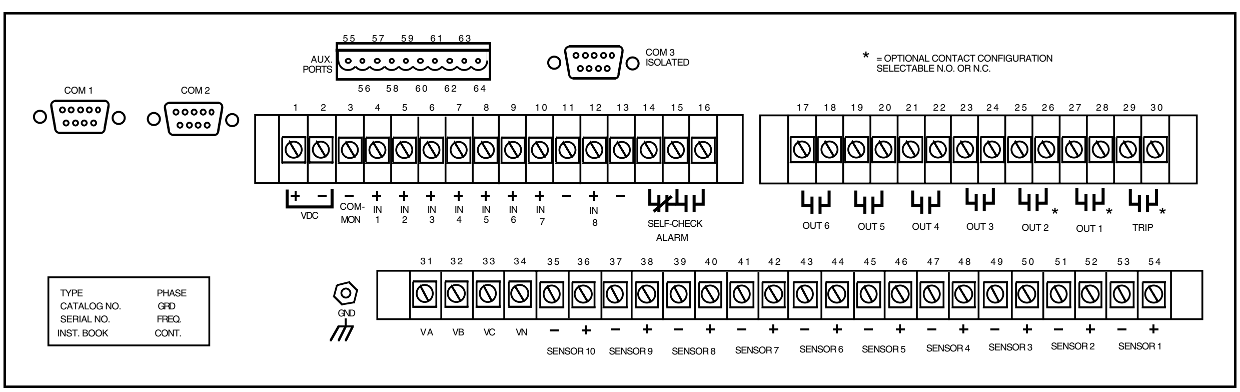


Figure 4-3. Rear Terminal Block

New Firmware Installation

WARNING: Interrupting the download process before it is completed will result in lost EEPROM data. In the event that the download is prematurely terminated, contact the factory.

To download new software to the TPU-2000R:

- If desired, save all settings to a disk as described in Section 12.
- On your computer's hard drive, create a directory called C:\FPI.
- Copy files from the FPI diskette (FPI.exe) and the SAF diskette (*filename*.abs) to the C:\FPI drive. Remember the filename from the SAF diskette as it will be needed later.
- Connect the TPU-2000R to the computer via the serial port on the front panel of the unit with a null modem cable.
- Ensure that the communications settings of the computer com port and the settings of the TPU-2000R are both set to 9600, 8, N, 1.
- At the C:\FPI prompt, type FPI
- At the Monitor Type ? prompt, select the appropriate monitor (color or black and white) and press <CR>.
- After the ABB description screen, the Communication Options screen appears. Use the spacebar to change the com settings or accept the default settings by scrolling through the screen with the <CR> key.
- If all com settings are correct, the Successful Connection To... screen appears. Press <CR> to continue. The next screen to appear will be the Main Menu. If com settings are not compatible or some other problem exists, the Communication Status screen appears. Reset the com settings and recheck connections and press <CR>.
- The only option necessary for downloading the software update is the **Update Unit Software** selection. Using the arrow keys, scroll to the Update Unit Software selection and press <CR>.
- At the warning message screen, select continue with unit software update.
- At the Load New Firmware Data screen, type *filename*.abs (*filename* is the name of the file) copied from the SAF disk) and press <CR>. This will highlight the default action, [READ FROM DISK]. Press <CR> again. Downloading should take about 20 minutes to complete.
- During download, the TARGET LEDs on the front panel will blink intermittently and in sequence starting with ØA with the following notes:

Computer display	LED	MMI (If present)
Monitor Has Been Entered	ØA blinks	TPU2000R Monitor
Flash Erase	ØB blinks	Flash Memory Erase in Progress
Flash Programming	ØC blinks	Flash Memory Download in Progress

- The message "Successfully Completed Downloading! Hit Any Key To Return To Main Menu" will appear. Hitting the <CR> key will cause the systems to reboot and the message "Please Wait While System Reboots" will appear.
- After the system has rebooted, the Main Menu will reappear. Scroll down to the Quit Program selection and press <CR>.
- Restore settings to the relay as described in Section 12.

Built-In Testing

The TPU-2000R continuously checks itself for proper functioning.

Self-Test Status

The TPU-2000R provides continuous self-testing of its power supply voltages, memory elements, digital signal processor and its program execution. In the event of a system failure, the protective functions are disabled and the Self-Check Alarm contacts are actuated. Except for a "processor stalled" condition, review the PASS/FAIL status of these self-test elements by using the man-machine interface (MMI). Normal status is indicated by a green TPU STATUS light (LED) and system failure is indicated by a red TPU STATUS light (or by the green TPU STATUS light not being lit in the case of a loss of control power). If the green light is flashing, refer to the Operations Menu in Section 9.

Self-Test Failures are recorded as a number in the Operations Record. The binary bit pattern of this number indicates the Self-Test Failure or Editor Access Status involved. The 1's in the bit pattern indicate where a failure has occurred. Count from the right of the bit pattern (starting with zero) to the position where a "1" occurs. Compare that bit position
with Table 4-1 to reveal the failure. See the following examples for further explanation.

If the self-test fails, the TPU-2000R is no longer providing protection. Replace the unit as soon as possible.

Table 4-1. Operations Record Value Information

Bit Position	Self-Test Failure	Editor Access Status
0	CPU RAM	INTERRUPT LOGGING
1	CPU EPROM	REMOTE EDIT DISABLE = 1
2	CPU NVRAM	LOCAL EDIT DISABLED = 1
3	CPU EEPROM	FRONT MMI EDIT ACTIVE
4	NOT USED	FRONT COMM PORT EDIT ACTIVE
5	NOT USED	REAR COMM PORT EDIT ACTIVE
6	NOT USED	REAR AUX COMM PORT EDIT ACTIVE
7	NOT USED	REAL TIME CLOCK EDITED
8	DSP ROM	PROGRAMMABLE I/O EDITED
9	DSP INTERNAL RAM	PRIMARY SET EDITED
10	DSP EXTERNAL RAM	ALTERNATE1 SETTINGS EDITED
11	DSP ANALOG/DIGITAL CONVETER	ALTERNATE2 SETTINGS EDITED
12	DSP +/-5 V POWER SUPPLY	CONFIGURATION SETTINGS EDITED
13	DSP +/-15 V POWER SUPPLY	COUNTER SETTINGS EDITED
14	DSP STALL or +5 V POWER SUPPLY	ALARM SETTINGS EDITED
15	DSP TO CPU COMMUNICATIONS	COMMUNICATIONS SETTINGS EDITED

Example of a Self-Test Failure

Value : 256 has a binary bit pattern of 0000000100000000 (bit order 15........0)

The 1 is in bit position 8 as you count from the right. This bit position correlates to DSP ROM failure.

Example of an Editor Access

Value : 145 has a binary bit pattern of 0000000010010001 (bit order 15.........0)

The 1's in this bit pattern have the following bit positions and corresponding Editor Access Status:

Bit 0 : Interrupt logging bit (Ignore this bit because it will always be set in this example.)
Bit 4 : Front communications port initiated the editor access and change.
Bit 7 : Real-time clock settings were changed.

TPU-2000R Settings Tables Diagnostics

Three copies of each settings table are stored in nonvolatile memory, preventing data loss during control power cycling. When you finish editing any settings table, the changed table's data is transferred from a temporary edit buffer into three separate locations in nonvolatile memory.

A background diagnostics task continuously runs a checksum on each copy of the settings tables to verify data consistency. If an invalid copy is detected, the diagnostic task attempts self-correction by transferring a valid copy to the invalid copy location. If this is unsuccessful, the task marks the copy as unusable and switches to the next available copy.

When the TPU-2000R detects that all three copies of a settings table are not valid, the diagnostic task adds a self-diagnostic error in the Operations Record, drops the self-check alarm, and disables all protective functions. In addition, the Self Test display under the MMI Test Menu shows the current status (PASS or FAIL) for all memory devices.

Man-Machine Interface (MMI)

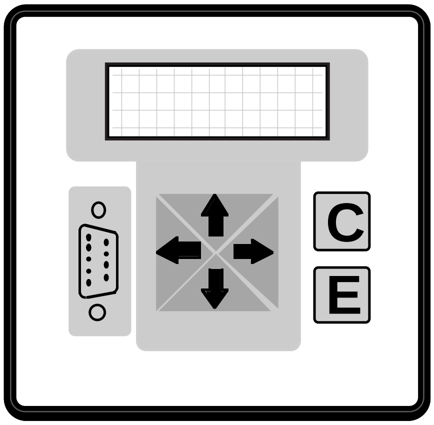


Figure 5-1. MMI Access Panel

The man-machine interface (MMI) on the front panel consists of a four-line liquid crystal display (LCD) with twenty characters per line, six push-buttons (keys) and thirteen LED targets. Press the Enter <E> key to access the Main Menu. Use the up and down arrow keys to move through the various menus and to change the character value when you enter the alphanumeric password. Use the Enter <E> key to select the desired menu or desired value when you change settings.

Use the left and right arrow keys to decrease and increase, respectively, setting values or record numbers. You can also use them to move from left to right within the password string. Hold down or repeatedly press the arrow keys to change the setting value.

Use the clear <C> key to return to the previous menu. You can also use the <C> key to:

- reset LED targets and the LCD after a fault (push <C> once)
- scroll through all metered values (push <C> twice)
- reset the peak demand values (push <C> three times)

Perform a system reset by simultaneously pressing the <C>, <E> and up arrow keys. This resets the microprocessor and re-initiates the software program. During a system reset, no stored information or settings are lost.

The following displays and menus are available through the MMI:

- Continuous Display—the enabled settings table and all currents
- Post-Fault Display—fault currents for last fault until targets are reset
- With optional VT inputs installed, Continuous Display and Post-Fault Display show currents and voltages

MMI Displays

Metering Display (Continuous)
(with optional VT inputs)

```
Ia2: 500  KVan:  13.00
Ib2: 500  KVbn:  13.00
Ic2: 500  KVcn:  13.00
In2:   0  Prim Set ¬
```

Main Menu

```
     MAIN MENU
  Meter
  Settings
  Records            ¬
```

Metering Display (Continuous)
(without optional VT inputs)

```
Ia1:  2      Ia2:  2
Ib1:  2      Ib2:  2
Ic1:  2      Ic2:  2
In1:  0      Ig2:  2   ¬
```

Display After a Fault Interruption

```
Diff Fault Rec  1
Fault #  7
Active Set  Prim
Date   17 Aug 1995     ¬
```

Man-Machine Interface Menus

Below is an outline of the menus available through the man-machine interface.

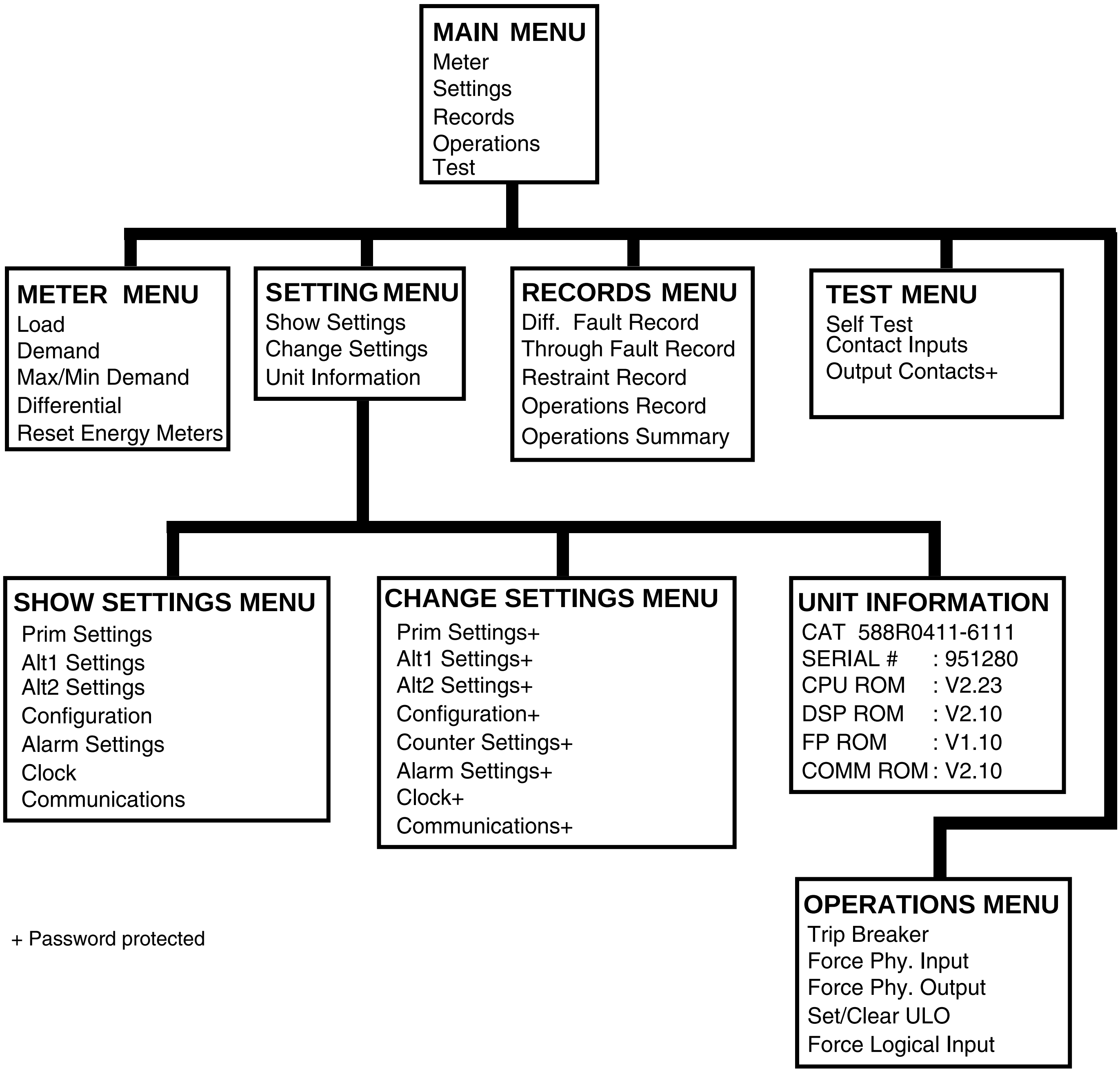


Figure 5-2. Man-Machine Interface Menus

External Communications Program

The External Communications Program (ECP) provides point-to-point communications with the TPU-2000R relay. With ECP, you can program the settings for the TPU-2000R's various functions, map logical inputs and outputs and monitor the relay's activity. ECP is a DOS®-based program and can be copied to your computer's hard drive. To execute the program, type "tpuecp". ECP will guide you in setting up the configuration and communication settings for establishing communication with the TPU-2000R.

You can also use the software without the TPU-2000R relay to explore the capabilities and functionality of the relay. When your PC is not connected to a TPU-2000R you will be prompted that communication to the TPU-2000R has not been established. Choose "Continue Without Connecting" and you will be prompted to enter a unit catalog number. Your catalog selection determines which options will be displayed in the settings screen. All the settings and configurations displayed are the factory default values. You can then change the values and save them to a file for later retrieval to a TPU-2000R. When the PC is connected to a TPU-2000R, the records can be viewed (Get Data From TPU-2000R), saved to a file (Save Data To Disk) and viewed later (Get Data From Disk).

Note: For the Through-fault Record and the Operations Record, only the screens you view are saved to a file. Therefore, to save all the data to a file, you must view all the screens before exiting the record display.

When changing the Configuration or Communication Settings through ECP, you must type in the four-digit password (the factory default password is four spaces) and then press ENTER.

The ECP contains terminal emulation commands that permit modem access to the relay or other devices connected to a remote modem. If communication is not established, a communications error message appears. If this message appears frequently, the line may be too noisy. Hang up and redial; if possible, use another line.

Use a straight through cable with a 9-pin null modem adaptor when you connect a PC via a 9-pin RS-232 cable directly to the TPU-2000R (not via modems). Table 5-6 provides communication ranges and default settings for PC/TPU communication. Refer to the Communications Ports section of this manual for more information on connecting the TPU to a PC.

To print ECP screens with a laser jet printer via the Print Screen key, you must change the character set mode of the printer from an ASCII character set to a line character set. Each printer has its own specific code to accomplish this. What code to use and how to program the code into the printer are detailed in the printer manual.

For example, on the HP Laser Jet III printer the code is "PC8" and then the printer can be programmed with the menu system located on the front of the printer. Follow these steps to program an HP Laser Jet III printer:

1. Take the printer off line by pressing the On Line key. This enables you to scroll through the menu options.
2. Press the Menu button until you see "Sym Set."
3. Press the "+" key until you see "PC8."
4. Press the Enter key to put the printer in the line character set mode.
5. Press the On Line key and you are ready to print ECP screens.

Once you have printed the desired ECP screens, you should reprogram the printer to its original mode; otherwise the printer will remain in the line character mode.

The application program on this disk has been carefully tested and performs accurately with most IBM-compatible personal computers. If you experience difficulty in using the External Communications Program, contact ABB at (610)395-7333.

External Communications Program Menus

Below is an outline of the menus available through the External Communications Program. Many of these menus are the same as those in the man-machine interface (MMI), but some are unique to the ECP. Tables 5-1 through 5-6 show the specific settings for the TPU-2000R.

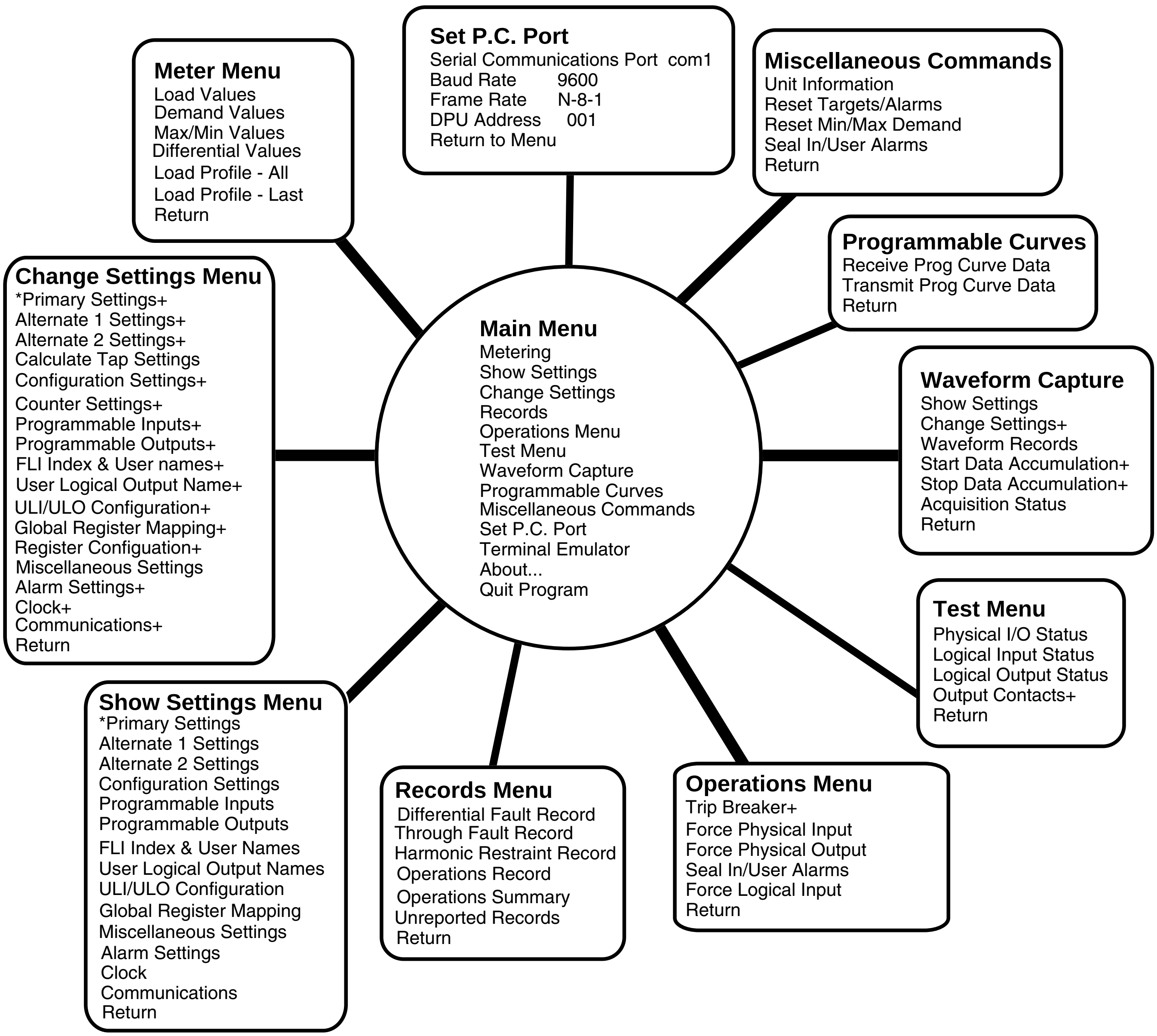


Figure 5-3. External Communications Program Menus

* Denotes active settings table
\+ Password protected

Changing Settings

Use the MMI or ECP to change the following settings:

- Primary
- Alternate 1
- Alternate 2
- Configuration
- Counter
- Alarm
- Communication

Tables 6-1 through 6-6 show the values for the different settings.

Basic Procedure

The procedure for changing settings is basically the same for all the settings. Follow these steps to change settings:

1. From the ECP Main Menu, select “Change Settings”.
2. From the Change Settings menu, select the settings you want to change.
3. A Load Screen appears, prompting you to load the data. Choose one of the following:
   - Get Data from TPU2000
   - Get Data from Disk
4. The screen for the selected settings appears. Scroll to the function you want and press ENTER.
5. A window appears with either the possible options or a prompt to change the settings by using the arrow keys.
6. Press Enter to accept the new setting or press ESC to close the window without any changes.
7. Select “Return to Menu”.
8. Save your changes.
   a. Press ESC.
   b. At the window prompting you to save, highlight the option by using the arrow keys and press ENTER.

Table 5-1. Primary, Alternate 1 and Alternate 2 Settings (Password Protected)

Function	Setting	Range	Step Size	Factory Default
87T	Curve Selection	Disable, % slope, HU 30% or HU 35%, 15% tap, 25% tap, or 40% tap		% Slope
	Minimum Operate Current	0.2 to 1.0 per unit operate current, which is the difference between Winding 1 and 2	0.1	0.2
	Percent Slope	15 to 60%	5	30%
	Restraint Mode	Disable, 2nd, 2nd and 5th, or all harmonics		2nd Harm.
	Percent Harmonic Restraint	2nd: 7.5 to 25% of fundamental	2.5%	2nd 15%
		5th and All: 15 to 40% of fundamental		5th 35%* All 20%*
87H	Pickup Setting	6 to 20 per unit operate current	0.1	6.0 (1.2)
87T-1	Winding 1 Tap	2 to 9 A or 0.4 to 1.8 A	0.1	6.0 (1.2)
51P-1	Curve Selection	See Table 1-1		Ext. Inv.
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)
	Time Dial/Delay	See Table 1-1		5.0
OA-1 (If 51P-1 is set to disable)	Current Rating	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)*
50P-1	Curve Selection	See Table 1-2		Standard
	Pickup X 51P	0.5 to 20 times 51P pickup setting	0.1	3.0
	Time Dial/Delay	See Table 1-2		1.0*
150P-1	Selection	Disable or Enable		Disable
	Pickup X 51P-1	0.5 to 20 times 51P-1 pickup setting	0.1	3.0*
	Time Delay	0 to 9.99 seconds	0.01	0.1*
46–1	Curve Selection	See Table 1-1		Disable
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)*
	Time Dial/Delay	See Table 1-1		5.0*
51N-1	Curve Selection	See Table 1-1		Ext. Inv.
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)
	Time Dial/Delay	See Table 1-1		5.0
50N-1	Curve Selection	See Table 1-2		Standard
	Pickup X 51N-1	0.5 to 20 times 51N-1 pickup setting	0.1	3.0
	Time Dial/Delay	See Table 1-2		2.0*
150 N-1	Selection	Disable or Enable		Disable
	Pickup X 51N-1	0.5 to 20 times 51N-1 pickup setting	0.1	3.0*
	Time Dial/Delay	0 to 9.99 seconds	0.01	0.1*
LDA–1	Pickup X 51P-1	Disable, 0.5 to 20 times 51P-1 pickup setting	0.1	Disable

Table 5-1. Primary, Alternate 1 and Alternate 2 Settings (Password Protected) (Continued)

Function	Setting	Range	Step Size	Factory Default
87T-2	Winding 2 Tap	2 to 9 A or 0.4 to 1.8 A		6.0 (1.2)
51P-2	Curve Selection	See Table 1-1		Ext. Inv.
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)
	Time Dial/Delay	See Table 1-1		5.0
OA-2 (If 51P-2 is set to disable)	Current Rating	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)*
50P-2	Curve Selection	See Table 1-2		Standard
	Pickup X 51P-2	0.5 to 20 times 51P-2 pickup setting	0.1	3.0
	Time Dial/Delay	See Table 1-2		1.0*
150P-2	Selection	Disable or Enable		Disable
	Pickup X 51P-2	0.5 to 20 times 51P-2 pickup setting	0.1	3.0*
	Time Delay	0 to 9.99 seconds	0.01	0.1*
46–2	Curve Selection	See Table 1-1		Disable
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)*
	Time Dial/Delay	See Table 1-1		5.0*
51G-2 (2w) 51N-2 (3w)	Curve Selection	See Table 1-1		Ext. Inv.
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)
	Time Dial/Delay	See Table 1-1		5.0
50G-2 (2w) 50N-2 (3w)	Curve Selection	See Table 1-2		Standard
	Pickup X 51N-2	0.5 to 20 times 51N-2 pickup setting	0.1	3.0
	Time Dial/Delay	See Table 1-2		2.0*
150G-2 (2w) 150N-2 (3w)	Selection	Disable or Enable		Disable
	Pickup X 51N-2	0.5 to 20 times 51N-2 pickup setting	0.1	3.0*
	Time Dial/Delay	0 to 9.99 seconds	0.01	0.1*
Disturbance 2	Pickup X 51P-2	0.5 to 5.0 times 51P-2 pickup setting	0.1	3.0
LDA–2	Pickup X 51P-2	Disable, 0.5 to 20 times 51P-2 pickup setting	0.1	Disable

* Not used when default values are present

( ) = Tap range (.2 to 2.4)

Table 5-1. Primary, Alternate 1 and Alternate 2 Settings (Password Protected) (Continued)
The following functions are available in the 3 Winding Relay only:

Function	Setting	Range	Step Size	Factory Default
87T-3	Winding 3 Tap	2 to 9 A or 0.4 to 1.8 A		6.0 (1.2)
51P-3	Curve Selection	See Table 1-1		Ext. Inv.
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)
	Time Dial/Delay	See Table 1-1		5.0
OA-3 (If 51P-3 is set to disable)	Current Rating	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)*
50P-3	Curve Selection	See Table 1-2		Standard
	Pickup X 51P-3	0.5 to 20 times 51P-3 pickup setting	0.1	3.0
	Time Dial/Delay	See Table 1-2		1.0*
150P-3	Selection	Disable or Enable		Disable
	Pickup X 51P-3	0.5 to 20 times 51P-3 pickup setting	0.1	3.0*
	Time Delay	0 to 9.99 seconds	0.01	0.1*
46–3	Curve Selection	See Table 1-1		Disable
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)*
	Time Dial/Delay	See Table 1-1		5.0*
51N-3	Curve Selection	See Table 1-1		Ext. Inv.
	Pickup Amps	1 to 12 A or 0.2 to 2.4 A	0.1 or 0.02	6.0 (1.2)
	Time Dial/Delay	See Table 1-1		5.0
50N-3	Curve Selection	See Table 1-2		Standard
	Pickup X 51N-3	0.5 to 20 times 51N-3 pickup setting	0.1	3.0
	Time Dial/Delay	See Table 1-2		2.0*
150N-3	Selection	Disable or Enable		Disable
	Pickup X 51N-3	0.5 to 20 times 51N-3 pickup setting	0.1	3.0*
	Time Dial/Delay	0 to 9.99 seconds	0.01	0.1*
Disturbance 3	Pickup X 51P-3	0.5 to 5.0 times 51P-3 pickup setting	0.1	3.0
LDA–3	Pickup X 51P-3	Disable, 0.5 to 20 times 51P-3 pickup setting	0.1	Disable
51G	Curve Selection	See table 1-1		Ext. Inv.
	Pickup Amps	1 to 12 or 0.2 to 2.4	0.1	6.0 (1.2)
	Time Dial/Delay	See table 1-1	0.1	5.0
50G	Selection	Disable or Enable		Standard
	Pickup	0.5 to 20 times 51G pickup setting	0.1	3.0
	Time Dial/Delay	See table 1-2		2.0*
150G	Curve Selection	Disable or Enable		Disable
	Pickup	0.5 to 20 times 51G pickup setting	0.1	3.0*
	Time Dial/Delay	0 to 9.99 seconds		0.1*

* Not used when default values are present

( ) = Tap range (.2 to 2.4)

Table 5-2. Two Winding Configuration Settings (Password Protected)

Setting	Range	Factory Default
Winding 1 Phase CT Ratio	1 to 2000	100
Winding 1 Neutral CT Ratio	1 to 2000	100
Winding 2 Phase CT Ratio	1 to 2000	100
Winding 2 Ground CT Ratio	1 to 2000	100
Winding 1 CT Configuration	Wye, Delta(Ia-Ic), or Delta (Ia-Ib)	Wye
Winding 2 CT Configuration	Wye, Delta(Ia-Ic), or Delta (Ia-Ib)	Wye
Transformer Configuration	Wye1-Wye2, Wye1-Delta2, Delta1-Wye2, Delta1, Delta2	Delta1-Wye2
Phase Compensation	0° to 330°	30°
VT Ratio	1 to 2000	100
VT Connection	69V Wye, 120V Delta, 120V Wye, 280V Delta	120 Wye
Phase Rotation	ABC or ACB	ABC
Alternate 1 Settings	Enable or Disable	Enable
Alternate 2 Settings	Enable or Disable	Enable
Cross Blocking Mode	Enable or Disable	Disable
Trip Failure Mode	Diff Trip, OC Trip, Diff and OC Trip	Diff and OC
Trip Failure Time	5 to 60 cycles	60
Trip Failure Dropout	5 to 90% of 51P-1 and 51P-2	5
Target Display Mode	Last or All Faults	Last
Meter Winding Mode	Winding 1 or 2	Wdg 1
Overcurrent Protection Mode	Fundamental or RMS	Fund.
Overcurrent Reset Mode (51/46)	Inst. (2 cycles) or Delayed	Instantaneous
Remote Edit (local HMI only)	Enable or Disable	Enable
Local Edit (comm. ports only)	Enable or Disable	Enable
Watt Hour Display	Kwhr, Mwhr	Kwhr
Volt Display	V_{ln} , V_{ll}	V_{ln}
LCD Light	Off, On	On
Unit (Relay) Identification	15 alphanumeric characters	TPU2000R
Demand Meter Time Constant	5, 15, 30, or 60 minutes	15
LCD Contrast Adjustment	0 to 63	16
Change Test Password?	Y or N	Y

Table 5-3. Three Winding Configuration Settings (Password Protected)

Setting	Range	Factory Default
Winding 1 Phase CT Ratio	1 to 2000	100
Winding 2 Phase CT Ratio	1 to 2000	100
Winding 3 Phase CT Ratio	1 to 2000	100
Ground CT Ratio	1 to 2000	100
Winding 1 CT Configuration	Wye	Wye
Winding 2 CT Configuration	Wye	Wye
Winding 3 CT Configuration	Wye	Wye
Transformer Configuration	Wye1-Wye2-Delta3 Wye1-Delta2-Wye3 Delta1-Wye2-Wye3 Wye1-Delta2-Delta3 Delta1-Delta2-Wye3 Delta1-Wye2-Delta3 Delta1-Delta2-Delta3 Wye1-Wye2-Wye3	Delta1-Wye2-Wye3
Phase Compensation 1-2	0° to 330°	30°
Phase Compensation 1-3	0° to 300°	30°
VT Ratio	1 to 2000	100
VT Connection	69V Wye, 120V Delta, 120V Wye, 280V Delta	120 Wye
Phase Rotation	ABC or ACB	ABC
Alternate 1 Settings	Enable or Disable	Enable
Alternate 2 Settings	Enable or Disable	Enable
Cross Blocking Mode	Enable or Disable	Disable
Trip Failure Mode	Diff Trip, OC Trip, Diff and OC Trip	Diff and OC
Trip Failure Time	5 to 60 cycles	60
Trip Failure Dropout	5 to 90% of 51P-1 and 51P-2	5
Target Display Mode	Last or All Faults	Last
Meter Winding Mode	Winding 1, 2 or 3	Wdg 1
Overcurrent Protection Mode	Fundamental or RMS	Fund.
Overcurrent Reset Mode (51/46)	Inst. (2 cycles) or Delayed	Instantaneous
Remote Edit (local HMI only)	Enable or Disable	Enable
Local Edit (comm. ports only)	Enable or Disable	Enable
Watt Hour Display	Kwhr, Mwhr	Kwhr
Volt Display	V_{ln} , V_{ll}	V_{ln}
LCD Light	Off, On	On
Unit (Relay) Identification	15 alphanumeric characters	TPU2000R
Demand Meter Time Constant	5, 15, 30, or 60 minutes	15
LCD Contrast Adjustment	0 to 63	16
Change Test Password?	Y or N	Y

Calculate Tap Settings (See Section 7 for details)

Table 5-4. Counter Settings (Password Protected)

Setting	Range	Factory Default
Through Faults Counter	0 to 9999	0
Through Fault kAmp Summation Phase A Winding 2	0 to 9999 kA	0
Through Fault kAmp Summation Phase B Winding 2	0 to 9999 kA	0
Through Fault kAmp Summation Phase C Winding 2	0 to 9999 kA	0
Through Fault Cycle (Duration) Summation	0 to 99990 cycle	0
Overcurrent Trip Counter	0 to 9999	0
Differential Trip Counter	0 to 9999	0

Duplicate table for Winding 3 exists for the 3 Winding TPU2000R

The Through Faults Counter, the Overcurrent Trip Counter and the Differential Trip Counters will be reset to zero (0) when the "CRI" (counter reset initiate) programmable input is asserted.

Summation Counters can only be reset to zero (0) via the Counter Settings Menu in ECP or the MMI. See Table 5-4.

Table 5-5. Alarm Settings (Password Protected)

Setting	Range	Factory Default
Through Faults Counter Alarm (TFCA)	0 to 9999	Disable
Winding 2 Through Fault kAmp Summation Alarm (TFCA)	1 to 9999 kA	Disable
Winding 3 Through Fault kAmp Summation Alarm (TFKA-3)	1 to 9999 kA	Disable
Through Fault Cycle (Duration) Summation (TFSCA)	0 to 99990 cycle	Disable
Overcurrent Trip Counter Alarm (OCTC)	0 to 9999	Disable
Differential Trip Counter Alarm (DTC)	0 to 9999	Disable
*Phase Demand Current Alarm (PDA)	1 to 9999 A	Disable
*Neutral Demand Current Alarm (NDA)	1 to 9999 A	Disable
*Load Current Alarm (LOAD A)	1 to 9999 A	Disable
*3 Phase KVAR Demand (Var DA)	10 to 99990 A	Disable
*Low Power Factor (LPFA)	0.5 - 1.0	Disable
*High Power Factor (HPFA)	0.5 - 1.0	Disable
*Positive KVAR (PVArA)	10 to 99990 A	Disable
*Negative KVAR (NVArA)	10 to 99990 A	Disable
Positive Kilowatts Winding 1 (Watt 1)	1 to 9999 A	Disable
Positive Kilowatts Winding 2 (Watt 2)	1 to 9999 A	Disable
#Positive Kilowatts Winding 3 (Watt 3)	1 to 9999 A	Disable

#Denotes 3 Winding Relay only
*Logical output asserts after condition is satisfied and a 60 second time delay

All of the alarms listed in Table 5-5 can be reset via the Target/Alarm Reset by pushing “C” on the MMI twice or by the Miscellaneous Command Menu in ECP.

Warning: If the counter exceeds the threshold setting and the alarms are reset, the alarms exceeding the threshold setting will be reactivated at the time of the next fault.

The Phase Demand Alarm (PDA) and the Neutral Demand Alarm (NDA) will reset when current drops to 98% of threshold setting.

Table 5-6. Communications Settings (Password Protected)

Setting	Range	Factory Default
FP232 Baud (Front Port)	300, 1200, 2400, 4800, 9600	9600
FP232 Frame	N,8,1 or N,8,2	N,8,1
RP232 Baud (Rear Port)*	300, 1200, 2400, 4800, 9600, 19200	9600
RP232 Frame	N,8,1; E,8,1; ODD,8,1; N,8,2; E,7,1; ODD,7,1; N,7,2	N,8,1
RP485 Baud (Rear Port)*	300, 1200, 2400, 4800, 9600, 19200	9600
RP485 Frame	N,8,1; E,8,1; ODD,8,1; N,8,2; E,7,1; ODD,7,1; N,7,2	N,8,1
INCOM (Rear Port)*	1200, 9600	9600
Unit Address	3 hexadecimal characters (0-9 & A-F)	001
IRIG-B Input	Disable or Enable	Disable

* Check catalog number for available communications port options.

Miscellaneous Settings (Password Protected)

Under the Miscellaneous Settings Menu, you will find the following:

Communications Configurable Settings – For use with Modbus/Modbus Plus™ Communications. Contact factory for details

Security Mask for Writable 4XXXX Control – For use with Modbus/Modbus Plus™ Communications. Contact factory for details.

User Display Message – For use with User Definable Interface (UDI) Programmable Input. The user can type a 4 line message here. When UDI is asserted, this message will blink on the MMI.

Programmable Inputs/Programmable Outputs – See Section 6

Global Register Mapping/ Register Configuration

For use with Modbus/Modbus Plus™ Communications. Contact factory for details.

User Logical Output Names

The user has the ability to change the names of “ULO1” through “ULO9”. See Section 6 for details on how to use the User Logical Outputs.

ULI/ULO Configuration

This allows the user to connect or disconnect ULIs from corresponding ULOs. The default is all ULIs connected to ULOs. See Section 6 for details on ULIs.

FLI Index and User Names

This allows the user to set up a table of Logical Inputs that can be forced in the Operations Menu. See Section 9.

Programmable Input and Output Contacts

By using the External Communications Program, you can individually program certain input and output contacts. **Inputs and outputs cannot be programmed via the front panel.**

Binary (Contact) Inputs

Binary inputs are either programmable single-ended or programmable double-ended. Single-ended inputs have one terminal connection marked "+" and share a common terminal (# 3) marked "–". Double-ended inputs have two terminal connections, marked "+" and "–". The recognition time for the change in state of an input is two (2) cycles.

Up to eight (8) user-programmable contact inputs are available. You can program these only through the External Communications Program. All protective functions remain operational (enabled) when not assigned to contact inputs in the Programmable Input Map. You must assign the remaining input functions to contact inputs for the functions to be operational (enabled). The user-programmable inputs can monitor, enable, initiate or actuate the input functions shown in Table 6-1. A 2 cycle debounce is included for each input. This should be considered when applying inputs to timing sensitive applications.

Figure 6-1 shows an example of a Programmable Inputs mapping screen. The "C" represents a closed contact to enable the function; to represent an open contact to enable the function, you place an "O" under the input in the desired contact line.

Press the F1 function key to assign names to the programmable contact inputs. Each name may contain up to eight (8) alphanumeric characters.

Press the F2 function key to program the feedback inputs. For more information on feedback, see "Multilevel Programmable Logic" later in this section.

Trip Circuit Monitor

You can use inputs IN7 or IN8 as a Trip Circuit Monitor (TCM) input. When the breaker is closed, a small trace current of 6 milliamperes is passed from the positive terminal through the negative terminal and the trip coil circuit. If an open circuit is detected while the breaker is closed, the Trip Circuit Failure Alarm (TCFA) actuated and a "Trip Coil Failed" message appears on the MMI display. Please note that this input **MUST** be "ORed" to another physical input wired to an external 52a or 52b contact. See the diagram below.

Programmable Inputs

Logical	Logic	52a IN 1	Trip Circuit IN 7
TCM	OR	O	C

Table 6-1. Programmable Inputs

Programmable Input	Function	Default Input Contact
87T	Two (2)-winding, 3-phase percentage differential current control; enables the 87T function	-
87H	Two (2)-winding, 3-phase instantaneous differential current control; enables the 87H function	-
51P-1	Winding 1 phase time overcurrent control; enables the 51P-1 function	-
51P-2	Winding 2 phase time overcurrent control; enables the 51P-2 function	-
#51P-3	Winding 3 phase time overcurrent control; enables the 51P-3 function	-
51N-1	Winding 1 neutral time overcurrent control; enables the 51N-1 function	-
51G-2 (2w) 51G-2 (3w)	Winding 2 ground/neutral time overcurrent control; enables the 51G-2/51N-2 function	-
#51N-3	Winding 3 neutral time overcurrent control; enables the 51N-3 function	-
50P-1	Winding 1 instantaneous control; enables the 50P-1 function	-
50P-2	Winding 2 instantaneous control; enables the 50P-2 function	-
#50P-3	Winding 3 instantaneous control; enables the 50P-3 function	-
50N-1	Winding 1 instantaneous control; enables the 50N-1 function	-
50G-2 (2w) #50N-2 (3w)	Winding 2 instantaneous control; enables the 50G-2/50N-2 function	-
#50N-3	Winding 3 instantaneous control; enables the 50N-3 function	-
150P-1	Winding 1 instantaneous control; enables the 150P-1 function	-
150P-2	Winding 2 instantaneous control; enables the 150P-2 function	-
#150P-2	Winding 3 instantaneous control; enables the 150P-3 function	-
150N-1	Winding 1 instantaneous control; enables the 150N-1 function	-
150G-2 (2w) 150N-2 (3w)	Winding 2 instantaneous control; enables the 150G-2/150N-2 function	-
#150N-3	Winding 3 instantaneous control; enables the 150N-3 function	-
46-1	Winding 1 negative sequence control; enables the 46-1 function	-
46-2	Winding 2 negative sequence control; enables the 46-2 function	-
#46-3	Winding 3 negative sequence control; enables the 46-3 function	-
# 51G	Ground time overcurrent control; enables the 51G function	-
# 50G	Ground instantaneous control; enables the 50G function	-
# 150G	Ground instantaneous control; enables the 50G function	-
ALT1 ALT2	Enables Alternate 1 & 2 Settings table. First table enabled takes precedance over the second when both tables are selected "ON"	IN-6 IN-7
ECI1 (Event Capture Initiated)	Initiates storage of data in fault summary and fault record	-
ECI2 (Event Capture Initiated)	Initiates storage of data in fault summary and fault record	-
WCI (Waveform Capture Initiated)	Initiates oscillographic data storage in the waveform capture record	-
TRIP	Initiates Differential Trip Output contacts	-
SPR (Sudden Pressure)	Sudden Pressure input	-
TCM (Trip Coil Monitoring)	Trip Coil Monitoring input	-
ULI1-ULI9	User Logical inputs; enables ULI1-ULI9 (see Appendix I)	-
CRI	Clears through fault and overcurrent counters	-
UDI	User Definable Interface. To type the displayed message in ECP, go to "Change Settings" then select "Miscellaneous Settings." When this input is asserted through the programmable inputs, the message will blink on the MMI.	-

#Refers to 3 Winding TPU2000R only

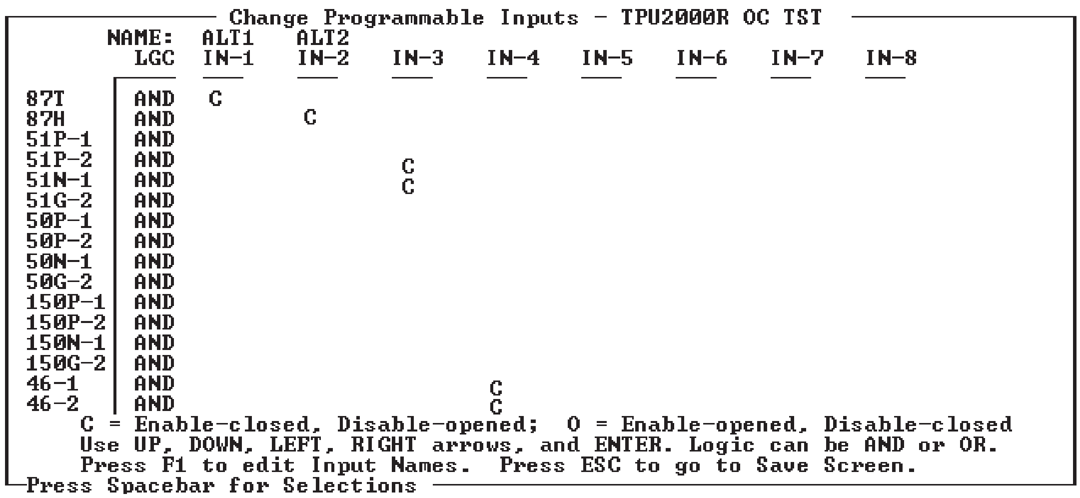


Figure 6-1. ECP Programmable Inputs Screen

Programming Examples:

If you want to also have IN-2 OR IN-8 enable the 50P-1 function, insert a “C” under IN-2 and a “C” under IN-8 and an “OR” under LOGIC in the 50P-1 LGC column. This is logically 50P-1 = IN-2 OR IN-8. Refer to Figure 6-2.

Programming the Binary (Contact) Inputs

Use ECP and follow these steps to program the binary (contact) inputs on the Programmable Input Map screen:

1. From the ECP Main Menu, select “Change Settings.”

2. From the Change Settings menu, select “Programmable Inputs.”

3. The Programmable Input Map screen appears.

4. To change the function listing:

   a. Use the arrow keys to highlight the function (far left column).
   b. Press the space bar to display a list of possible functions.
   c. Scroll through the list until the contact you want is highlighted.
   d. Press ENTER to change the function or press ESC to close the function list window without changing the current listing.

5. To change the Logic of a contact:

   a. Use the arrow keys to highlight the Logic value of a contact.
   b. Press the space bar to display a window with AND and OR.
   c. Highlight AND or OR.
   d. Press ENTER to change the Logic or press ESC to close the Logic window without any changes.

6. To change the status of a contact:

   a. Use the arrow keys to highlight the area across from the contact name and underneath the input you want.
   b. Press the space bar to display a window with a blank, a “C,” and an “O” (nothing, closed and open).
   c. Highlight the status you want.
   d. Press ENTER to change the status or press ESC to close the status window without any changes.

7. To assign a name to an input:

   a. Press F1.
   b. Use the right arrow key to highlight the input you want to change and press the space bar.
   c. A window appears prompting you to enter the new name. Type in the new name (up to 8 characters).
   d. Press ENTER to change the name or press ESC to close the input window without any changes.

8. Save your changes.

   a. Press ESC.
   b. At the window prompting you to save, highlight the option you want by using the arrow keys and press ENTER.

Change Programmable Inputs - TPU2000R OC TST

	NAME:	ALT1	ALT2						
	LGC	IN-1	IN-2	IN-3	IN-4	IN-5	IN-6	IN-7	IN-8
87T	AND								
87H	AND								
51P-1	AND								
51P-2	AND								
51N-1	AND								
51G-2	AND								
50P-1	OR		C						C
50P-2	AND								

Figure 6-2. Programming Example

Output Contacts

Like the binary inputs, the relay output contacts are divided into two categories: permanently programmed and user-programmable. Jumpers on the main boards allow you to choose whether the programmable output contact is normally open or normally closed. Jumper J6 is the TRIP contact, J7 is OUT1 and J8 is OUT2.

Permanently Programmed Output Contacts

Permanently programmed output contacts include the following:

- The TRIP output contact is actuated by the ENABLED Percentage Differential Trip 87T and High Set Instantaneous Differential 87H protective functions. The trip output is maintained closed until the fault current drops below the Trip Failure Dropout setting.
- Self-Check Alarm output contacts, one form 4C with one normally open and one normally closed contact, change state when control power is applied. Upon a loss of control power or on a failure status of a specific self-test, the contacts return to their normal state. A contact can be connected to a local annunciator light or, if available, to a remote terminal unit for indication of a self check alarm condition.

User-Programmable Output Contacts

Up to six (6) output contacts can be programmed only through the External Communications Program. You can program these six output contacts for time delay on pickup. The time delay interval is adjustable from 0 to 60 seconds in 0.01 steps. You can program the user-programmable output contacts to indicate up to 32 of the conditions shown in Table 6-2.

To access the feedback outputs, press F2 while in the programmable output screen in ECP. See “Multilevel Programmable Logic” later in this section for more details.

Table 6-2. Programmable Outputs

Programmable Output	Description	Default Output Contact
DIFF TRIP	Same as permanently programmed contact	OUT-3
ALARM	Same as permanently programmed contact	–
87T†	Harmonic Restrained Percentage Differential Trip Alarm	–
87H†	Unrestrained High Set Instantaneous Differential Trip Alarm	–
2HROA†	2nd Harmonic Restraint Alarm	OUT-4
5HROA†	5th Harmonic Restraint Alarm	–
AHROA†	All Harmonics Restraint Alarm (2nd through the 11th harmonic)	–
TCFA (Trip Circuit Failure Alarm)	Indicates that the trip circuit is open. This alarm remains until continuity is re-established.	–
TFA (Trip Failure Alarm)	Indicates that a fault has not been cleared within the programmable Trip Failure time setting of 5 to 60 cycles. Use the Trip Failure Mode setting (Differential, Overcurrent, or Differential and Overcurrent) to select the type of faults for which a trip failure alarm will be given. The trip failure alarm clears when the current drops below the Trip Failure drop-out setting.	OUT-5

† Dropout time is 3 cycles for all trip alarms.

Table 6-2. Programmable Outputs (continued)

Programmable Output	Description	Default Output Contact
51 P-1	Winding 1 Phase Time Overcurrent Trip Alarm	OUT-1
51P-2	Winding 2 Phase Time Overcurrent Trip Alarm	OUT-2
51P-3 (3w)	Winding 3 Phase Time Overcurrent Trip Alarm	OUT-3
50P-1*	2nd Winding 1 Phase Instantaneous Overcurrent Trip Alarm	OUT-1
50P-2*	1st Winding 1 Phase Instantaneous Overcurrent Trip Alarm	OUT-1
150P-1*	1st Winding 2 Phase Instantaneous Overcurrent Trip Alarm	OUT-2
150P-2*	2nd Winding 2 Phase Instantaneous Overcurrent Trip Alarm	OUT-2
50P-3* (3w)	1st Winding 3 Phase Instantaneous Overcurrent Trip Alarm	OUT-3
150P-3* (3w)	1st Winding 3 Phase Instantaneous Overcurrent Trip Alarm	OUT-3
51N-1*	Winding 1 Neutral Time Overcurrent Trip Alarm	OUT-1
51G-2* (2w) 51N-3* (3w)	Winding 2 Ground/Neutral Time Overcurrent Trip Alarm	OUT-2
51N-3* (3w)	Winding 3 Neutral Time Overcurrent Trip Alarm	OUT-3
50N-1*	1st Winding 1 Neutral Instantaneous Overcurrent Trip Alarm	OUT-1
150N-1*	2nd Winding 1 Neutral Instantaneous Overcurrent Trip Alarm	OUT-1
50G-2* (2w) 50N-2* (3w)	1st Winding 2 Ground/Neutral Instantaneous Overcurrent Trip Alarm	OUT-2
150G-2* (2w) 150N-2* (3w)	2nd Winding 2 Ground/Neutral Instantaneous Overcurrent Trip Alarm	OUT-2
50N-3* (3w)	1st Winding 3 Neutral Instantaneous Overcurrent Trip Alarm	OUT-3
50N-3* (3w)	2nd Winding 3 Ground/Neutral Instantaneous Overcurrent Trip Alarm	OUT-3
46-1*	Winding 1 Negative Sequence Time Overcurrent Trip Alarm	OUT-1
46-2*	Winding 2 Negative Sequence Time Overcurrent Trip Alarm	OUT-2
46-3* (3w)	Winding 3 Negative Sequence Time Overcurrent Trip Alarm	OUT-3
51G (3w)	Ground Time Overcurrent Trip Alarm	–
50G (3w)	1st Ground Instantaneous Overcurrent Trip Alarm	–
150G (3w)	2nd Ground Instantaneous Overcurrent Trip Alarm	–
87T-D	Percentage Differential Function Disabled Alarm	–
87H-D	High Set Instantaneous Function Disabled Alarm	–
51P-1D	Winding 1 Phase Time Overcurrent Function Disabled Alarm	–
51P-2D	Winding 2 Phase Time Overcurrent Function Disabled Alarm	–
51P-3D (3w)	Winding 3 Phase Time Overcurrent Function Disabled Alarm	–
51N-1D	Winding 1 Neutral Time Overcurrent Function Disabled Alarm	–

† Dropout time is 3 cycles for all trip alarms.

(2w) = Two Winding Relay only
(3w) = Three Winding Relay only

Table 6-2. Programmable Outputs (continued)

Programmable Output	Description	Default Output Contact
51G-2D (2w) 51N-2D (3w)	Winding 2 Ground Time Overcurrent Function Disabled Alarm	–
51N-3D (3w)	Winding 3 Neutral Time Overcurrent Function Disabled Alarm	–
50P-1D	1st Winding 1 Phase Instantaneous Overcurrent Function Disabled Alarm	–
50P-2D	1st Winding 2 Phase Instantaneous Overcurrent Function Disabled Alarm	–
50P-3D (3w)	1st Winding 3 Phase Instantaneous Overcurrent Function Disabled Alarm	–
50N-1D	1st Winding 1 Neutral Instantaneous Overcurrent Function Disabled Alarm	–
50G-2D (2w) 50N-2D (3w)	1st Winding 2 Ground/Neutral Instantaneous Overcurrent Function Disabled Alarm	–
50N-3D (3w)	1st Winding 3 Neutral Instantaneous Overcurrent Function Disabled Alarm	–
150P-1D	2nd Winding 1 Phase Instantaneous Overcurrent Function Disabled Alarm	–
150P-2D	2nd Winding 2 Phase Instantaneous Overcurrent Function Disabled Alarm	–
150P-3D	2nd Winding 3 Phase Instantaneous Overcurrent Function Disabled Alarm	–
150N-1D	2nd Winding 1 Neutral Instantaneous Overcurrent Function Disabled Alarm	–
150G-2D (2w) 150N-2D (3w)	2nd Winding 2 Ground/Neutral Instantaneous Overcurrent Function Disabled Alarm	–
150N-2D (3w)	2nd Winding 3 Ground/Neutral Instantaneous Overcurrent Function Disabled Alarm	–
46-1D	Winding 1 Negative Sequence Time Overcurrent Function Disabled Alarm	–
46-2D	Winding 2 Negative Sequence Time Overcurrent Function Disabled Alarm	–
46-3D (3w)	Winding 3 Negative Sequence Time Overcurrent Function Disabled Alarm	–
51G-D (3w)	Ground Time Overcurrent Function Disabled Alarm	–
50G-D (3w)	1st Ground Instantaneous Overcurrent Function Disabled Alarm	–
150G-3D (3w)	2nd Ground Instantaneous Overcurrent Function Disabled Alarm	–
PATA	Phase A LED Target Alarm	–
PBTA	Phase B LED Target Alarm	–
PCTA	Phase C LED Target Alarm	–
PUA (Pickup Alarm)	Differential and Overcurrent (87/51/50/150/46) Pickup Alarm. Indicates that an enabled protective function is picked up and can be used as a fault detector output alarm. The contact resets 500 milliseconds after the picked up state has dropped out.	OUT-6

(2w) = Two Winding Relay only
(3w) = Three Winding Relay only

Table 6-2. Programmable Outputs (continued)

Programmable Output	Description	Default Output Contact
THRUFA	Through Fault Alarm; actuated by the Winding 2 Disturbance pickup setting	OUT-6
TFCA†	Through Fault Counter Alarm	–
TFKA†	Through Fault kAmp Summation Alarm for winding 2	–
TFKA-3 (3w)†	Through Fault kAmp Summation Alarm for winding 3	–
TFSCA†	Through Fault Cycle Summation Alarm	–
DTC †	Differential Trip Counter Alarm	–
OCTC†	Overcurrent Trip Counter Alarm	–
PDA	Phase Demand Current Alarm: Pickup time delay is 60 seconds and dropout is 98% of setting.	–
NDA	Neutral Demand Current Alarm: Pickup time delay is 60 seconds and dropout is 98% of setting.	–
PRIM	Primary Settings Enabled Alarm	–
ALT1	Alternate 1 Settings Enabled Alarm	–
ALT2	Alternate 2 Settings Enabled Alarm	–
63	Sudden Pressure Input Alarm	–
HLDA-1	Winding 1 High Level Detector Alarm	–
LLDA-1	Winding 1 Low Level Detector Alarm	–
HLDA-2	Winding 2 High Level Detector Alarm	–
LLDA-2	Winding 2 Low Level Detector Alarm	–
HLDA-3 (3w)	Winding 3 High Level Detector Alarm	–
LLDA-3 (3w)	Winding 3 Low Level Detector Alarm	–
ULO1-ULO9	User Logical Outputs 1 – 9	–
HPFA	High Power Factor Alarm	–
LPFA	Low Power Factor Alarm	–
OCA-1	Winding 1 Overcurrent Alarm	–
OCA-2	Winding 2 Overcurrent Alarm	–
OCA-3 (3w)	Winding 3 Overcurrent Alarm	–
OCG (3w)	Ground Overcurrent Alarm	–
LOAD A	Load Current Alarm	–
VarDA	3 Phase kVar Demand Alarm	–
PVARA	Positive 3 Phase kVar Alarm	–
NVARA	Negative 3 Phase kVar Alarm	–
PWATT-1	PWinding 1 Positive 3 Phase kWatt Alram	–
PWATT-2	Winding 2 Positive 3 Phase kWatt Alarm	–
PWATT-3 (3w)	Winding 3 Positive 3 Watt Alarm	–

* Seal-in alarms drop out when targets are reset via the MMI or the ECP.

†Dropout time is 3 cycles for all trip alarms. The counter alarms are cleared when the targets are reset. The alarms activate with each operation or power-up until the counters are reset.

Table 6-2. Programmable Outputs (continued)

Programmable Output	Description	Default Output Contact
STCA*	Settings Table Changed Alarm is activated whenever the Change Settings menu is accessed. This alarm is cleared when the targets are reset.	
87T*	Percentage Differential Seal In Alarm	
87H*	High Set Instantaneous Differential Seal In Alarm	
2HROA*	2nd Harmonic Restraint Seal In Alarm	–
5HROA*	5th Harmonic Restraint Seal In Alarm	–
AHROA*	All Harmonics Restraint Seal In Alarm (2nd Through the 11th Harmonic)	–
51P-1*	Winding 1 Phase Time Overcurrent Seal In Alarm	–
51P-2*	Winding 2 Phase Time Overcurrent Seal In Alarm	–
51P-3* (3w)	Winding 3 Phase Time Overcurrent Seal In Alarm	–
50P-1*	1st Winding 1 Phase Instantaneous Overcurrent Seal In Alarm	–
150P-1*	2nd Winding 1 Phase Instantaneous Overcurrent Seal In Alarm	–
50P-2*	1st Winding 2 Phase Instantaneous Overcurrent Seal In Alarm	–
150P-2*	2nd Winding 2 Phase Instantaneous Overcurrent Seal In Alarm	–
50P-3* (3w)	1st Winding 3 Phase Instantaneous Overcurrent Seal In Alarm	–
150P-3* (3w)	2nd Winding 3 Phase Instantaneous Overcurrent Seal In Alarm	–
51N-1*	Winding 1 Neutral Time Overcurrent Seal In Alarm	–
51G-2* (2w) 51N-2* (3w)	Winding 2 Ground/Neutral Time Overcurrent Seal In Alarm	–
51N-3* (3w)	Winding 3 Ground/Neutral Time Overcurrent Seal In Alarm	–
50N-1*	1st Winding 1 Neutral Instantaneous Overcurrent Seal In Alarm	–
150N-1*	2nd Winding 1 Neutral Instantaneous Overcurrent Seal In Alarm	–
50G-2* (2w) 50N-2* (3w)	1st Winding 2 Ground/Neutral Instantaneous Overcurrent Seal In Alarm	–
150G-2* (2w) 150N-2* (3w)	2nd Winding 2 Ground/Neutral Instantaneous Overcurrent Seal In Alarm	–
50N-3* (2w) 150N-3* (3w)	1st Winding 3 Instantaneous Overcurrent Seal In Alarm 2nd Winding 3 Instantaneous Overcurrent Seal In Alarm	–
46-1*	Winding 1 Negative Sequence Time Overcurrent Seal In Alarm	–
46-2*	Winding 2 Negative Sequence Time Overcurrent Seal In Alarm	–
46-3* (3w)	Winding 3 Negative Sequence Time Overcurrent Seal In Alarm	–
51G3* (3w)	1st Ground Instantaneous Overcurrent Seal In Alarm	–
150G3* (3w)	2nd Ground Instantaneous Overcurrent Seal In Alarm	–
63*	Sudden Pressure Input Seal In Alarm	–

* Seal-in alarms drop out when targets are reset via the MMI or the ECP.

(2w) = 2 Winding Relay only
(3w) = 3 Widning Relay only

Figure 7-2 shows the Programmable Outputs mapping screen. The “X’s” indicate what functions are mapped to which outputs. Delay output timers can be programmed for each output contact by pressing the F1 function key.

```
                Change Programmable Outputs - TPU2000R
TIMERS:     0.00      0.00      0.00      0.00      0.00      0.00
        OUT-1     OUT-2     OUT-3     OUT-4     OUT-5     OUT-6
 NAME:  PRI Trip  SEC Trip  DIFF Trp  Harm Rst  TRP Fail  PICKUP

LOGIC  |  OR        OR        OR        OR        OR        OR
       |  --        --        --        --        --        --
DIFF   |                      X
ALARM  |
TFA    |                                          X
87T    |
87H    |
2HROA  |                                X
5HROA  |
AHROA  |
51P-1  |  X
51P-2  |            X
50P-1  |  X
150P-1 |  X
50P-2  |            X
150P-2 |            X
 X = Output is selected.  LOGIC can be AND or OR.  Use UP, DOWN, LEFT, RIGHT
 arrows, and ENTER. Use F1 to edit Timer fields. ESC to Exit screen.
 Press Spacebar for Selections
```

Figure 6-3. Programmable Outputs Screen

Programming Examples

The figure above displays the factory default output contacts mapping.

1. Output 4 above is mapped to the 2nd harmonic restraint output alarm (2HROA) logic function. If the TPU-2000R restrains on the 2nd harmonic, the OUT-4 contact will alarm for the duration of the restraint.

2. To assign the 5th harmonic restraint output alarm (5HROA) logic function to OUT-4 also, The LOGIC is set to “OR” and an “X” is placed in the 5HROA row under column OUT-4.

The OR logic implies that output 4 will alarm under either restraint condition, 2nd harmonic or 5th harmonic. Up to 32 logic functions can be mapped to a single output contact.

Programming the Output Contacts

Use ECP and follow these steps to program the output contacts on the Programmable Output Map screen. You can select up to 32 attributes to be displayed on the Programmable Output Map.

1. From the ECP Main Menu, select “Change Settings.”

2. From the Change Settings menu, select “Programmable Outputs.”

3. The Programmable Output Map screen appears.

4. To change the function listing:

   a. Use the arrow keys to highlight the function in the far left column.
   b. Press the space bar to display a list of possible contacts.

NOTE: You cannot access the Trip function.

   c. Scroll through the list until the contact you want is highlighted.
   d. Press ENTER to change the contact or press ESC to close the contact list window without changing the current contact.

5. To change the Logic of a contact:

   a. Use the arrow keys to highlight the Logic value of a contact.
   b. Press the space bar to display a window with AND and OR.
   c. Highlight AND or OR.
   d. Press ENTER to change the Logic or press ESC to close the Logic window without any changes.

6. To select an output:

   a. Use the arrow keys to highlight the area across from the contact name and underneath the output you want.
   b. Press the space bar to display a window with a blank and an “X.”
   c. Highlight the status you want.
   d. Press ENTER to change the status or press ESC to close the status window without any changes.

7. To change the name:

   a. Use the arrow keys to highlight the output name you want to change.
   b. Type in the new name (up to 8 alphanumeric characters).
   c. Press ENTER to keep the new name or press ESC.

8. To change a Timer value:

   a. Press F1.
   b. Use the right arrow key to highlight the timer you want to change and press ENTER.
   c. A window appears. Use the arrow keys to increase or decrease the timer’s value.
   d. Press ENTER to keep the value or press ESC to close the window without any changes.

9. Save your changes.

   a. Press ESC.
   b. At the window prompting you to save, highlight the option you want by using the arrow keys and press ENTER.

MULTILEVEL PROGRAMMABLE LOGIC

INTRODUCTION

The programmable inputs and outputs in the DPU2000R and TPU2000R can be interconnected to produce more complex logic functions than the single level logic functions described earlier in this section. This subsection goes into more detail on how to create functions with many inputs and logic levels. It is assumed that the user already knows how to select and change values in the Programmable Input and Output Tables from reading the previous pages in section 6.

Figure 6-4 shows a typical Input and Output logic gate and all of their possible interconnections. The output of a Programmable Input gate can be fed to the next stage of logic, the input to a Programmable Output gate, by CONNECTing the Input User Logical Input (ULIk) to its' User Logical Output (ULOk). Likewise, the output of a Programmable Output can be fed to the input of a Programmable Input gate by using FEEDBACK. The FEEDBACK feature is only available in the TPU-2000R units with version 2.10 CPU firmware or later and ECP version 2.10 or later.

Output gates that control physical output contacts can have a timer associated with them. The output contacts will energize after the gate logic is active for the set pickup time.

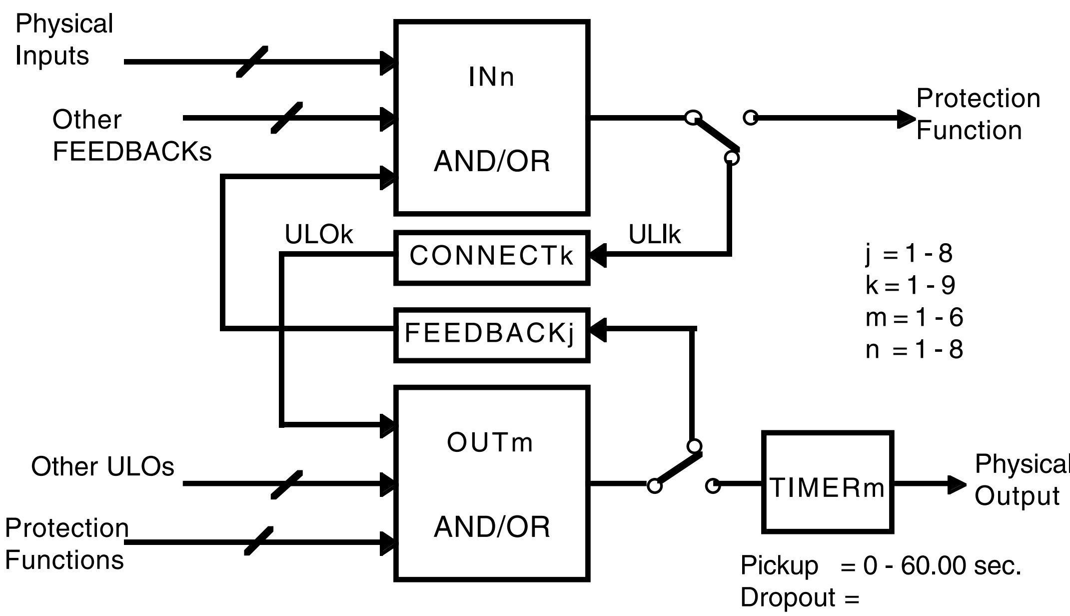


Figure 6-4. Programmable Input and Output Interconnects

PROCEDURE

A logical Function can be made from the Programmable Input and Output tables using the following procedure:

Draw a logic diagram of the function using only AND and OR gates. Any logic gate can have eight or more inputs.

Label the gates as either a Prog. Input or a Prog. Output depending on these rules:

- Any physical input (IN-n contact) must go to a Prog. Input gate.
- Any protection functions must go into a Prog. Output gate.
- Any physical outputs (contact operation) must come from a Prog. Output gate.

Add gates, CONNECTs, and FEEDBACKs to the diagram so that the following rules are followed:

- The output of a Prog. Output gate connects to the input of a Prog. Input gate through a FEEDBACKj. See Figure 6-5a.
- The output of a Prog. Input gate can be connected to the input of a Prog. Output by making a CONNECT between the Input gate's ULIk and ULOk. See Figure 6-5b.

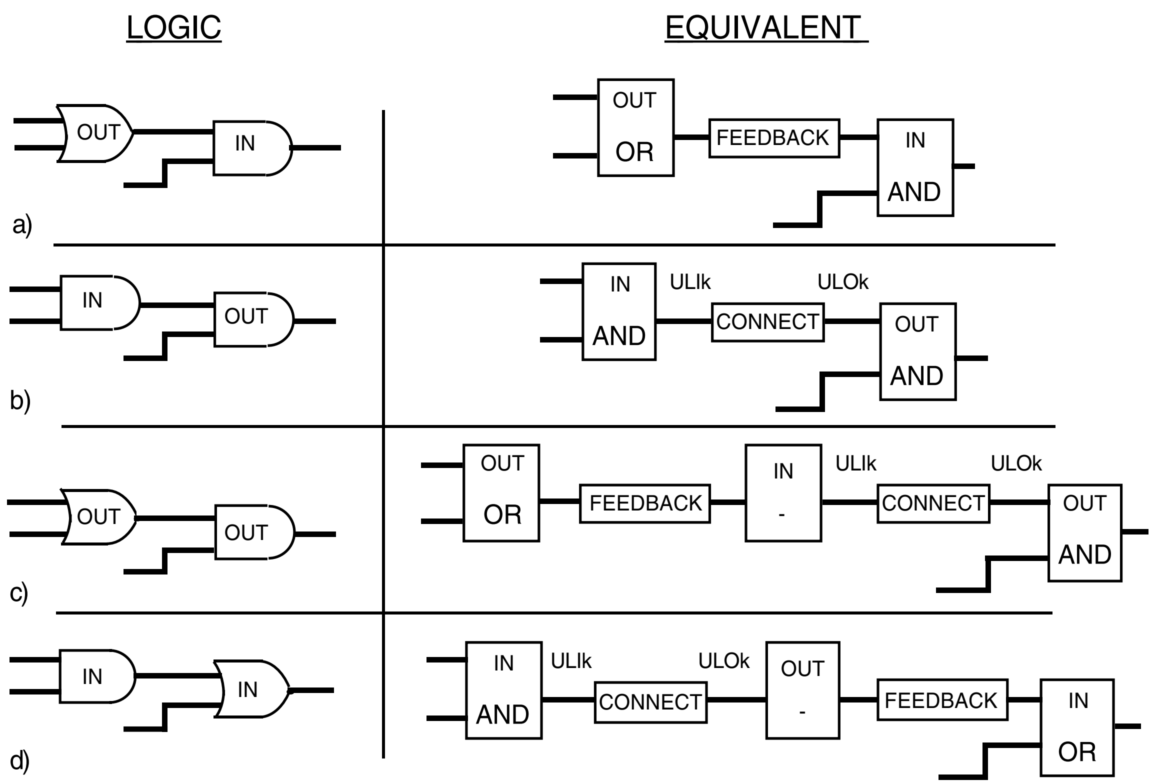


Figure 6-5. Equivalent Gates

- The output of a Prog. Output gate must go to the input of another Prog. Output through a FEEDBACK-Prog. Input CONNECT combination. The logic of the added input gate does not matter. See Figure 6-5c.
- The output of a Prog. Input gate must go to the input of another Prog. Input through a CONNECT-Prog. Output-FEEDBACK combination. The logic of the added output gate does not matter. See Figure 6-5d.

Programmable Inputs

1. Using ECP, place the input gates in the Prog. Inputs Table. Each input gate is a row in that table. The output of the gate is the ULIk or function in the far left column. The type of gate, AND or OR, is the second column of each row. The remaining items in the row are potential inputs to the gate.
2. On the diagram, number the ULIks and ULOks to be joined by a CONNECT, the FEEDBACKj, and any IN-n to correspond to unused values in the table.
3. If they do not already appear there, program the function or ULIk for each gate/row to the far left column. See Programming Binary Inputs earlier in Section 6.
4. Change the logic function for each row depending on if it represents an AND or an OR gate.
5. For each gate/row, mark the space under the IN-n and FEEDBACKj columns which compose the inputs for that gate. Use a “C” if you want the input contact to be active closed (when sensing control voltage). Use an “O” if you want the contact active open (no control voltage). Up to 32 entries can be made in the table. An unmarked space will have no effect on the gate logic.

   Note: Using an “O” in place of a “C” or a “C” in place of an “O” is a way to put a logical inversion, or NOT gate, in the diagram
6. Enter a descriptive name for the connected ULIk-ULOk pairs. Use the User Logical Output Names item on the Change Settings menu.

Programmable Outputs

1. Again using ECP, place the output gates in the Prog. Outputs Table. Each output gate is a column in that table. The output of the gate is the OUT-n or FEEDBACKj in the top row. The type of gate, AND or OR, is two rows below the gate output in the LOGIC row. The remaining items in the column are potential inputs to the gate.
2. If they do not already appear there, program every protection function or ULOk input for each gate/column to the far left column. See Programming the Output Contacts earlier in this section.
3. Change the logic function for each column depending on if it represents an AND or an OR gate.
4. For each output contact or FEEDBACKj column, mark the spaces across from the ULOk or protection function which compose the inputs for that gate. An “X” will mark that function as an input to the gate. Up to 32 “X’s” can be put in the table. An unmarked space will have no effect on the gate logic.
5. Enter a descriptive name for each Physical Output and Feedback, OUT-m and FB-j.
6. Enter a value for the timer on the Physical Outputs, if necessary.

User Logical Inputs/Output Configuration

Again using ECP, connect all of the ULIk and ULOk pairs used in the logic.

1 From the Change Settings Menu, select “ULI/ULO Configuration.”

2 From the User Logical I/O Cfg screen, program connections between all of the ULIk and ULOk that are connected in the diagram.

EXAMPLE

This process is best illustrated by an example. Figure 6-6a shows some typical logic which will be implemented using the Prog. Inputs and Outputs.

It is desired that a differential fault detection (87T or 87H) cause a trip output which will be sealed in until the breaker is opened as indicated with a 52a contact. This function will be implemented using the process just described.

Draw the logic with AND and OR gates. Indicate all inputs and outputs. This is shown in Figure 6-6a.

The gates are labeled as Prog. Input or Prog. Output. Gate A has protection inputs 87T and 87H, so it must be an Output gate. Gate B has a physical input from a contact, so it must be an input gate. Gate C controls a physical contact, so it must be an Output gate. See Figure 6-6b.

A FEEDBACK, two CONNECTs, and another Input gate are added according to Figure 6-5. Since there is a direct connection between two Output gates, A and C, it is necessary to add the additional Input gate, D. This is all shown in Figure 6-6c.

Figure 6-7 shows how this information is entered in the Prog. Inputs Table.

Figure 6-8 shows the necessary additions to the Prog. Output Table.

Finally, the ULOs and ULIs are joined by a CONNECT in the User Logical I/O Cfg screen (not shown). All ULOs and ULIs are connected by default.

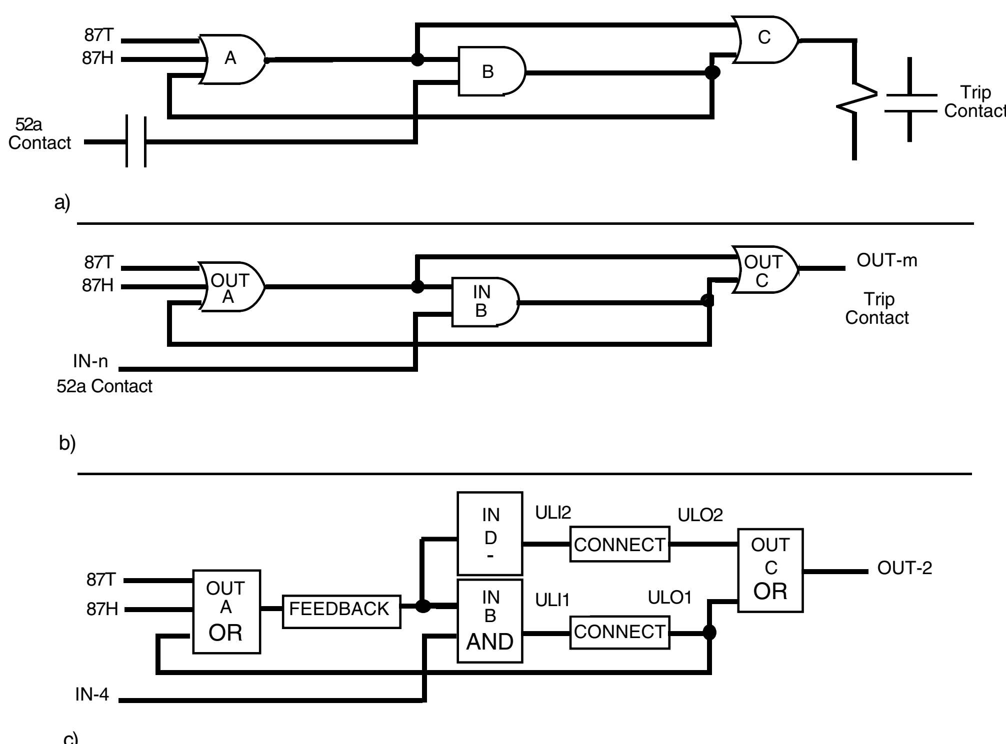


Figure 6-6.   Programmable Logic Example

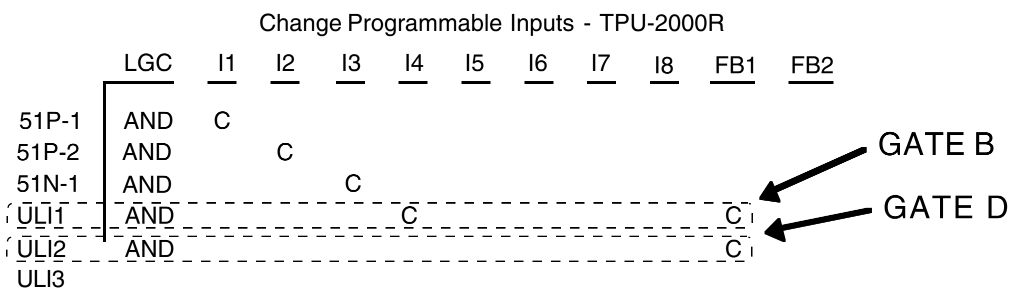


Figure 6-7. Programmable Inputs Screen

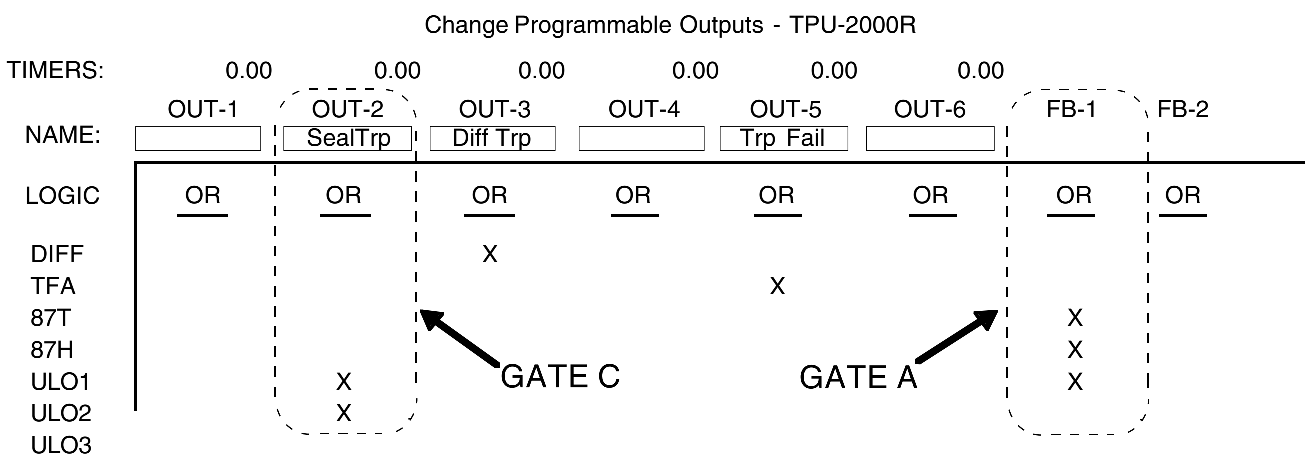


Figure 6-8. Programmable Outputs Screen

Calculation Of Differential Settings for a 2 Winding Relay

Follow these steps to calculate the relay settings. An example is provided at the end of the procedure.

1. Determine the power transformer phase shift between the high voltage and low voltage sides. Assign the high side as winding 1 and the low side as winding 2. Set the Phase Compensation setting equal to the angle by which the winding 1 currents lead the winding 2 currents. Follow the procedure in Section 2 to determine this setting or see Method to Determine Phase Compensation Setting later in this section.

2. Determine the maximum load currents, IH and IL, on the high side and low side of the power transformer.

3. Determine the maximum through-fault currents, IHF and ILF, for both sides of the transformer.

4. Choose the current transformer (CT) ratio in accordance with Step 1 to give approximately 5 A of secondary current at the maximum load current while keeping the maximum external fault current less than 100 amperes secondary. For two winding transformers, the through-fault current is limited by the transformer impedance.

5. Calculate the load currents, IHS and ILS, on the CT secondary sides.

6. Calculate the CT secondary currents flowing into the terminals of the TPU-2000R: IHR=IHS*HSECF; ILR=ILR*LSECF where HSECF and LSECF are the multiplying factors from Table 7-1 that take into account the effect of the external CT connections.

7. Calculate the restraint currents used within the relay after the internal phase compensation is applied:
   IHAR = IHR * HSICF; ILAR = ILR * LSICF where HSICF and LSICF are the multiplying factors for internal compensation from Table 7-1.

 # Table 7-1

Transformer Connection HS	Transformer Connection LS	C T Connection HS	C T Connection LS	Internal Compensation Multiplying Factor HS	Internal Compensation Multiplying Factor LS	External Compensation Multiplying Factor HS	External Compensation Multiplying Factor LS
Wye	Wye	Delta	Delta	1	1	$\sqrt{3}$	$\sqrt{3}$
		Wye	Wye	$\sqrt{3}$	$\sqrt{3}$	1	1
Delta	Delta	Wye	Wye	1	1	1	1
Wye	Delta	Wye	Wye	$\sqrt{3}$	1	1	1
		Delta	Wye	1	1	$\sqrt{3}$	1
Delta	Wye	Wye	Delta	1	1	1	$\sqrt{3}$
		Wye	Wye	1	$\sqrt{3}$	1	1

8. Select the high and low side tap settings by rounding off IHAR and ILAR respectively to the nearest 0.1 ampere. If either value is larger or smaller than the available tap range, then form the ratio of the two values and set the taps in the same ratio.

9. Check that the through-fault currents on the high and low side current transformer secondaries are less than 35 times the selected tap settings (IHFS - 35 x T_H and ILFS - 35 x T_L). This is an internal analog to digital converter limitation.

10. Select the percentage differential characteristic curve. The example shown is for the linear percentage slope. For security, select a slope of 20% to 30% for transformers without load tap changers and 30% to 40% for transformers with load tap changers.

11. Select the minimum operating current between 0.2 and 0.4 per unit. The minimum operate-current is the per-unit difference between the winding 1 and 2 per-unit restraint currents.

12. To block tripping on transformer in-rush current, select the Harmonic Restraint Mode and Percent Harmonic Restraint. The choices are 2nd, 2nd & 5th or All Harmonics and 7.5% to 25% of Fundamental in steps of 2.5%.

13. Select the Unrestrained High Set Instantaneous Differential setting 87H so that it will not trip on transformer in-rush current. If the transformer in-rush current is not known, use 10 times the power transformer self-cooled load current rating.

Use the Harmonic Restraint Record to adjust the Harmonic Restraint Mode, Percent Harmonic Restraint and Unrestrained High Set Instantaneous Differential settings after the transformer has been energized several times.

Settings Calculation Example for the 2 Winding Relay

The following transformer ratings and connections are assumed for this example:

12/16/20 MVA OA/FA/FA,	**Phase shift: High side leads Low side by 30°**
115-kV Delta, 13.8-kV Wye	**8.5% impedance, load tap changer range +/- 10%.**
High side (115-kV Delta)	**Low side (13.8-kV Wye)**

1. Phase angle compensation setting is 30° with the High side connected as Winding 1 and the Low side connected as Winding 2.
2. Maximum load current at 20 MVA

   IH = 20,000/(115 * 1.73) = 100 A **IL = 20,000/(13.8 * 1.73) = 837 A**
3. Maximum through-fault currents assuming an infinite bus:

   IHF = 12,000/(115 * 1.73 * 0.085) **= 709 A**
   ILF= 12,000/(13.8 * 1.73 * 0.085) **= 5907 A**
4. Choose CT Ratios:

   High Side 100/5 = 20

   Low Side 1000/5 = 200

   CT secondary currents at maximum through-fault:

   IHFS = 709/20 = 35.5 **ILFS = 5907/200 = 29.5 A** **<100A**
5. Load Currents on CT secondary side at maximum transformer rating of 20 MVA:

   IHS = 100/20 = 5.0 A **ILS = 837/200 = 4.19 A**
6. Relay currents at maximum load currents:

High-side CT secondary connection	Low-side CT secondary connections	
Wye (HSECF=1)	Delta (LSECF=1.73)	Wye (LSECF=1)
IHR = 5.0 A	ILR = 4.19A * 1.73	ILR = 4.19A * 1.00
	= 7.26 A	**= 4.19A**

7. Apparent relay currents at maximum load currents

High Side	Low Side	
Wye (HSICF=1)	**Delta (LSICF=1)**	**Wye (LSICF=1.73)**
IHAR=5.0A	**ILAR= 7.26A**	**ILAR=4.19 * 1.73=7.26A**

8. Select the high-side 87T-1 and the low-side 87T-2 tap settings:

87T-1 = 5.0 A	**87T-2 = 7.3 A**	**87T-2 = 7.3 A**

9. Check that the through apparent relay fault currents on the high and low side current transformer secondaries are less than 35 times the selected tap settings.

	Delta	Wye
35.5 - 35 * 5 = 175A	**29.5 * 1.73 - 35 * 7.3 = 255.5**	**29.5 * 1.73 - 35 * 7.3 = 255.5**

10. Select a linear percentage slope of 30% for a power transformer with +/- 10% load tap changer.
11. Select a minimum operating current of 0.3 per unit.
12. Select the 2nd harmonic for the Harmonic Restraint Mode and 15% for the percent Harmonic Restraint.
13. Select the Unrestrained High Set Instantaneous Setting 87H:

    High-side relay current at self-cooled rating = 12,000/(115 * 1.73 * 20) = 3.0 A

    Transformer inrush is 10 times self-cooled rating (typically 8 to 10 times)

    87H setting = (3.0 A * 10)/5-A high-side tap setting = 6.0 per-unit operate current

Calculation Of Differential Settings for a 3 Winding Relay

Follow these steps to calculate the relay settings. Look at the example at the end of the procedure.

1. Determine the power transformer phase shift between the high voltage and low voltage sides. Assign the high side as winding 1 and the low side as winding 2. Set the Phase Compensation 1-2 setting equal to the angle by which the winding 1 primary currents lead the winding 2 primary currents. Follow the procedure in Section 2 to determine this setting or see Method to Determine Phase Compensation setting later in this section.
2. Determine the power transformer phase shift between the high voltage and tertiary voltage sides. Assign the tertiary voltage side as winding 3. Set the Phase Compensation 1-3 equal to the angle by which the winding 1 primary currents lead the winding 3 primary currents.
3. Determine the maximum load currents IH, IL and IT for all windings **based on the highest rated winding.**
4. convert the impedances X_{HT}, X_{HL} and X_{TL} to a common base.
5. Assuming an infinite bus, calculate the worst case max 3Ø through fault. This will give IHF, ILF and ITF.
6. Choose the current transformer (CT) ratio to give approximately 5 A of secondary current at the maximum load current for each individual winding.
7. Calculate the secondary maximum through fault currents IHFS, ILFS and ITFS. Be sure that these currents are less than 100 amps secondary.
8. Calculate the secondary load currents **based on the highest rated winding.**
9. Calculate the relay currents IHR, ILR and ITR using the currents from step 8 and the compensation factors from table 7-2.
10. Calculate the tap settings based on the currents in step 9. If all currents in step 9 are less than 9 amps but greater then 2 amps, then set the taps equal to IHR, ILR and ITR rounded off to the nearest 0.1 ampere. If at least one current is greater than 9 amps, then set the tap according to the procedure below:
    a. Find the highest one of IHR, ILR and ITR and set this tap = 9.0
    b. Let us assume ITR is the highest and therefore 87T-3 Tap is set equal to 9.0
    c. 87T-2 Tap = 9.0 x (ILR/ITR) rounded off to the nearest 0.1
    d. 87T-1 Tap = 9.0 x (IHR/ITR) rounded off to the nearest 0.1

Table 7-2

Transformer Connection			CT Connection			Internal Compensation Multiplying Factor		
High	Low	Tertiary	High	Low	Tertiary	High	Low	Tertiary
Delta	Delta	Wye	Wye	Wye	Wye	1	1	√3
Delta	Wye	Delta	Wye	Wye	Wye	1	√3	1
Wye	Delta	Delta	Wye	Wye	Wye	√3	1	1
Wye	Delta	Wye	Wye	Wye	Wye	√3	1	√3
Wye	Wye	Delta	Wye	Wye	Wye	√3	√3	1
Delta	Wye	Wye	Wye	Wye	Wye	1	√3	√3
Delta	Delta	Delta	Wye	Wye	Wye	1	1	1
Wye	Wye	Wye	Wye	Wye	Wye	√3	√3	√3

11. Check that the through fault currents on the high, low and tertiary side CT secondaries are less than 35 times the selected tap settings (IHFS - x 87T-1, ILFS - 35 x 87T-2, and ITFS - 35 x 87T-3).
12. Select the differential characteristic curve. For security, select a slope of 20% to 30% for transformers without load tap changers and 30% to 40% for transformers with load tap changers.
13. Select the minimum operate current between 0.2 and 0.4 per unit. The operate current is the vectorial summation of winding 1, winding 2 and winding 3 per-unit restraint currents.
14. To block tripping on transformer inrush current, select the Harmonic Restraint Mode and Percent Harmonic Restraint. The choices are 2nd, 2nd and 5th or All Harmonics. Selectable from 7.5% to 25% of fundamental in steps of 2.5%
15. Select the Unrestrained High Set Instantaneous Differential setting 87H so that it will not trip on transformer inrush current. If the transformer inrush current is not known, use 10 times the power transformer self-cooled load current rating.

Settings Calculation Example for the 3 Winding Relay

Assume relay has 5A CT inputs.
Transformer Nameplate Data:

161kV Y⏚ /115kV Y⏚ /13.2kV Δ

X_{HT} = 16% on 48 MVA	**High 161Kv = > rated 80 MVA max.**
X_{HL} = 10% on 36 MVA	**Low 115Kv = > rated 60 MVA max.**
X_{TL} = 8% on 12 MVA	**Tertiary 13.2Kv = > rated 20 MVA max.**

1. Calculate max load currents **based on highest rated winding**

   IH = 80MVA/(161kV x $\sqrt{3}$) = <u>287A</u>

   IL = 80MVA/(115kV x $\sqrt{3}$) = <u>402A</u>

   IT = 80MVA/(13.2kV x $\sqrt{3}$) = <u>3,499A</u>

2. Convert impedances to a common base (100MVA)

   X_{HT} = (100MVA/48MVA)(.16) = <u>.33</u> per unit

   X_{HL} = (100MVA/36MVA)(.10) = <u>.28</u> per unit

   X_{TL} = (100MVA/12MVA)(.08) = <u>.67</u> per unit

3. Calculate worse case max 3Φ through fault (assume infinite bus)

   I_{H1} = (1/.33)(100MVA/(161kV x $\sqrt{3}$) = 1,088A
   I_{H2} = (1/.28)(100MVA/(161kV x $\sqrt{3}$) = 1,281A
   IHF = 1,281A

   I_{L1} = (1/.28)(100MVA/(115kV x $\sqrt{3}$) = 1,793A
   I_{L2} = (1/.67)(100MVA/(115kV x $\sqrt{3}$) = 750A
   ILF = 1,793A

   I_{T1} = (1/.33)(100MVA/(13.2kV x $\sqrt{3}$) = 13,254A
   I_{T2} = (1/.67)(100MVA/(13.2kV x $\sqrt{3}$) = 6,528A
   ITF = 13,254A

4. Choose CT Ratios

High	300/5	=	60			
Low	60MVA/(115kV x $\sqrt{3}$)	=	301	choose 300/5	=	60
Tertiary	20MVA/(13.2kV x $\sqrt{3}$)	=	875	choose 1000/5	=	200

5. Calculate secondary max through fault current

   IHFS = 1,281/60 = 21.35 A
   ILFS = 1,793/60 = 29.9 A — OK, all <100 A
   ITFS = 13,254/200 = 66.27A

   Calculate secondary load current (based on 80MVA)

   IHS = 287/60 = 4.78 A
   ILS = 402/60 = 6.7 A
   ITS = 3499/200 = 17.50 A

   Calculate relay current (YYΔ) using compensation factors from Table 7-2

   IHR = 4.78 x $\sqrt{3}$ = 8.28
   ILR = 6.7 x $\sqrt{3}$ = 11.6
   ITR = 17.5 x 1 = 17.5

   User should check to make sure line currents (based on actual winding MVA) are <16A.

6. Select tap settings based on load currents calculated in Step 5

SELECT $87T\text{-}3 = 9.0$

$$87T\text{-}2 = 9.0 \left(\frac{11.6}{17.5}\right) = 6.0$$

$$87T\text{-}1 = 9.0 \left(\frac{8.28}{17.5}\right) = 4.3$$

7. Select 87H setting

$$87H = \left(\frac{48MVA}{161Kv\ (\sqrt{3})(60)} \times 10\right) / 4.3 = 6.7$$

87H = 6.7

8. Check tap settings

High	Low	Tertiary
$(18.1)(\sqrt{3}) < (35)(4.3)$	$(13.95)(\sqrt{3}) < (35)(6.0)$	$(66.27) < (35)(9.0)$

Automatic Tap Calculation

The TPU-2000R has an automated transformer tap setting calculation screen (see Figures 7-1). After you enter information at the Calculate Tap Settings screen, ECP calculates the following values:

- 87T-1, 87T-2 and 87T-3 (if applicable), and 87H Tap settings
- Maximum transformer load currents IH, IL and IT (if applicable)
- Maximum primary transformer through-fault current on all windings (IHF, ILF and ITF if applicable)
- Maximum CT load on all windings (IHS, ILS and ITS if applicable)
- Maximum secondary through fault current on all windings (IHFS, ILFS and ITFS if applicable)
- Apparent Relay Currents on all windings of transformers (IHAR, ILAR and ITAR if applicable)

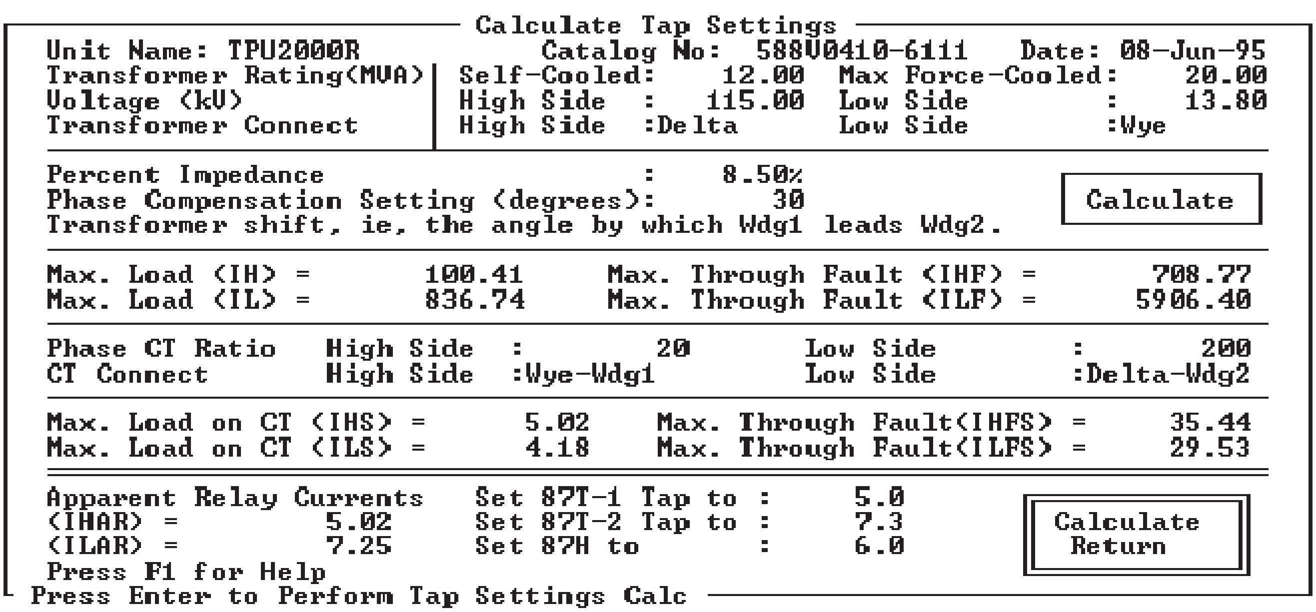
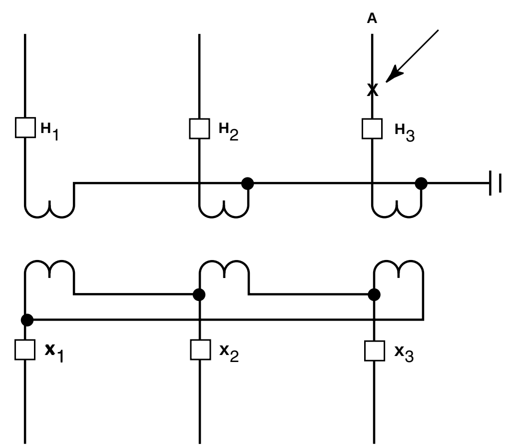


Figure 7-1. Calculate Tap Settings Screen (2 Winding Relay Shown)

Method for Determining Phase Angle Compensation Setting

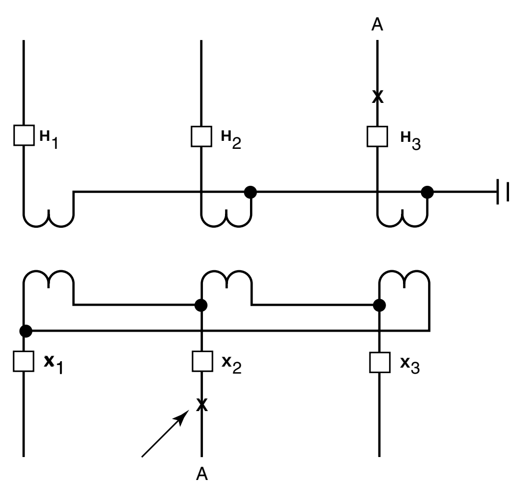
Step 1

Look at the sample transformer nameplate drawing below. Looking ONLY at the high side of the transformer, determine which Power Transformer winding (H1, H2 or H3) will have the CT's wired to the IA-1 coil in the relay. Mark this winding.



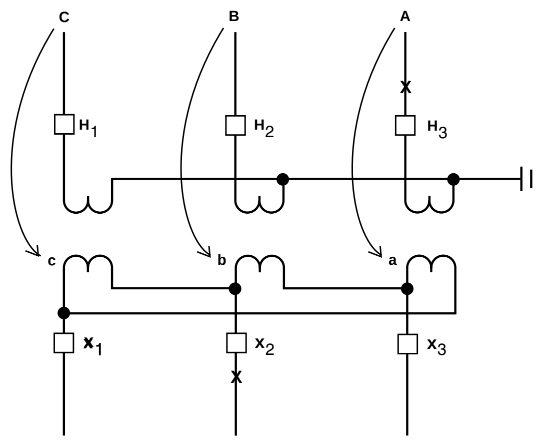
Step 2

Looking ONLY at the low side of the transformer, determine which Power Transformer winding (X1, X2 or X3) will have the CT's wired to the IA-2 coil in the relay. Mark this winding.



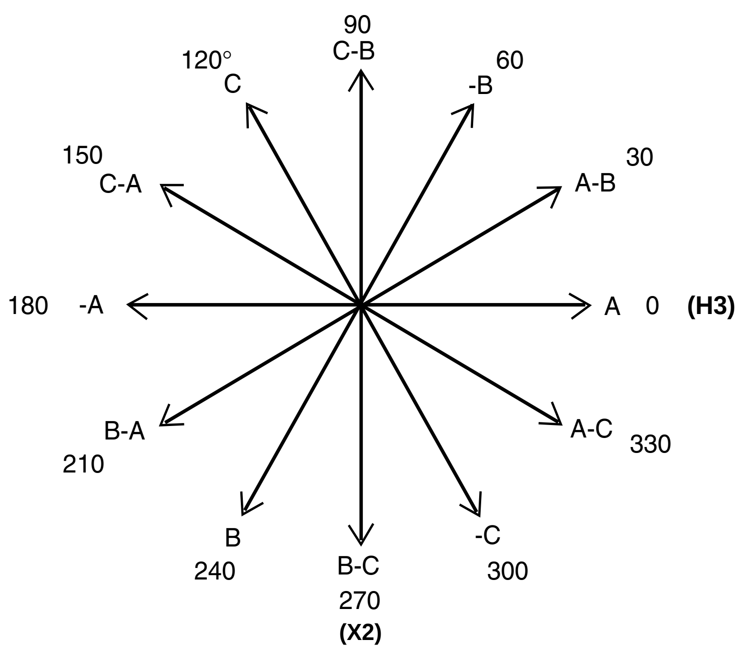
Step 3

Looking ONLY at the high side of the transfomer, determine what phases are connected to what windings. In our example H1 = C phase, H2 = B phase, H3 = A phase. **At this point, IGNORE the low side transformer connections and temporarily transfer the high side connections to the low side windings.**



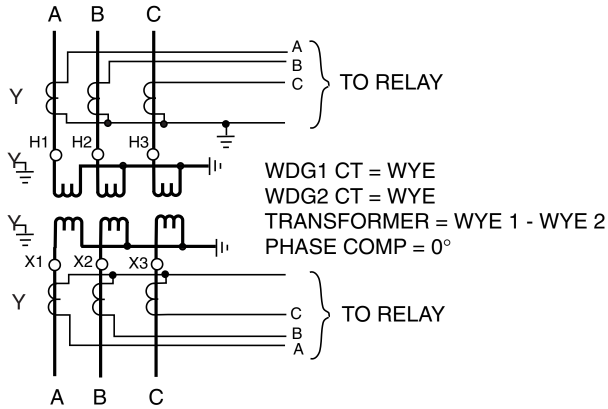
Step 4

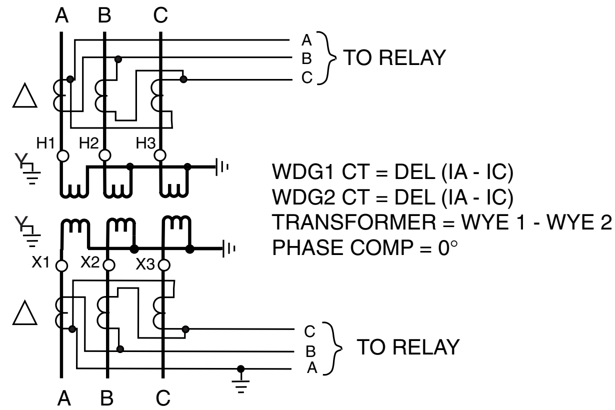
We now have enough information to determine the Phase Compensation Setting. This is the setting by which the high side **marked** winding <u>leads</u> the low side **marked** winding. Assuming a standard ABC phase rotation, where B lags A by 120° use the convention below to determine the setting.

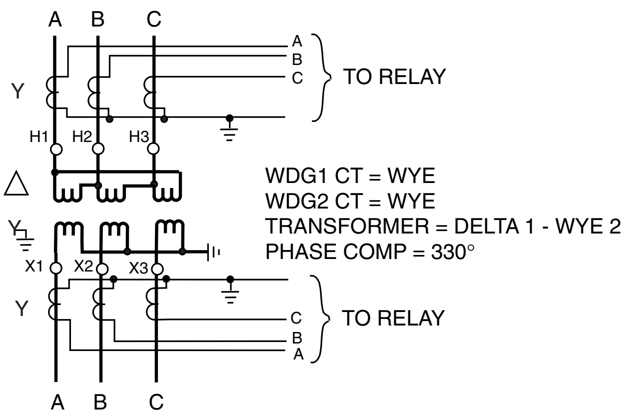


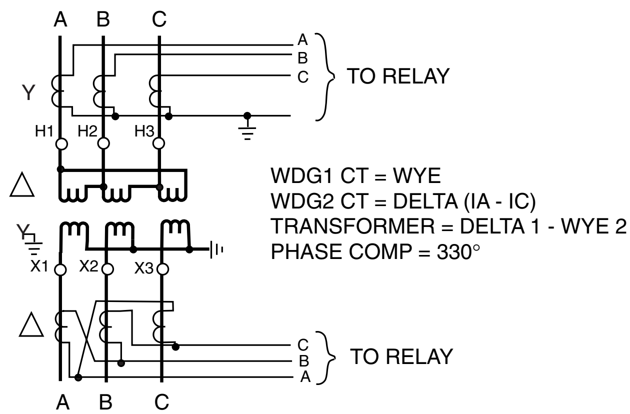
H3 Leads X2 by 90°. Therefore, the Phase Compensation Setting = 90°. Various transformer configurations and corresponding Phase Compensation Settings are show on the following pages.

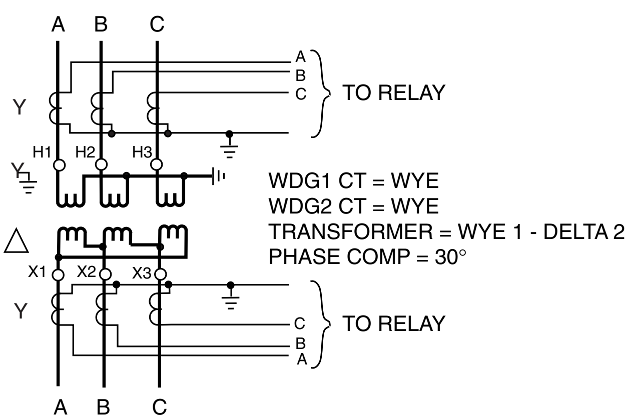
NOTE: Assume Phase Rotation is "ABC" unless otherwise noted.

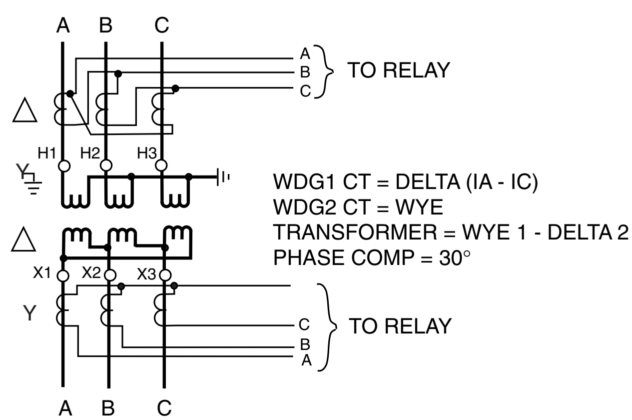


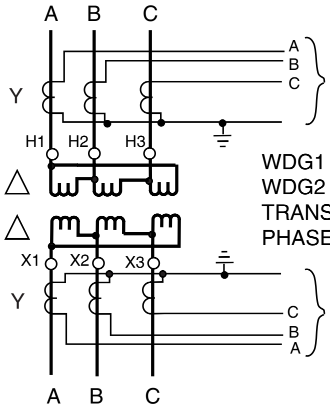




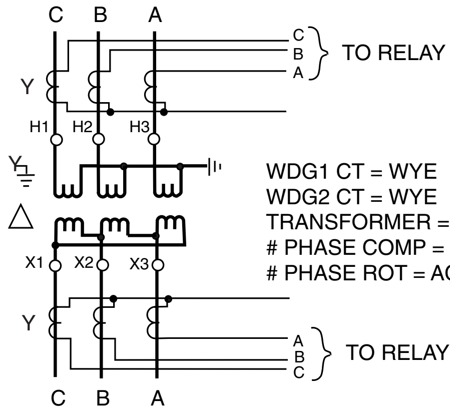




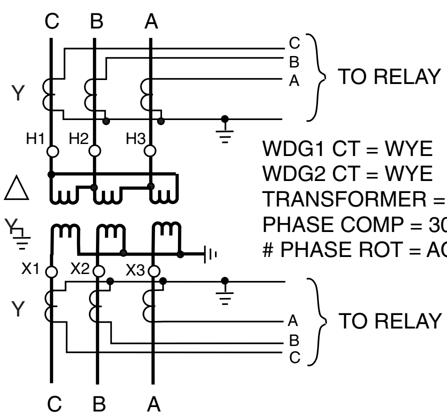




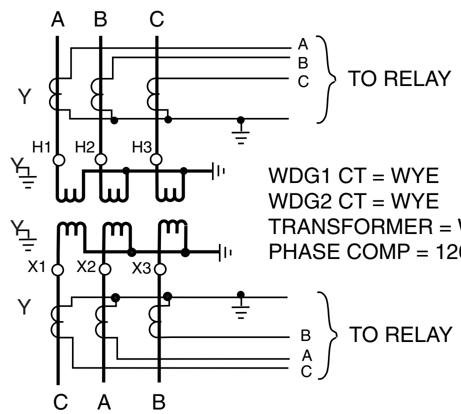
WDG1 CT = WYE
WDG2 CT = WYE
TRANSFORMER = DELTA 1 – DELTA 2
PHASE COMP = 0°



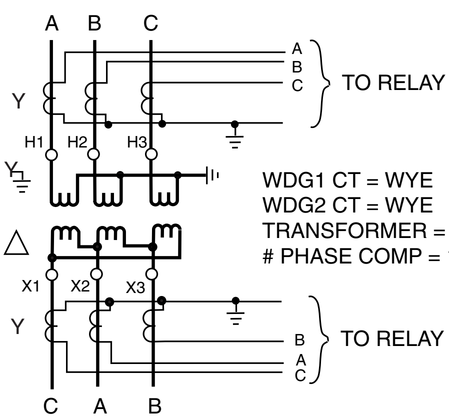
WDG1 CT = WYE
WDG2 CT = WYE
TRANSFORMER = WYE 1 – DELTA 2
# PHASE COMP = 30°
# PHASE ROT = ACB



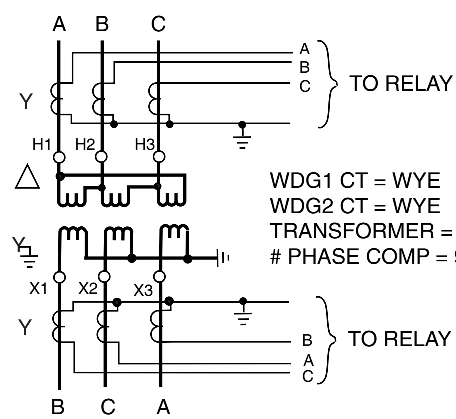
WDG1 CT = WYE
WDG2 CT = WYE
TRANSFORMER = DELTA 1 – WYE 2
PHASE COMP = 30°
PHASE ROT = ACB



WDG1 CT = WYE
WDG2 CT = WYE
TRANSFORMER = WYE 1 – WYE 2
PHASE COMP = 120°



WDG1 CT = WYE
WDG2 CT = WYE
TRANSFORMER = WYE 1 – DELTA 2
# PHASE COMP = 120°



WDG1 CT = WYE
WDG2 CT = WYE
TRANSFORMER = DELTA 1 – WYE 2
# PHASE COMP = 90°

Records Menu

The TPU-2000R provides fault and operations records.

Differential Fault Record

The differential fault record contains the last 32 faults. The fault record displays one fault at a time and includes the following information (see Figure 8-1):

```
Records Menu
  Differential Fault Record
  Through Fault Record
  Harmonic Restraint Record
  Operations Record
  Operations Summary
  Unreported Records
  Return
Differential Fault Records
```

- Record number
- Differential fault number
- Enabled settings table
- Tripping element
- Date and time
- Fault clearing time in seconds
- Winding 1, 2 and 3 (if applicable) tap settings
- Operate currents for all three phases
- 2nd, 5th and total (2nd through 11th) harmonic current content in percent of fundamental for all three phases for all windings
- Three-phase restraint current for all windings (magnitude and angle)
- Windings 1, 2 and 3 (if applicable) phase and neutral currents (magnitude and angle)
- Winding 1, 2 and 3 positive, negative and zero sequence currents (magnitude and angle)

After a differential trip, the MMI continuously displays the fault currents (magnitude only) for all windings until the targets are reset. Save the differential fault record as a file by using TPUECP.EXE.

Differential Record – TPU2000R OC TST

Differential Record : 1   Differential Number: 120
Active Set : Prim   Fault Element : 87H
Date : 08-Jun-95   Clear Time : 0.066
Time : 11:22:16.81   Wdg-1 Tap: 3.00 Wdg-2 Tap: 6.00

HARMONIC	WDG-1	WDG-2
2nd-A	58.5%	10.0%
5th-A	4.0%	7.5%
All-A	93.5%	24.0%
2nd-B	48.5%	19.5%
5th-B	2.0%	5.0%
All-B	91.5%	42.0%
2nd-C	63.0%	37.0%
5th-C	1.0%	10.0%
All-C	93.0%	63.0%

I Operate A : 5.42
I Operate B : 14.55
I Operate C : 13.23

RESTRAINT CURRENTS	WDG-1		WDG-2	
	MAGNITUDE	ANGLE	MAGNITUDE	ANGLE
Ires-A	4.87	0	1.46	284
Ires-B	13.95	236	1.61	165
Ires-C	11.89	73	1.57	40

Use Page Down key to view current magnitude and angle   Next Record   Latest Record   Return

Show Next Record

Differential Record – TPU2000R

All-B	0.0%	28.5%					
2nd-C	0.0%	39.5%	Ires-A	3.52	0	1.47	180
5th-C	0.0%	12.5%	Ires-B	0.01	313	2.83	1
All-C	0.0%	66.0%	Ires-C	0.00	16	1.37	183

Use Page Down key to view current magnitude and angle   Next Record   Latest Record   Return

LINE CURRENTS	WDG-1		WDG-2		
	MAGNITUDE	ANGLE		MAGNITUDE	ANGLE
IA	1392	0	IA	1857	25
IB	1	36	IB	1341	144
IC	0	171	IC	4372	12
IN/IG	1	351	IN/IG	5461	27
I0	465	0	I0	1823	27
I1	464	0	I1	1573	273
I2	464	0	I2	1526	90

Show Next Record

Figure 8-1. Differential Fault Record (2 Winding Relay Shown)

Through-Fault Record

The through-fault record contains the last 32 through-faults. A through-fault is stored on any overcurrent trip output or whenever the Disturbance-2 pickup setting is exceeded. The fault record displays one fault at a time and includes the following information:

```
Through Fault Record - TPU2000R OC TST
Through Fault Record :   1                  Fault Number : 596
Active Set           : Prim                 Relay Time   :        0.004
Date: 08-Jun-95  Time: 11:22:16.87          Clear Time   :       0.037
Fault Element        : 50P-2

IA-1:    407  IA-1 Angle:   0               IA-2:    518  IA-2 Angle:  72
IB-1:    489  IB-1 Angle: 270               IB-2:    460  IB-2 Angle: 305
IC-1:    626  IC-1 Angle: 130               IC-2:    440  IC-2 Angle: 195
IN-1:     20  IN-1 Angle: 277               IG-2:      0  IG-2 Angle: 200
I0-1:      6  I0-1 Angle: 292               I0-2:      0  I0-2 Angle: 200
I1-1:    497  I1-1 Angle:  14               I1-2:    471  I1-2 Angle:  71
I2-1:    139  I2-1 Angle: 237               I2-2:     48  I2-2 Angle:  84

                                              Next Record
                                             Latest Record
                                                Return
Show Next Record
```

Figure 8-2. Through-fault Record (2 Winding Relay)

- Record number
- Through-fault number
- Enabled settings table
- Date and time
- Tripping element
- Relay operate time for overcurrent trips (the time from the time of pickup to the time of the trip)
- Fault clearing time (the time from the time of the trip to the time of the cleared fault)
- Phase and neutral currents (magnitude and angle) for all windings
- Positive and negative and zero sequence currents (magnitude and angle) for all windings

Save the through-fault record as a file by using TPUECP.EXE.

Harmonic Restraint Record

The harmonic restraint record contains the last 32 harmonic restraint operations. The harmonic restraint record displays one harmonic restraint operation at a time and includes the following information:

- Record number
- Harmonic restraint number
- Enabled settings table
- Restraint mode setting
- Date and time
- Restraint duration in seconds
- Tap settings for all windings
- Operate currents for all three phases
- 2nd, 5th and total (2nd through 11th) harmonic current content in percent of fundamental for all three phases for all windings at the time that the harmonic restraint was started and stopped
- Three-phase restraint current for all windings (magnitude and angle) when the harmonic restraint was started and stopped.

Figure 8-3. Harmonic Record (2 Winding Relay)

```
Harmonic Restraint Record - TPU2000R
Restraint Record :   1              Restraint  Number   : 103
Active Set       : Prim             Restraining Mode    : 2nd & 5th Harm
Restraint Date   : 08-Jun-95        Restraint Duration  :     0.020
Restraint Time   : 11:22:16.86      Wdg-1 Tap:   3.00  Wdg-2 Tap:   6.00

         START        |    STOP       ||          START         |    STOP
HARMONIC| WDG-1| WDG-2 | WDG-1 | WDG-2 || Iop-A     |    2.11    |    0.27
2nd-A   | 35.0%| 26.0% | 86.5% |107.5% || Iop-B     |    1.21    |    0.63
5th-A   | 13.5%|  2.5% | 27.0% | 30.0% || Iop-C     |    2.46    |    0.41
All-A   |125.5%| 38.5% |127.5% |127.5% ||           | MAG | ANGLE| MAG | ANGLE
2nd-B   | 22.0%| 32.0% | 89.5% | 66.5% ||           |     |      |     |
5th-B   |  5.5%|  1.0% | 29.5% | 24.0% ||Ires-A WD-1| 1.18|     0| 0.38|     0
All-B   | 44.0%| 49.5% |127.5% |127.5% ||Ires-B WD-1| 1.44|   288| 0.40|   193
2nd-C   | 22.5%| 45.0% | 70.0% | 89.5% ||Ires-C WD-1| 2.07|   140| 0.09|    88
5th-C   |  5.5%|  2.0% | 56.5% | 31.0% ||Ires-A WD-2| 1.38|   290| 0.19|   222
All-C   | 61.5%| 69.0% |127.5% |127.5% ||Ires-B WD-2| 1.16|   161| 0.27|   157
                                       ||Ires-C WD-2| 1.11|    56| 0.39|     3
                                   Next Record   Latest Record   Return
Show Next Record
```

Save the harmonic restraint record as a file by using TPUECP.EXE.

Operations Record

The operations record contains the last 128 operations. The operations record includes the:

- Record number
- Operation number
- Description of the operation
- Date and time of the operation

Operations include differential and overcurrent trips, activation of binary inputs and output contacts and all alarm conditions. Save the operations record as a file by using TPUECP.EXE. Refer to Table 4-1 to decode the value after an "Editor Access" or a "self check" message is logged.

Operations Records - TPU2000R

Rec	No	Type	Date	Time	Value
1	57	50N-1 Trip	27-Jun-95	08:42:02.29	0
2	56	50P-1 Trip	27-Jun-95	08:42:02.29	0
3	55	Fault Clear Failed	27-Jun-95	08:41:43.03	0
4	54	87T Trip	27-Jun-95	08:41:42.73	0
5	53	Fault Clear Failed	27-Jun-95	08:41:28.49	0
6	52	87T Trip	27-Jun-95	08:41:28.19	0
7	51	Fault Cleared	26-Jun-95	15:44:13.19	0
8	50	Fault Clear Failed	26-Jun-95	15:44:12.55	0
9	49	87T Trip	26-Jun-95	15:44:12.25	0
10	48	50G-2 Trip	26-Jun-95	15:44:11.43	0
11	47	50P-2 Trip	26-Jun-95	15:44:11.43	0
12	46	50P-1 Trip	26-Jun-95	15:31:33.40	0
13	45	Editor Access	26-Jun-95	09:50:51.66	273
14	44	Editor Access	26-Jun-95	09:48:56.88	273
15	43	Control Power Fail	23-Jun-95	15:51:54.01	0
16	42	Fault Clear Failed	23-Jun-95	14:56:50.67	0
17	41	87T Trip	23-Jun-95	14:56:50.36	0
18	40	Fault Cleared	23-Jun-95	14:56:41.45	0

Next Latest Return

Show Next Page

Table 8-1. Operations Record Log Definitions

87T Trip 87H Trip 51P-1 Trip 51N-1 Trip 50P-1 Trip 50N-1Trip 150P-1 Trip 150N-1 Trip 46-1 Trip 51P-2 Trip 51G-2 Trip 150P-2 Trip 150G-2 Trip 46-2 Trip #51P-3 Trip #51N-3 Trip #50P-3 Trip #50N-3 Trip #150P-3 Trip #150N-3 Trip #46-3 Trip #51G Trip #50G Trip #150G Trip	Element picked up and timed out. It is possible that this is not the actual tripping element.
Thru Flt	Logical Output "THRUFA" went high.
Fault Clear Failed	Fault failed to clear by relay.
Fault Cleared	Fault cleared by relay.

Table 8-1. Operations Record Log Definitions (continued)

Harmonic Restraint	Operate current above trip level, but relay restrainted.
Manual Trip	Breaker tripped externally to the relay.
87T Enabled 87H Enabled 51P-1 Enabled 51P-2 Enabled #51P-3 Enabled 51N-1 Enabled 51G-2 Enabled #51N-3 Enabled 50P-1 Enabled 50P-2 Enabled #50P-3 Enabled 50N-1 Enabled 50G-2 Enabled #50G-3 Enabled 150P-1 Enabled 150P-2 Enabled #150P-3 Enabled 150N-1 Enabled 150G-2 Enabled #150N-3 Enabled 46-1 Enabled 46-2 Enabled #46-3 Enabled #51G Enabled #50G Enabled #150G Enabled	Programmable Input was asserted and setting is active in the settings table.
Event Cap1 Init Event Cap2 Init	Indicates that Programmable Input "ECI1" or "ECI2" was asserted and event record logged.
Wave Cap Init	Programmable Input 'WCI' asserted and wave form capture taken.
SPR Input Closed	"SPR" Programmable Input asserted.
TCM Input closed	"TCM" Programmable Input asserted.
Primary Set Active	Primary settings enabled.
Alt1 Set Active	Alternate 1 settings enabled.
Alt2 Set Active	Alternate 2 settings enabled.

#Denotes 3 Winding Relay only

Table 8-1. Operations Record Log Definitions (continued)

Thru Flt Cntr Alm Thru Flt kASum Alm Thru Flt cycle alm OC Trip Cntr alarm Diff Trip Cntr alm Phase Demand Alarm Neutral Demand Alm Load Current alarm High PF Alarm Low PF Alarm kVAR Demand Alarm Pos. kVAR Alarm Neg. kVAR Alarm Pos. Watt Alarm 1 Pos. Watt Alarm 2 #Pos. Watt Alarm 3	Indicates that the alarm has exceeded its threshold setting.
Trip Coil Failure	Logical Input "TCM" indicated a trip coil failure.
High Level Detection Alarm, Wdg 1	HLDA-1 Logical Output asserted.
Low Level Detection Alarm, Wdg 1	LLDA-1 Logical Output asserted.
High Level Detection Alarm, Wdg 2	HLDA-2 Logical Output asserted.
Low Level Detection Alarm, Wdg 2	LLDA-2 Logical Output asserted.
High Level Detection Alarm, Wdg 3	HLDA-3 Logical Output asserted.
Low Level Detection Alarm, Wdg 3	LLDA-3 Logical Output asserted.
Self Test Failed	Internal System failure. Refer to Table 4-1 to decode value.
Control Power Fail	Loss of DC supply.
Editor Access	Indicates setting change has been made. Refer to Table 4-1 to decode value.
87T Disabled 87H Disabled 51P-1 Disabled 51P-2 Disabled #51P-3 Disabled 51N-1 Disabled 51G-2 Disabled #51N-3 Disabled 50P-1 Disabled 50P-2 Disabled #50P-3 Disabled 50N-1 Disabled 50G-2 Disabled #50N-3 Disabled 150P-1 Disabled	Indicates that the associated Programmable Input was de-asserted.

#Denotes 3 Winding Relay only

Table 8-1. Operations Record Log Definitions (continued)

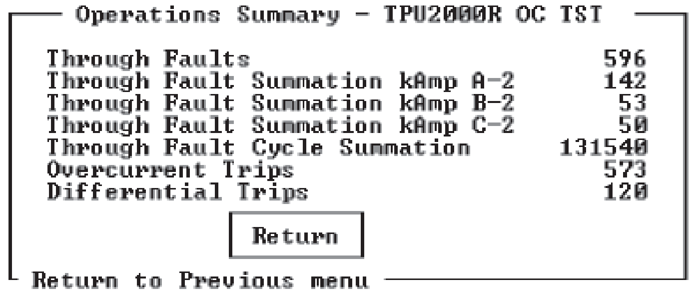
150P-2 Disabled #150P-3 Disabled 150N-1 Disabled 150G-2 Disabled #150N-3 Disabled 46-1 Disabled 46-2 Disabled #46-3 Disabled #51G Disabled #50G Disabled #150G Disabled	Indicates that the associated Programmable Input was de-asserted.
Event Cap1 Reset Event Cap2 Reset	Programmable Input "ECI1" or "ECI2" was de-asserted.
Wave Cap Reset	Indicates that Programmable Input "WCI" was de-asserted.
Trip Input Opened	
SPR Input Opened	
TCM Input Opened ULI1 Input Closed ULI1 Input Opened ULI2 Input Closed ULI2 Input Opened ULI3 Input Closed ULI3 Input Opened ULI4 Input Closed ULI4 Input Opened ULI5 Input Closed ULI5 Input Opened ULI6 Input Closed ULI6 Input Opened ULI7 Input Closed ULI7 Input Opened ULI8 Input Closed ULI8 Input Opened ULI9 Input Closed ULI9 Input Opened	Input closed indicates that the ULI transitioned from a logical 0 to a logical 1. Input opened indicates that the ULI transitiioned from a logical 1 to a logical 0.
CRI Input Closed	CRI transitioned from logical 0 to Logical 1
CRI Input Opened	CRI transitioned from logical 1 to Logical 0

#Denotes 3 Winding Relay only

Operations Summary

The operations summary includes the:

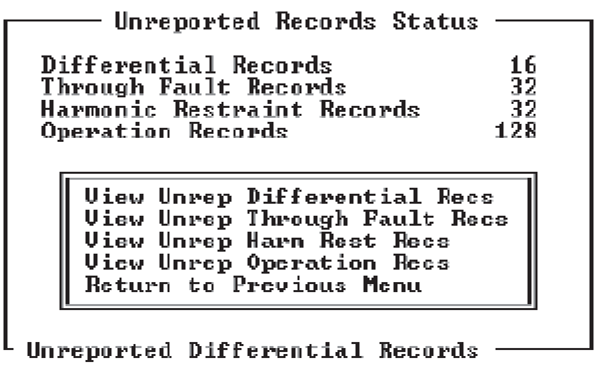
- Number of through-faults
- Summation of through-fault current on a per-phase basis in kiloamperes (thousand symmetrical amperes)
- Number of overcurrent trips
- Number of differential trips



(2 Winding Relay shown)

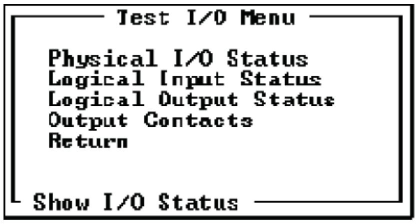
Unreported Records

When a SCADA application polls a relay, it sends the fault and operations information to the appropriate Unreported Record. Records remain in the Unreported Record until either SCADA downloads the information or you physically view the Unreported Records screen. When SCADA downloads the information, that entire Unreported Record file is cleared, the record counter on the Unreported Records Status screen drops to 0, and access to that Unreported Records file is denied until more information is reported. When you view a screen of Unreported Records, the record counter decreases by the number of records that can fit onto your screen. For example, if your computer screen can show 15 records, the record counter decreases by 15 when you exit the Unreported Records screen.



The Unreported Records help by showing the faults and operations records that have occurred since the last time SCADA downloaded or you viewed the Unreported Records. The Fault Summary, Fault Record, Operations Summary and Operations Record do not identify which records have been reported and which remain in the Unreported Records.

Test Menu



The Test menu displays options for viewing the status of input and output contacts.

Physical I/O Status

The Physical I/O Status screen displays the open/close status of all contact inputs and the energized/de-energized status of all output relays. Use this display to confirm continuity through each optically isolated contact input for both the opened (no voltage applied) and closed (voltage applied) states. Also use this display to confirm the status of each output relay.

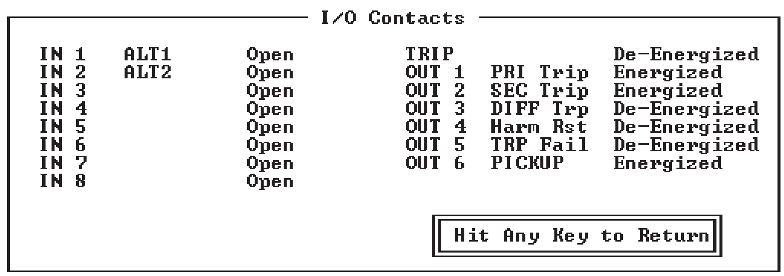


Figure 9-1. I/O Contacts

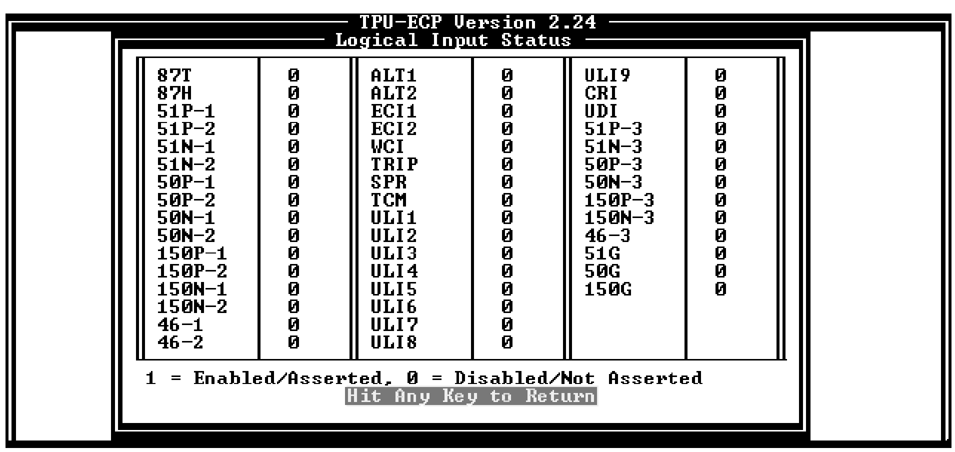
Logical Input/Output Status

Both the logical input and output status displays are available only through the External Communications Program (ECP). The status of the logical input and output is shown in real time.

With these screens you can verify that the logic you entered in the mapping screens is working properly without physically looking at the contacts.

Logical Input Status

The logical input status shows which functions are enabled (asserted) and disabled (not asserted) based on the contact input logic. Use this screen to confirm whether or not the input logic is correct and provides the desired results. The 87T, 87H, 51P, 50P, 150P, 51N, 51G, 50N, 50G, 150N, 150G, 46 and TCM input functions remain enabled (asserted) whether or not they are assigned to contact inputs in the Programmable Input Logic Map. You must assign the remaining input functions to contact inputs for the functions to be enabled (asserted).


TPU-ECP Version 2.24
Logical Input Status

87T	0	ALT1	0	ULI9	0
87H	0	ALT2	0	CRI	0
51P-1	0	ECI1	0	UDI	0
51P-2	0	ECI2	0	51P-3	0
51N-1	0	WCI	0	51N-3	0
51N-2	0	TRIP	0	50P-3	0
50P-1	0	SPR	0	50N-3	0
50P-2	0	TCM	0	150P-3	0
50N-1	0	ULI1	0	150N-3	0
50N-2	0	ULI2	0	46-3	0
150P-1	0	ULI3	0	51G	0
150P-2	0	ULI4	0	50G	0
150N-1	0	ULI5	0	150G	0
150N-2	0	ULI6	0		
46-1	0	ULI7	0		
46-2	0	ULI8	0		

1 = Enabled/Asserted, 0 = Disabled/Not Asserted
Hit Any Key to Return

Figure 9-2. Logical Input Status (3 Winding Relay shown)

Logical Output Status

The logical output status shows which output functions are energized and de-energized. Use this screen to confirm whether or not the functions are programmed correctly in the Primary, Alternate 1, Alternate 2, Programmable Inputs and Alarm Settings tables. Also use it to check that the settings provide the desired results.

Logical Output Status

DIFF	0	51G-2	0	50G-2D	0	DTC	0	150P-1*	0	UL05	0	NVArA	0
ALARM	1	50N-1	0	150P-1D	0	OCTC	0	50P-2*	0	UL06	0	PWatt1	0
87T	0	150N-1	0	150P-2D	0	PDA	0	150P-2*	0	UL07	0	PWatt2	0
87H	0	50G-2	0	150N-1D	0	NDA	0	51N-1*	0	UL08	0		
2HROA	0	150G-2	0	150G-2D	0	PRIM	1	51G-2*	0	UL09	0		
5HROA	0	46-1	0	46-1D	0	ALT1	0	50N-1*	0	LOAD A	0		
AHROA	0	46-2	0	46-2D	0	ALT2	0	150N-1*	0	OCA-1	1		
TCFA	1	87T-D	0	PATA	0	STCA	0	50G-2*	0	OCA-2	1		
TFA	0	87H-D	0	PBTA	0	87T*	0	150G-2*	0	HLDA-1	0		
51P-1	1	51P-1D	0	PCTA	0	87H*	0	46-1*	0	LLDA-1	0		
51P-2	1	51P-2D	0	PUA	1	2HROA*	0	46-2*	0	HLDA-2	0		
50P-1	0	51N-1D	0	63	0	5HROA*	0	63*	0	LLDA-2	0		
150P-1	0	51G-2D	0	THRUFA	0	AHROA*	0	UL01	0	HPFA	0		
50P-2	1	50P-1D	0	TFCA	0	51P-1*	0	UL02	0	LPFA	0		
150P-2	0	50P-2D	0	TFKA	0	51P-2*	0	UL03	0	VarDA	0		
51N-1	0	50N-1D	0	TFSCA	0	50P-1*	0	UL04	0	PVArA	0		

1 = Energized, 0 = Not Energized   Hit Any Key to Return
* = Alarms are sealed in until cleared

Figure 9-3a. Logical Output Status (2 Winding Relay)

Logical Output Status

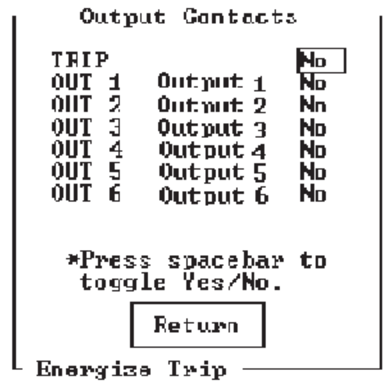
DIFF	0	50G-2	0	46-2D	0	87H*	0	UL01	0	PVArA	0	46-3D
ALARM	0	150G-2	0	PATA	0	2HROA*	0	UL02	0	NVArA	0	51G-D
87T	0	46-1	0	PBTA	0	5HROA*	0	UL03	0	Watt1	0	50G-D
87H	0	46-2	0	PCTA	0	AHROA*	0	UL04	0	Watt2	0	150G-D
2HROA	0	87T-D	0	PUA	0	51P-1*	0	UL05	0	51P-3	0	51P-3*
5HROA	0	87H-D	0	63	0	51P-2*	0	UL06	0	50P-3	0	50P-3*
AHROA	0	51P-1D	0	THRUFA	0	50P-1*	0	UL07	0	150P-3	0	150P-3*
TCFA	0	51P-2D	0	TFCA	0	150P-1*	0	UL08	0	51N-3	0	51N-3*
TFA	0	51N-1D	0	TFKA	0	50P-2*	0	UL09	0	50N-3	0	50N-3*
51P-1	0	51G-2D	0	TFSCA	0	150P-2*	0	LOAD A	0	150N-3	0	150N-3*
51P-2	0	50P-1D	0	DTC	0	51N-1*	0	OCA-1	0	46-3	0	46-3*
50P-1	0	50P-2D	0	OCTC	0	51G-2*	0	OCA-2	0	51G	0	51G*
150P-1	0	50N-1D	0	PDA	0	50N-1*	0	HLDA-1	0	50G	0	50G*
50P-2	0	50G-2D	0	NDA	0	150N-1*	0	LLDA-1	0	150G	0	150G*
150P-2	0	150P-1D	0	PRIM	0	50G-2*	0	HLDA-2	0	51P-3D	0	TFKA-3
51N-1	0	150P-2D	0	ALT1	0	150G-2*	0	LLDA-2	0	50P-3D	0	HLDA-3
51G-2	0	150N-1D	0	ALT2	0	46-1*	0	HPFA	0	150P-3D	0	LLDA-3
50N-1	0	150G-2D	0	STCA	0	46-2*	0	LPFA	0	51N-3D	0	OCA-3
150N-1	0	46-1D	0	87T*	0	63*	0	VarDA	0	50N-3D	0	Watt3
										150N-3D	0	OCG

1 = Energized, 0 = Not Energized   Hit Any Key to Return
* = Alarms are sealed in until cleared

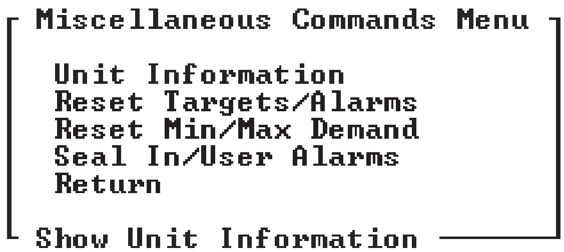
Figure 9-3b. Logical Output Status (3 Winding Relay)

Output Contacts (Password Protected)

By using the output contacts option, you can activate all permanently programmed and user-programmed output contacts via the MMI or the ECP. The output contacts are activated for a period of time equal to the Trip Failure Time setting.



Miscellaneous Commands Menu



The Miscellaneous Commands menu lets you:

- View information about the TPU-2000R unit (for example, catalog number, firmware version, etc.).
- Reset targets and alarms.
- Reset minimum and maximum demand values.
- Reset Seal In alarms.
- Set or reset alarms for user-programmable logic functions.

When you select Seal In/User Alarms from the Miscellaneous Commands Menu, a screen appears showing all the Seal In and user-programmed alarms. On this screen you can remotely set (user-programmed logic functions only) or reset the programmed output state of each alarm contact.

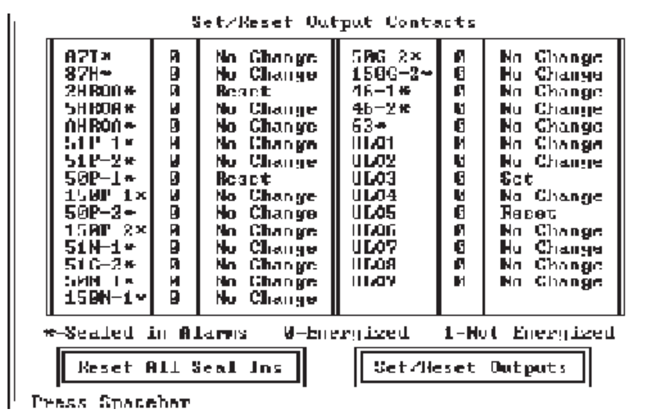


Figure 9-4. Set/Reset Output Contact (2 winding relay shown)

Operations Menu

The Operations Menu allows for quick and easy testing of user logic. The user can operate the trip contact, force physical inputs and outputs, force sealed-in outputs high or low, and force logical inputs. Figure 9-6 on the following page shows an example of forcing logical inputs.

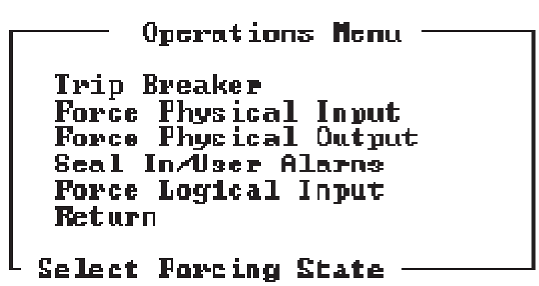


Figure 9-5. Operations Menu

Please note, when any logic is in a “forced state,” the green normal LED will blink. See the example below:

Forced Logical Inputs - TPU2000

87T	87T	1	Normal	ALT1	ALT1	0	Normal
87H	87H	1	Normal	ALT2	ALT2	0	Normal
51P-1	51P-1	1	Normal	ECI1	ECI1	0	Normal
51P-2	51P-2	1	Normal	ECI2	ECI2	0	Normal
51N-1	51N-1	1	Normal	WCI	WCI	0	Normal
51G-2	51G-2	1	Normal	TRIP	TRIP	0	Normal
50P-1	50P-1	1	Normal	SPR	SPR	0	Normal
50P-2	50P-2	1	Normal	TCM	TCM	1	Normal
50N-1	50N-1	1	Normal	ULI1	ULI1:	1F	Closed
50G-2	50G-2	1	Normal	ULI2	ULI2:	0	Normal
150P-1	150P-1	1	Normal	ULI3	ULI3:	0	Normal
150P-2	150P-2	1	Normal	ULI4	ULI4:	0	Normal
150N-1	150N-1	1	Normal	ULI5	ULI5:	0	Normal
150G-2	150G-2	1	Normal	ULI6	ULI6:	0	Normal
46-1	46-1	1	Normal	ULI7	ULI7:	0	Normal
46-2	46-2	1	Normal	ULI8	ULI8:	0	Normal

1 = Enabled/Asserted
0 = Disabled/Not Asserted
F = Forced

Send Command
Refresh Screen
Return to Menu

Figure 9-6. Forced Logical Input

The “1F” next to ULI1 indicates that ULI1 is high and in the forced state. All forced I/O should be set to normal after testing is completed.

Optional Features

In addition to the protection functions, the TPU-2000R has load profile, oscillographic waveform capture and user-programmable curve optional features.

Load Profile

An optional load profile feature records per-phase demand kilowatts, demand kiloVARs and line-to-ground voltages when the unit is equipped with the optional VT inputs. If the unit is not equipped with the option VT inputs, the load profile feature records per-phase currents. You can select a 5-, 15-, 30- or 60-minute time interval (Demand Meter Constant) for which the load profile record then contains 13.3, 40, 80 or 160 days of information, respectively (default is 15 minutes and 40 days). The load profile feature requires Wye-connected VTs to accurately measure per-phase kilowatts and kiloVARs for unbalanced loads (Figure 10-1a). For Delta-connected VTs, the load profile feature records three-phase kilowatts and kiloVARs, per-phase and ground demand currents and line-to-line voltages (Figure 10-1b). Load profile data can be retrieved only through the External Communications Program which stores the load profile and its header in a comma-delimited ASCII file (default is ***filename.dla***). View this file by using any text editor program (word processor or spreadsheet) or by using the following DOS command: ***Type [name of file].dla|more***. Use the pipe character (|) between "dla" and "more." Sample load profile data is shown below. The graph in Figure 10-2 is a sample of the type of load profile data analysis that can be performed.

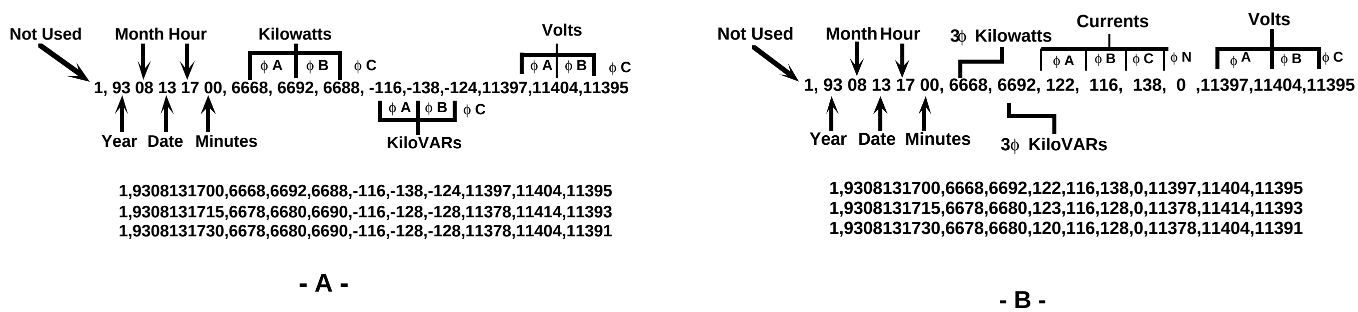


Figure 10-1. Sample Load Profile for (-A-) Wye-Connected VTs and (-B-) Delta-Connected VTs

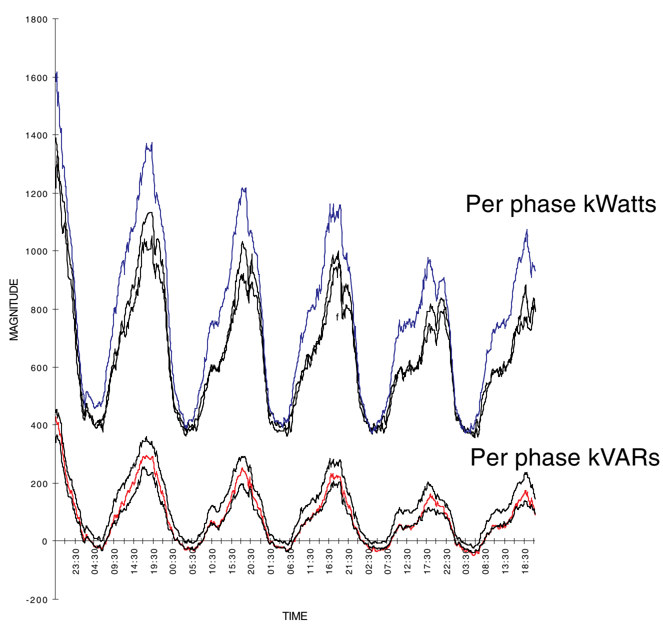


Figure 10-2. Load Profile Analysis

Using the Load Profile Feature

Use ECP and follow these steps to retrieve the optional Load Profile information.

```
┌───────────── Meter Menu ─────────────┐
│                                      │
│  Load Values                         │
│  Demand Values                       │
│  Max/Min Values                      │
│  Differential Values                 │
│  Load Profile - All                  │
│  Load Profile - Last                 │
│  Return                              │
│                                      │
└ Show Load Values ────────────────────┘
```

1. Under the Meter Menu, select Load Profile – All or Load Profile – Last. As the names suggest, choosing Load Profile – All downloads all the load profiles, while choosing Load Profile – Last downloads only the most recent load profile.

2. Type in the filename (8 characters) and select SAVE ON DISK.

3. View the load profile information by doing one of the following:

   - Open the file from your word processing or spreadsheet program.

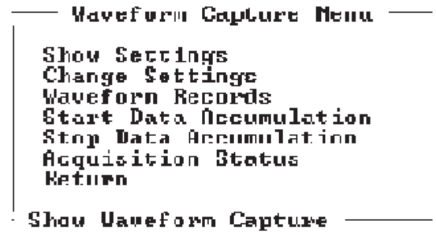
   - Type the following DOS command and press Enter.

     type [name of file].dla|more

     Type the pipe character (|) between "dla" and "more".

Oscillographic Data Storage (Waveform Capture)

To enhance disturbance analysis, the TPU-2000R can be furnished with optional oscillographic data storage that captures the waveform data for each of the eight input currents. The storage capacity is 64 cycles of each waveform. Retrieve the waveform data from the TPU-2000R by using the Waveform Capture Menu in the External Communications Program. Fault analysis is enhanced by the Oscillographics Tool, which uses a Microsoft® Windows™–based Graphical User Interface.



You can program the TPU-2000R to capture eight, four, two or one record(s) containing 8, 16, 32 or 64 cycles of data. Thirty-two points per cycle for each of the eight analog current inputs, Winding-1 and Winding-2 for both two and three Winding units, and numerous protective and logic functions are stored in each waveform record. The capturing of waveform data, can be triggered when the trip output is actuated or the waveform capture input (WCI) is initiated (provided the WCI logic function has been mapped to an input contact). You can also program the TPU-2000R to trigger the capturing of waveform data on trip of the following functions: 87T, 87H, 50N, 50P, 150N, 150P, 50G and 46. To provide as many cycles of prefault and fault data as possible, you can program the trigger position at any quarter-cycle within the fault record. The time stamp of a waveform record is captured at the time of trigger.

NOTE: Download the captured waveform records to a file before changing any Waveform Capture settings. Changing settings may lose waveform records.

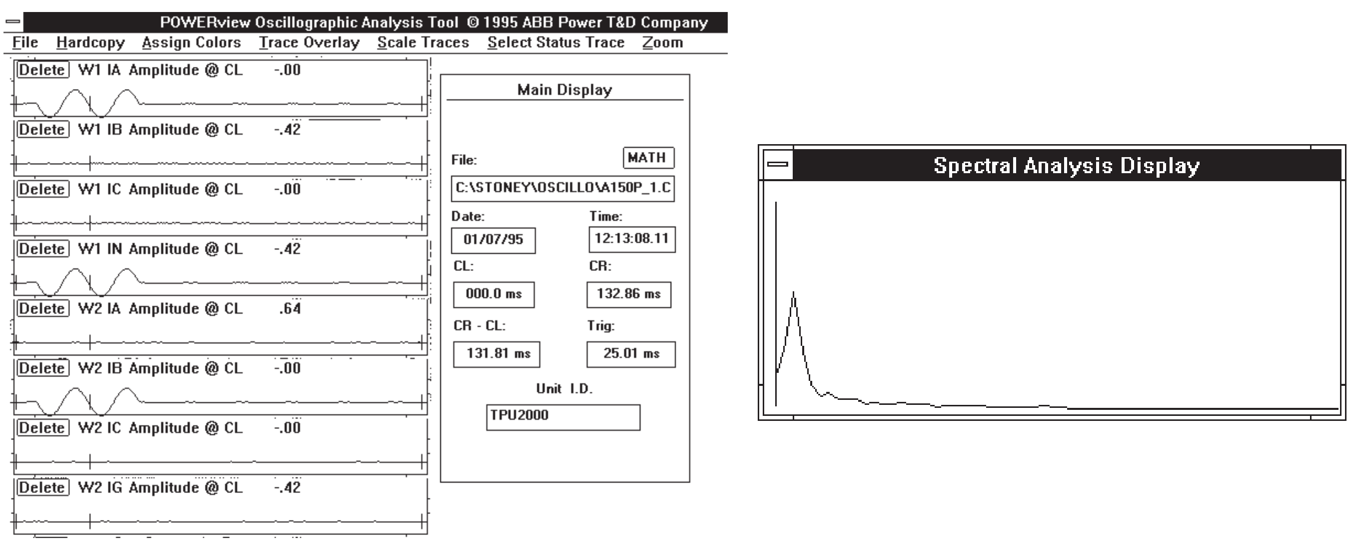


Figure 10-3. Oscillographic Wave Forms

The waveform capture program includes an option called Single-Shot Mode. When you select Single-Shot Mode and the Record Type is 3, the accumulation of data stops when one record is captured. In this way, you can ensure that a waveform record will not be overwritten by new captures. Select "Start Data Accumulation" to capture a new record and overwrite the old one.

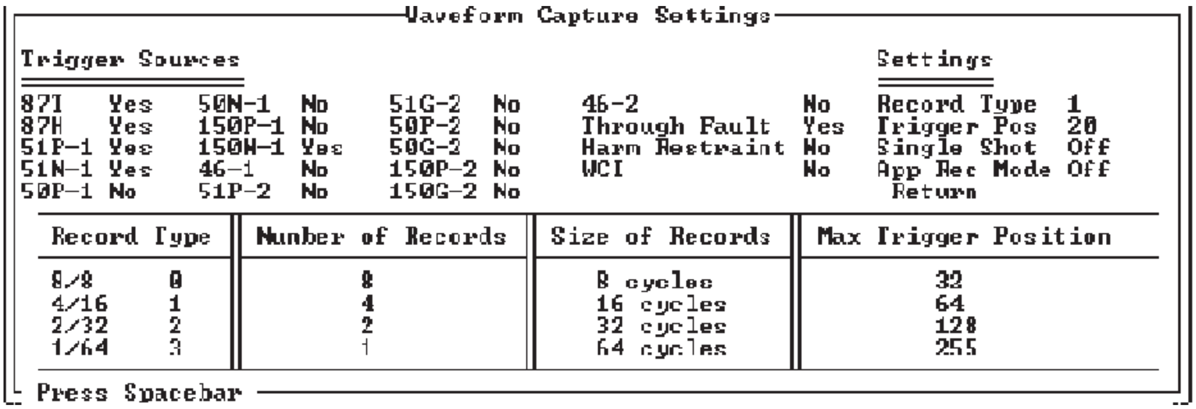


Figure 10-4. Waveform Capture Settings Screen

Selecting "On" for the Appended Record Mode enables the TPU-2000R to capture a new triggered record while it is still completing the capture of another record. If Appended Record Mode is "Off," the new record cannot be captured until the current record has been completed.

Saving a Waveform Capture Record

To save a waveform capture record, do the following:

1. Select "Waveform Records" from the Waveform Capture Menu.
2. Select the record you want to save and press Enter.
3. Type the path and filename you want for the record and press Enter.

Oscillographics Analysis Tool

ABB's Oscillographics Program Analysis Tool software program enhances the fault analysis capabilities of the ABB Protection Units. The Oscillographics Program Analysis Tool displays the waveform data captured by these units. Besides all analog waveforms, this program shows digital input/output, pickup and fault information.

The analog waveforms are displayed simultaneously in individual windows. Each window contains a trigger indicator, a left cursor and a right cursor. You can move either cursor to any position within the window for that waveform. When you move the cursor in one window, it moves in the other windows as well. Each waveform window can be resized to enhance viewing and can be deleted individually.

The time location of the left and right cursors and the difference in time between the cursors are provided in the Main Display window. Other information in the Main Display window includes the file name from which the waveform records were extracted; the date, time and trigger position of the sample taken at the Protection Unit; the unit ID number; and the catalog number.

You can overlay an individual analog waveform onto any other analog waveform. For example, you can overlay W1 Ia onto W2 Ia to examine the phase relationship.

You can scale all current waveforms with respect to the largest amplitude within that group. This is called the Actual Scale and is the default setting. But you can also scale waveforms with respect to the largest amplitude encountered for that waveform only; this is called the Normalized Scale. The Normalized Scale accentuates noise and other characteristics of the waveform.

A zoom feature allows you to position the left and right cursors within the waveform and then “zoom in” to closely examine that section of the waveform.

System Requirements and Installation

The Oscillographics Program Analysis Tool requires at least a 386-based PC running Microsoft® Windows™ 3.1. It is recommended that you set the screen resolution to 1024 x 768 to allow all the windows generated by the Oscillographics Program Analysis Tool to be seen at one time.

To install the Oscillographics Program Analysis Tool, follow these steps:

1. Start Windows and enter the File Manager program.

2. Create a directory where the program will reside on your hard drive. This may be any directory name you choose.

3. Place the 3.5” disk in your floppy drive and copy the files named PWRVIEW.EXE and TEST.CAP from the 3.5” disk to the directory you created. The test file is used to explain the operation of the Oscillographic Display and Analysis software (refer to figure 10-3).

4. Create an icon for the program in the Program Manager window:
   a. Go to the Main window in the Program Manager window.
   b. Double-click on “Windows Setup.”
   c. The Windows Setup window appears. Select “Set Up Application” under the Options menu.
   d. Another window appears. Select “Ask you to specify an application,” and click on “OK.”
   e. Enter the application path and filename (e.g., C:\Yourdir\pwrview.exe) and click on “OK.” The icon should appear in the Applications window of the Program Manager.

Using the Oscillographics Analysis Tool

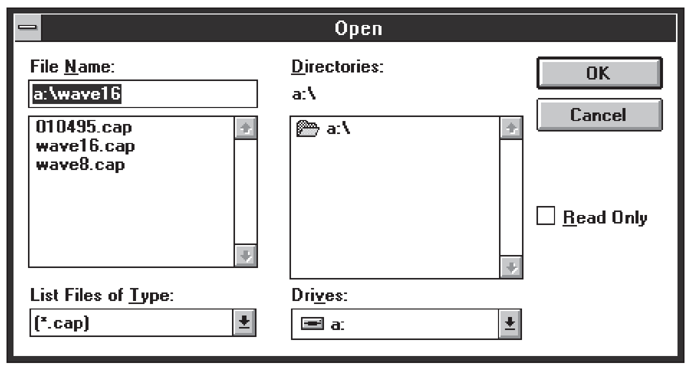
Running on Windows, the Oscillographics Program Analysis Tool is a menu-driven program. A parent window contains windows for the analog waveforms and for digital information.

Opening a File

To open a file, do the following:

1. Double-click on the icon in the Applications window of the Program Manager.
2. Click on “Continue” at the prompt.
3. Under the File menu, select “Load Graph Data File.”
4. The “Open” window appears. POWERview Analysis Tool files are listed as *.CAP files, including the TEST.CAP file. Click on the file you want and select “OK,” or double-click on the filename.

The file loads and the individual analog waveform windows appear.



Analog Display Windows

The analog waveform windows appear within the Main Display window. The Main Display window appears to the right of the analog waveforms and lists the file name, date and time the data was captured at the Protection Unit and locations of the trigger point and the left and right cursors.

The left cursor is at the far left side of each analog waveform window and the right cursor is at the far right side. You can “drag” the cursors by moving the mouse cursor close to the left or right cursors. Hold down the left mouse button while dragging the left or right cursor to the desired position. Release the mouse button.

After you move the left or right cursor, the time value for that cursor changes in the parent window. Also, the cursor position in all the other analog waveform windows mirrors your cursor movement. **The trigger cursor cannot be moved.**

To resize an analog waveform window, move the mouse to the border on that window. A double-headed arrow appears when the mouse is properly positioned. Hold down the left mouse button and drag the window border to the desired position. Release the mouse button.

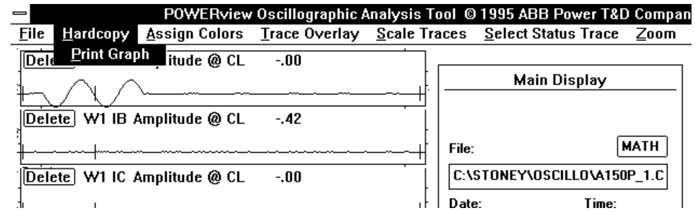
Each analog waveform window can be deleted. Simply click on the DELETE button in the window. That waveform window disappears and the other waveform windows shift to take up the empty space.

Menu Commands

Each menu on the Oscillographics Program Analysis Tool parent window has specific features.

Hardcopy Menu

Under the Hardcopy menu is the command “Print Graph.” When you want to print a copy of the window(s) you are viewing, select this command.

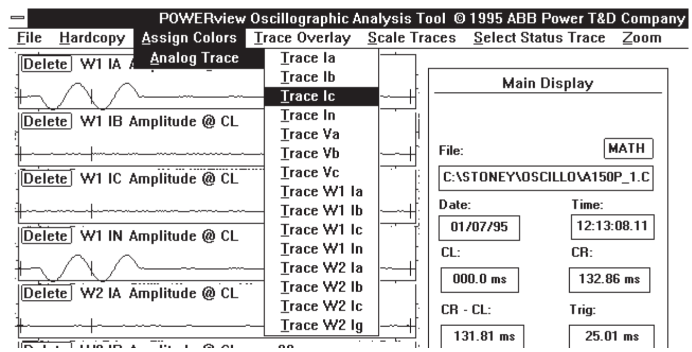


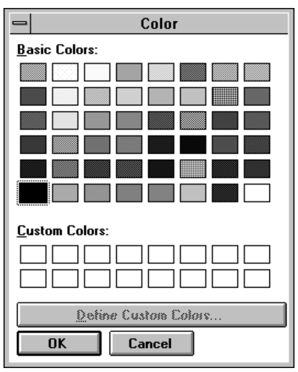
Assign Colors Menu

Use this menu to assign colors to the analog waveforms and the digital traces. This is especially helpful when you overlay two waveforms.

When you select Analog or Digital Trace, a list of the analog or digital traces appears.

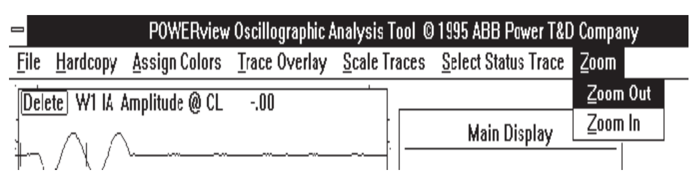
Click on the trace you want and a window with color patterns appears. Click on a color and select “OK.”

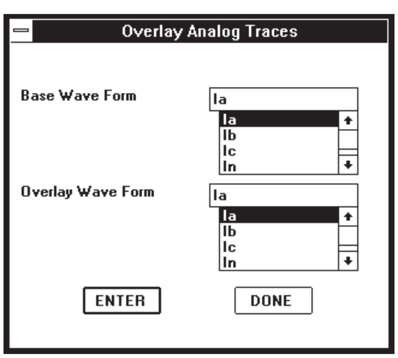




Trace Overlay Menu

Use the Trace Overlay menu to overlay any analog waveform on any other analog waveform. This way you can directly compare the two. From the Trace Overlay menu, choose “Select From Existing Traces.” You can also use this menu to remove overlays.

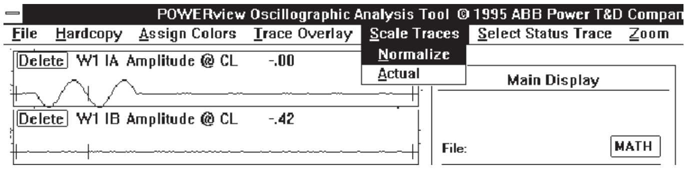




After selecting from the Trace Overlay menu, a window appears that requests you to enter a base trace and an overlay trace. Enter each trace and select “Enter.” The overlay trace appears in the window of the base trace. Enter other traces as you desire and select “Done” when you are finished.

NOTE: Only one waveform may be overlaid onto any base trace.

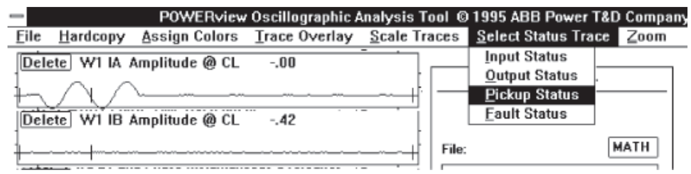
Scale Traces Menu



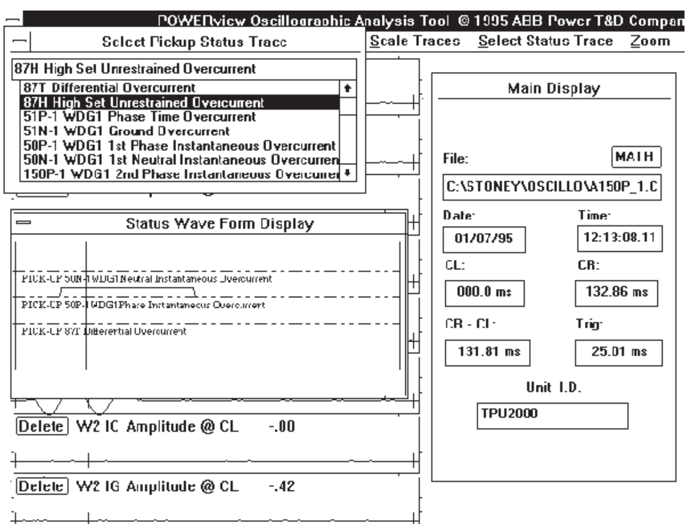
You can scale analog waveforms to an Actual Scale or a Normalized Scale. Actual Scale shows an analog waveform in relation to the other six waveforms. When you choose Normalized Scale, the waveform is scaled with respect to the largest amplitude for that waveform only. In other words, the peaks expand to fit that individual window. From the Scale Traces menu, select Actual Scale or Normalized Scale. The program launches in Actual Scale.

Select Status Trace Menu

You can present digital input/output, pickup and fault information in a window by using the Select Status Trace menu. Follow these steps to display digital information.



1. Select the digital information you want under the menu.

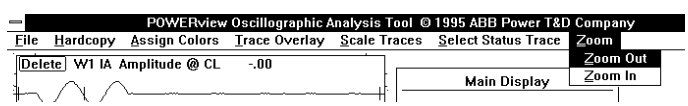


2. A window appears with a list of the different parameters measured. Click on the parameters you want. As you click on a parameter, a digital line appears in the graph window.

3. When you have selected all the parameters you want, click on Done.

Zoom Menu

Zooming in allows you to enlarge a selected portion of the analog waveform. To do this, set the left and right cursors to the desired range. Then select “Zoom In” from the “Zoom” menu. The portion you selected enlarges. Use “Zoom Out” to return to the original size.



Math Button

At the top of the Main Display window is a button marked “Math.” Press this button to perform math functions associated with the analog waveforms.

Spectral Analysis

The Spectral Analysis Tool window appears when you click on the Math button. By using this tool, you can create a spectrum window for a selected region of waveform data.

Follow these steps to perform a spectral analysis:

1. Click on the Math button at the top of the Main Display window.

2. The Spectral Analysis Tool window appears.

3. Select the waveform you want by scrolling up or down in the "Waveform" box. Double-click on the desired waveform. An extended cursor appears in place of the left cursor in the window of the selected waveform. (The default is the uppermost waveform.)

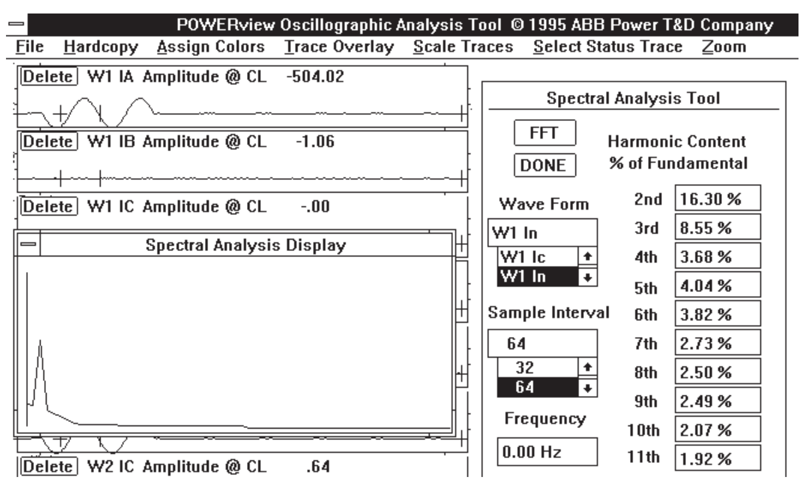
4. Select the desired sample interval by scrolling up or down in the "Sample Interval" box. Double-click on the interval you want. The extended cursor in the waveform window changes size accordingly. (Default = 32 or one cycle for a 50-Hz or 60-Hz waveform.)

5. Move the extended cursor over the section of the waveform on which you want to perform the spectral analysis. Do this by clicking on the left vertical of the cursor and dragging in the waveform window.

6. Click on the FFT (Fast Fourier Transformer) button in the Spectral Analysis Tool window. The Spectral Analysis Display window appears with the generated spectrum. The harmonic content as a percentage of the fundamental (50 or 60 Hz) appears in the Spectral Analysis Tool window for the harmonics (2nd to the 11th).

7. As you wish, move the cursor within the Spectral Analysis Display window by clicking the left mouse button in the region you want. The cursor snaps to that position and the frequency appears in the "Frequency" box of the Spectral Analysis Tool window.

8. Double-click on the upper left corner of the Spectral Analysis Display window to close it or click on "Done" in the Spectral Analysis Tool window to remove the Spectral Analysis Display and Spectral Analysis Tool windows.



Customer-Programmable Curves

An external PC-based program, CurveGen, is used to create and program time-current curves for the TPU-2000R. With CurveGen you can program time-overcurrent curves other than the ones currently provided in the TPU-2000R (see Tables 1-1 and 1-2). You can manipulate the curves in the time and current domains just like any other curve currently programmed into the TPU-2000R. CurveGen generates all of the necessary variables for the user-defined curves to be stored in the TPU-2000R (i.e. the alpha's, beta's and pointers to the curve table). The method of accomplishing this task is curve definition.

The standard curve entered into the TPU-2000R has the form of:

$$t = \left(\frac{A}{M^p - C}\right) + B$$

M is the per-unit current above the pickup value

t is total trip time at M

A, p, C and B are variables to be defined.

To define the curve, you must define the variables in this equation. There are two ways to do this:

- Enter variables by hand: With the CurveGen program you can define all four variables by hand. This is designed for users who do not want curves based on already established functions but instead are ready to define curves through mathematical manipulation.
- Determine variables via curve fitting: Define a series of time versus current points and fit them to the standard equation listed above.

With the CurveGen program you can enter these series of time/current points from an already defined curve. CurveGen then fits the four variables to these points. There are two ways to enter these points into the CurveGen program:

- Enter all sampled points by hand. The ability to remove, sort, plot, edit and view points gives you total power over the curve to be generated.
- File entry: CurveGen can also read files with points defined in them. The ability to remove, sort, plot, edit and view points gives you total power over the curve to be generated.

Once all the points are entered, the CurveGen program is cued to fit a standard curve. After A, p, C and B have been determined, you can plot the curve against the points given as well as determine the overall error of the curve versus the plotted points.

After all four variables have been determined, you can generate a linear approximation of the curve. A maximum error criteria must be satisfied before CurveGen can determine the coefficients needed for the TPU-2000R. Errors and warnings indicate whether or not the error criteria can be met or if the number of entries in the curve table is above the maximum value allowed.

When the curve tables have been defined by CurveGen, download them into the TPU-2000R. When you want to use a customer-defined curve, select "Receive Prog Curve Data" from the Programmable Curve Menu in the External Communications Program. After you have retrieved a curve file from a disk, you can download it into the TPU-2000R.

Programmable Curve Menu

```
Programmable Curve Menu

  Receive Overcurrent Curve Data
  Transmit Overcurrent Curve Data
  Receive Differential Curve Data
  Transmit Differential Curve Data
  Return

Receive OC Data from Unit
```

By using the Programmable Curve Menu, you can send (transmit) curve data that you have created via the CurveGen program from your computer to the TPU-2000R. You can also download (receive) curve data from the TPU-2000R into your computer for storage and for modification through the CurveGen program.

To transmit or receive curve data, highlight the selection you want and press Enter. Type in the curve's filename (including all directories) and press Enter again. The curve data is sent or retrieved as you selected.

CurveGen Software Release 1.0

PC Requirements

386 processor or higher

Disk Space:

200K in specified Directory
6 MB in Windows/System Directory

Memory:

480K RAM in the lower 640K for setup

Installation

Step 1: Exit Windows™

Step 2: Type WIN at the **c:** prompt

Step 3: After you hit return, hold down the <SHIFT> key until Windows™ has completely booted up. This will ensure that nothing in your startup file will interfere with the CurveGen installation.

Step 4: While in the windows desktop, insert disk 1 of 2 into drive a:

Step 5: Click on **File**

Step 6: Click on **Run**

Step 7: Type **a:\setup** and press enter

Step 8: Follow the installation instruction

Step 9: If you encounter errors during the installation, go into your windows/system directory and delete the following files:

0C25.DLL	COMDLG16.DLL	TABCTL.OCX
THREED.OCX	VCFI16.OCX	

Repeat installation from **Step 1**.

When the installation is complete, Windows will reboot (no need to hold down the "SHIFT" key and CurveGen can be run.

Using CurveGen

Click on the CurveGen 1.0 icon to run CurveGen. At this point, the user has two options. Curve coefficients can be calculated by the software by manually entering data points.

The standard equations for timing curves are shown below:

Trip Time (ANSI) = $(A/(M^p\text{-}C)+B) \times ((14n-5)/9)$
Trip Time (IEC) = $(A/(M^p\text{-}C)+B) \times n$

Where A, B, C and P are the coefficients to be computed and/or entered

n = time dial

M = Relay current in multiples of tap setting

Computing Coefficients

Step 1: If desired, the user may enter a description in the **Description** field.

Step 2: Under **Standard**, the user should select either **ANSI** curves or **IEC** curves.

Step 3: Under the **data entry method,** the user should select **Compute Coefficients.** At this point, the **Compute Coefficients Tab** towards the top of the screen should appear. Click this tab.

Step 4: Using the mouse, place the cursor on Row 1, Column 1 (Current M)

Step 5: Type the desired multiple of tap, M, and press the TAB key. Now type the corresponding time. Press the TAB key again to enter a second point. Continue until at least 5 data points are keyed in (100 points max). Please note that whether you are using ANSI or IEC type curves, the points you enter are equivalent to a time dial of 1.

Step 6: After all points are entered, click on **solve**. The computed coefficients will appear on the screen. In order to see these points on a graph, hit the **Apply** button.

Step 7: Click on the **Relay Data** tab. At this point, you'll see that the coefficients previously calculated appear under **Coefficients**. Under **Curve Series**, select default. Time dial 1 through 10 should appear on the screen for **ANSI** or 0.05 to 1 for **IEC**. Any combination of valid time dials can be used.

Step 8: Select **Apply**. At this point, a graph will appear on the screen. The graph format can be changed by selecting different options under the **Graph** menu at the top of the screen. The Curves can also be printed for a clearer view.

Step 9: If you are satisfied with the results, select **Save As** under **File** and Type in a filename with a .crv extension. This is the file to be used when downloading curves to your 2000R relay.

Step 10: The user also has the ability to save the worksheet. To do this, select **Save Worksheet As** under **File** and type in a filename with a .wrk extension.

Manually Entering Coefficients

Step 1: If desired, the user may enter a description in the **Description** field.

Step 2: Under **Standard,** select **ANSI** or **IEC**.

Step 3: Under **Data Entry Method** select **Manually Enter Coefficients**.

Step 4: The user can now enter the known coefficients **A, B, C** and **P**.

Step 5: Under **Curve Series,** select **Default**. Time dial 1 through 10 should appear on the screen for **ANSI** or 0.05 to 1 for **IEC**. Any combination of valid time dials can be used.

Step 6: Select **Apply**. At this point, a graph will appear on the screen. The graph format can be changed by selecting different options under the **Graph** menu at the top of the screen. The Curves can also be printed for a clearer view.

Step 7: If you are satisfied with the results, select **Save As** under **File** and type in a filename with a .crv extension. This is the file to be used when downloading curves to your 2000R relay.

Step 8: the user also has the ability to save the worksheet. to do this select **Save Worksheet As** under **File** and type in a filename with a .wrk extention.

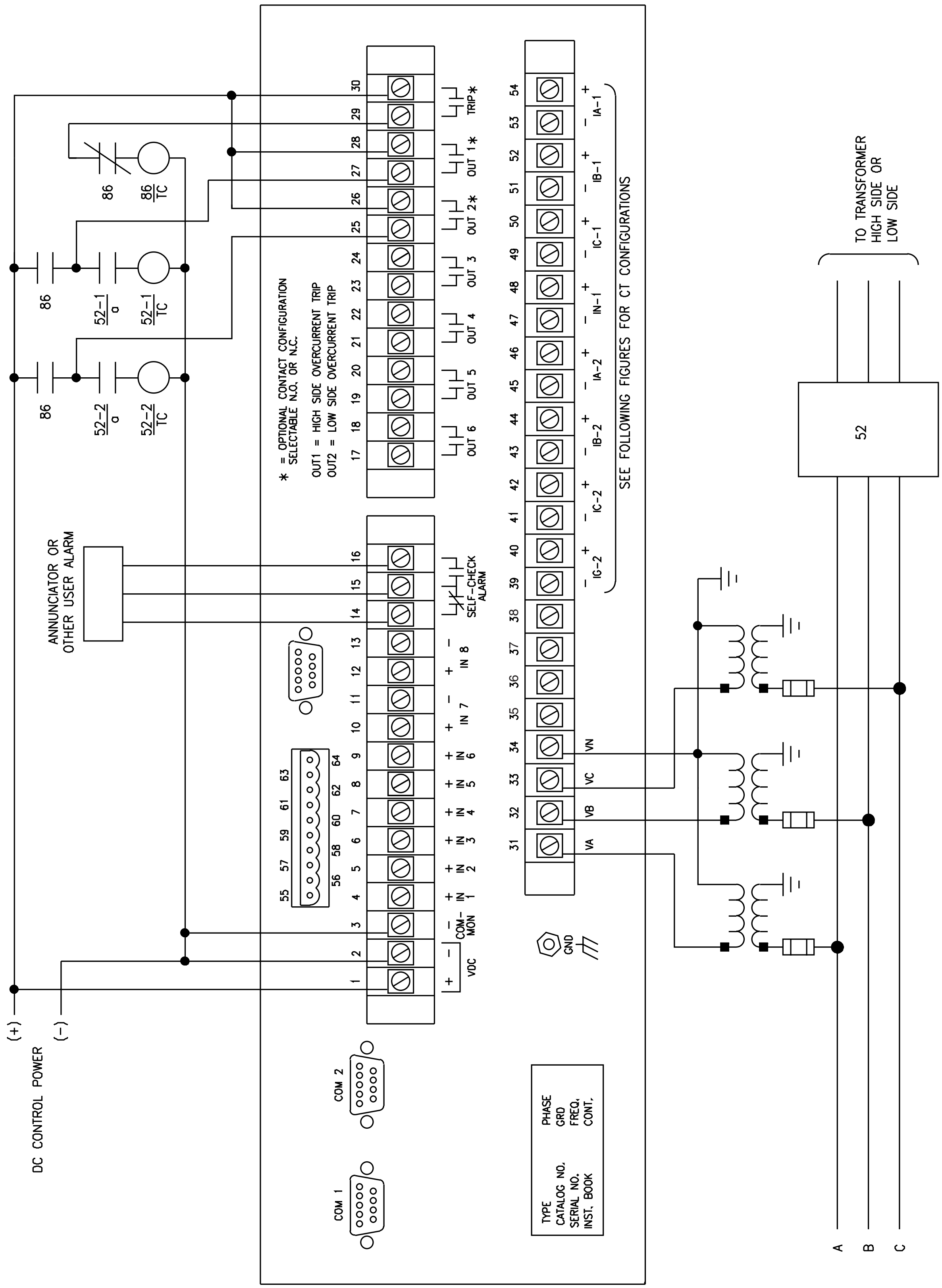


Figure 11-1. Typical External Connections for 2 Winding Relay

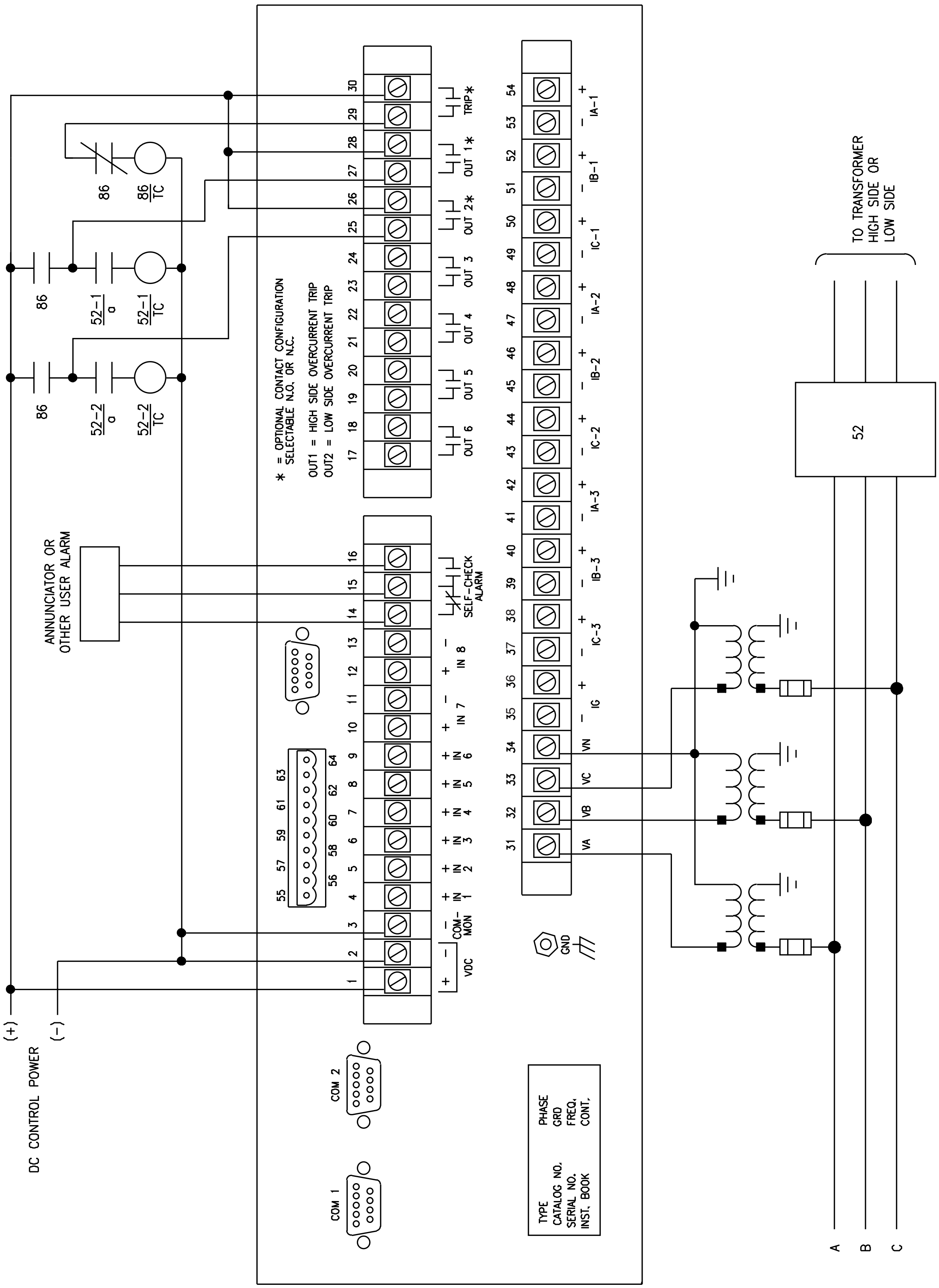
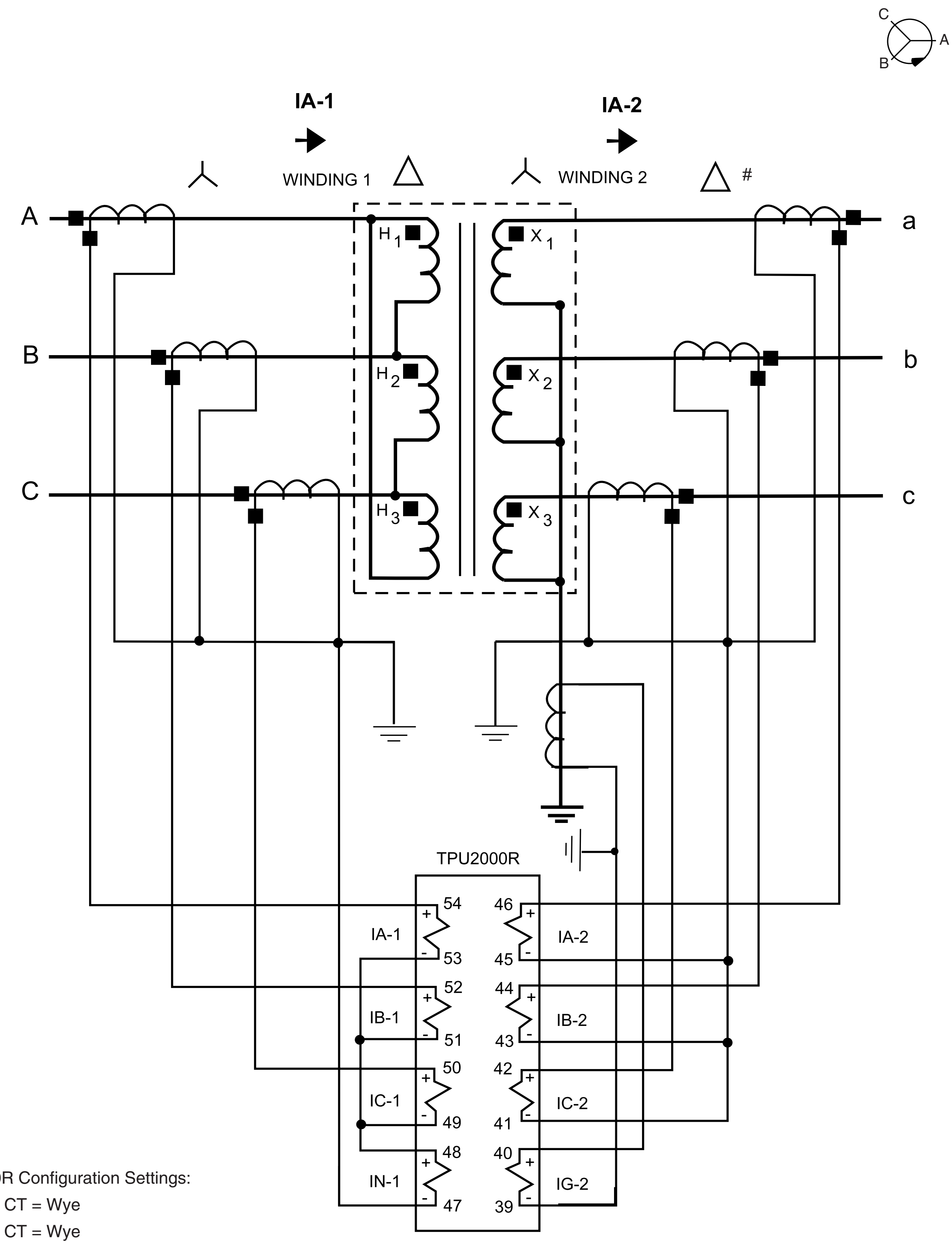
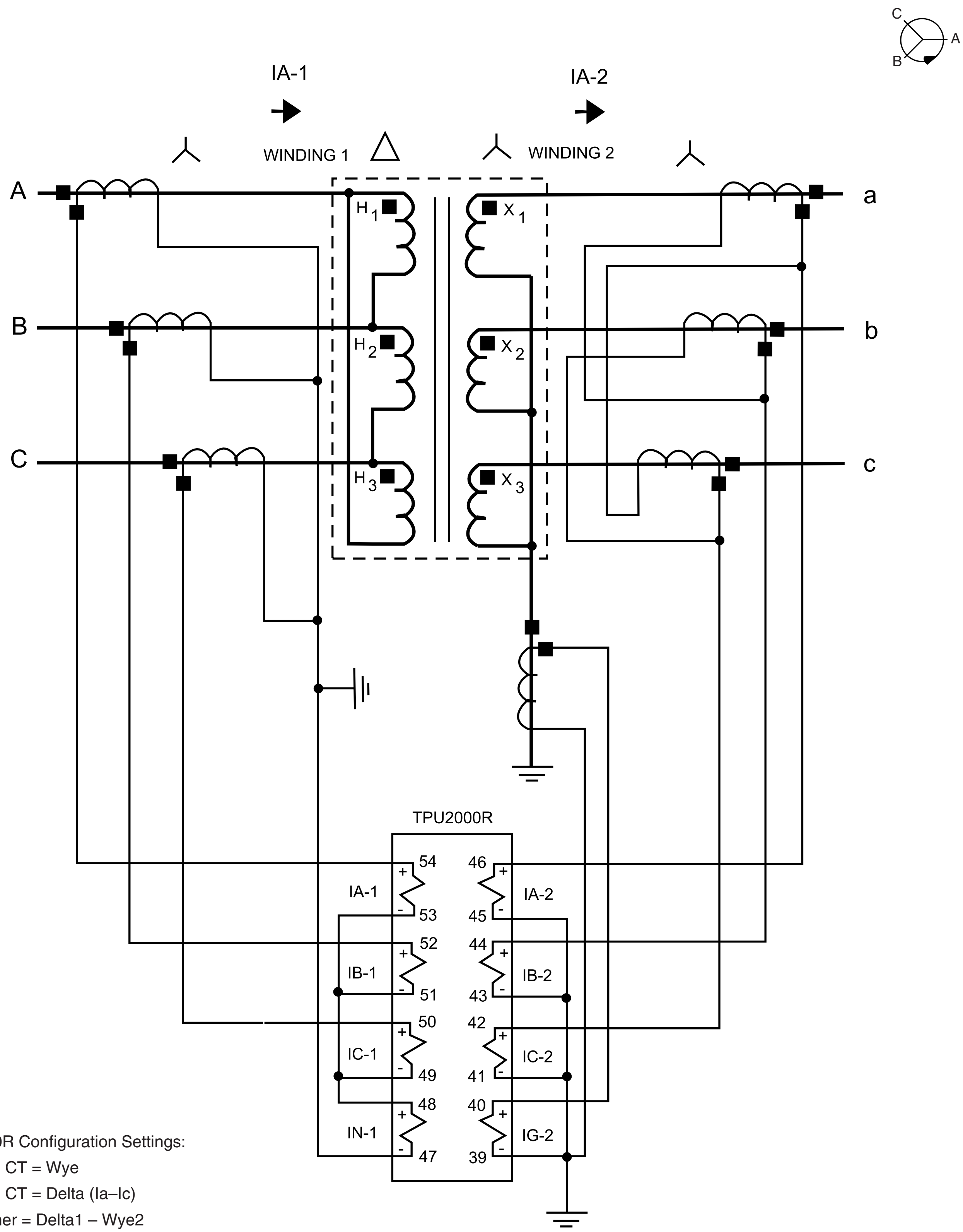


Figure 11-2. Typical External Connections 3 Winding Relay



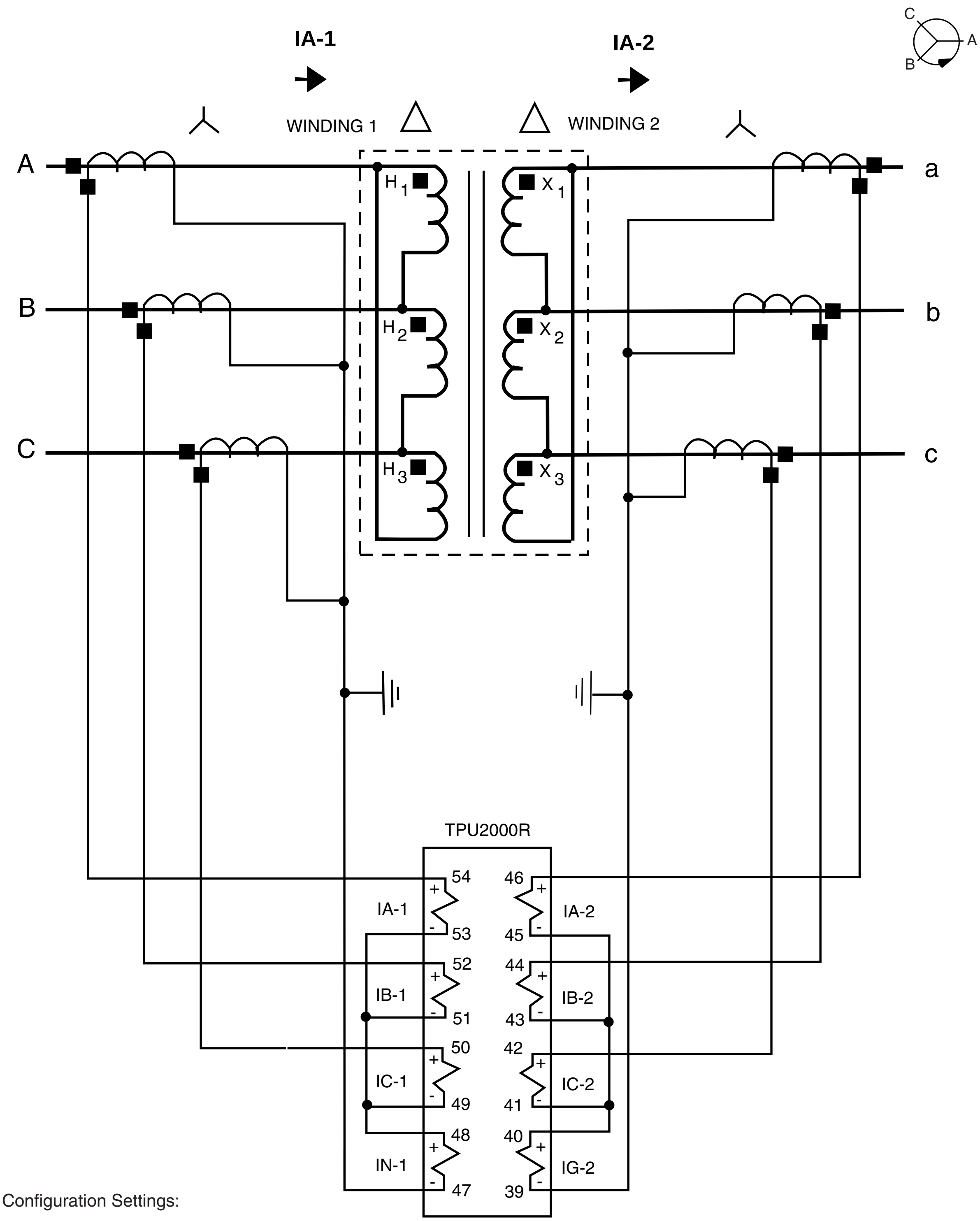
TPU-2000R Configuration Settings:
Winding 1 CT = Wye
Winding 2 CT = Wye
Transformer = Delta1 – Wye2
Phase Compensation = 330°

Figure 11-3. Delta-Wye Power Transformer and Wye-Wye Current Transformer Configuration (2 Winding Relay)



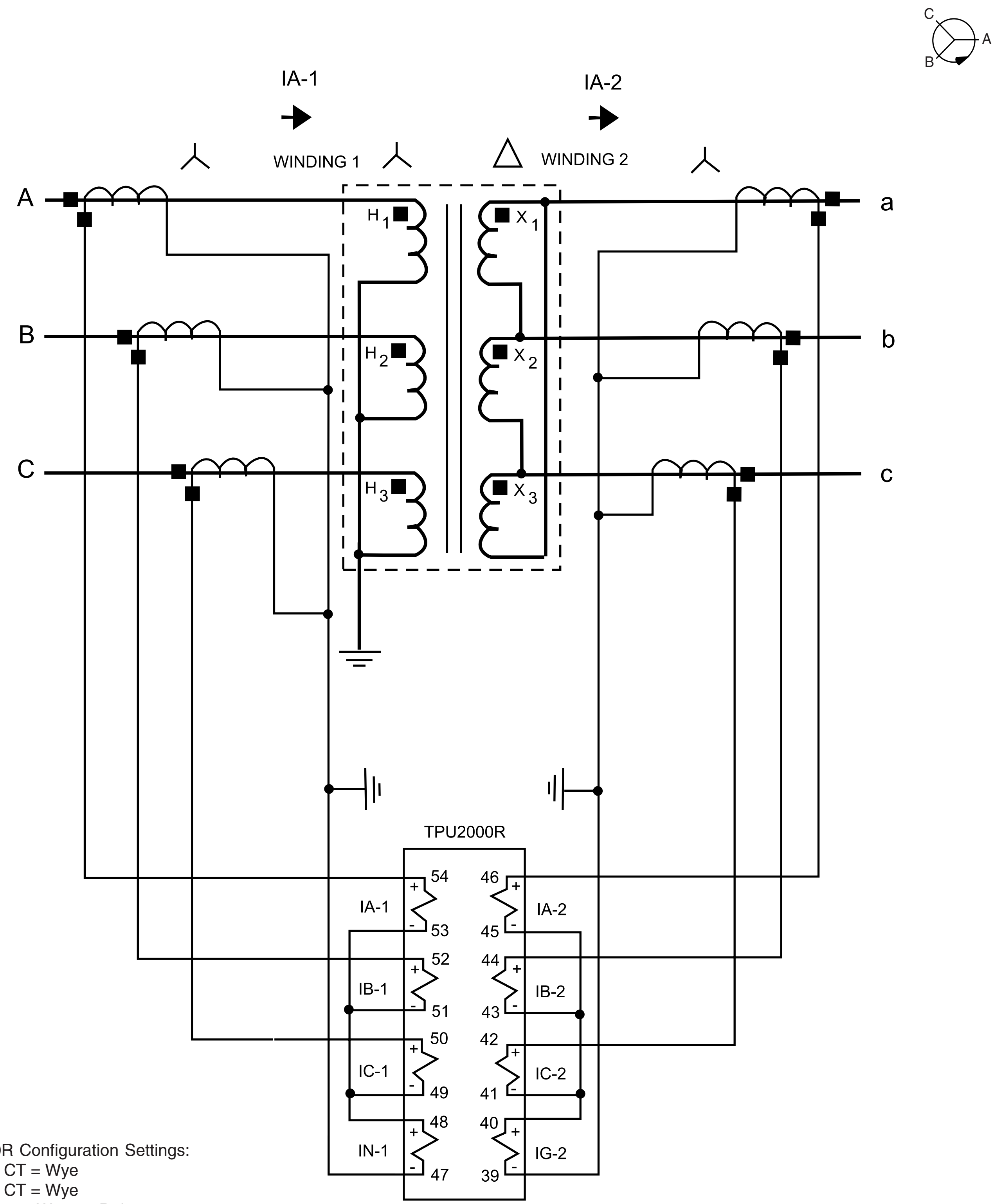
TPU-2000R Configuration Settings:
Winding 1 CT = Wye
Winding 2 CT = Delta (Ia–Ic)
Transformer = Delta1 – Wye2
Phase Compensation = 330°

Figure 11-4. Delta-Wye Power Transformer and Wye-Delta Current Transformer Configuration (2 Winding Relay)



TPU-2000R Configuration Settings:
Winding 1 CT = Wye
Winding 2 CT = Wye
Transformer = Delta1 – Delta2
Phase Compensation = 0°

Figure 11-5. Delta - Delta Transformer with Wye Wye CTs (2 Winding Relay)



TPU-2000R Configuration Settings:
Winding 1 CT = Wye
Winding 2 CT = Wye
Transformer = Wye1 – Delta2
Phase Compensation = 30°

Figure 11-6. Wye-Delta Power Transformer with Wye-Wye Current Transformer Configuration (2 Winding Relay)

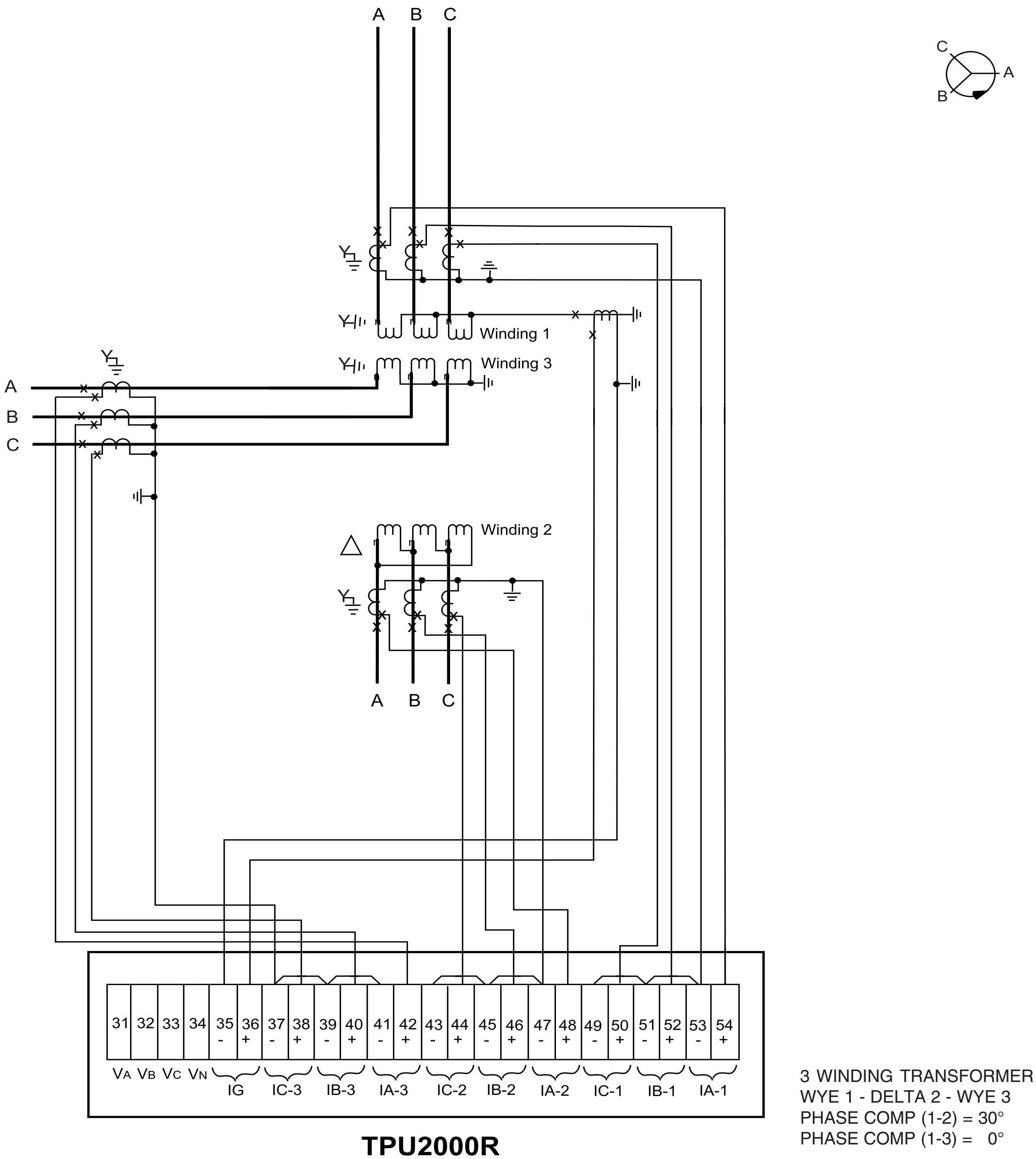
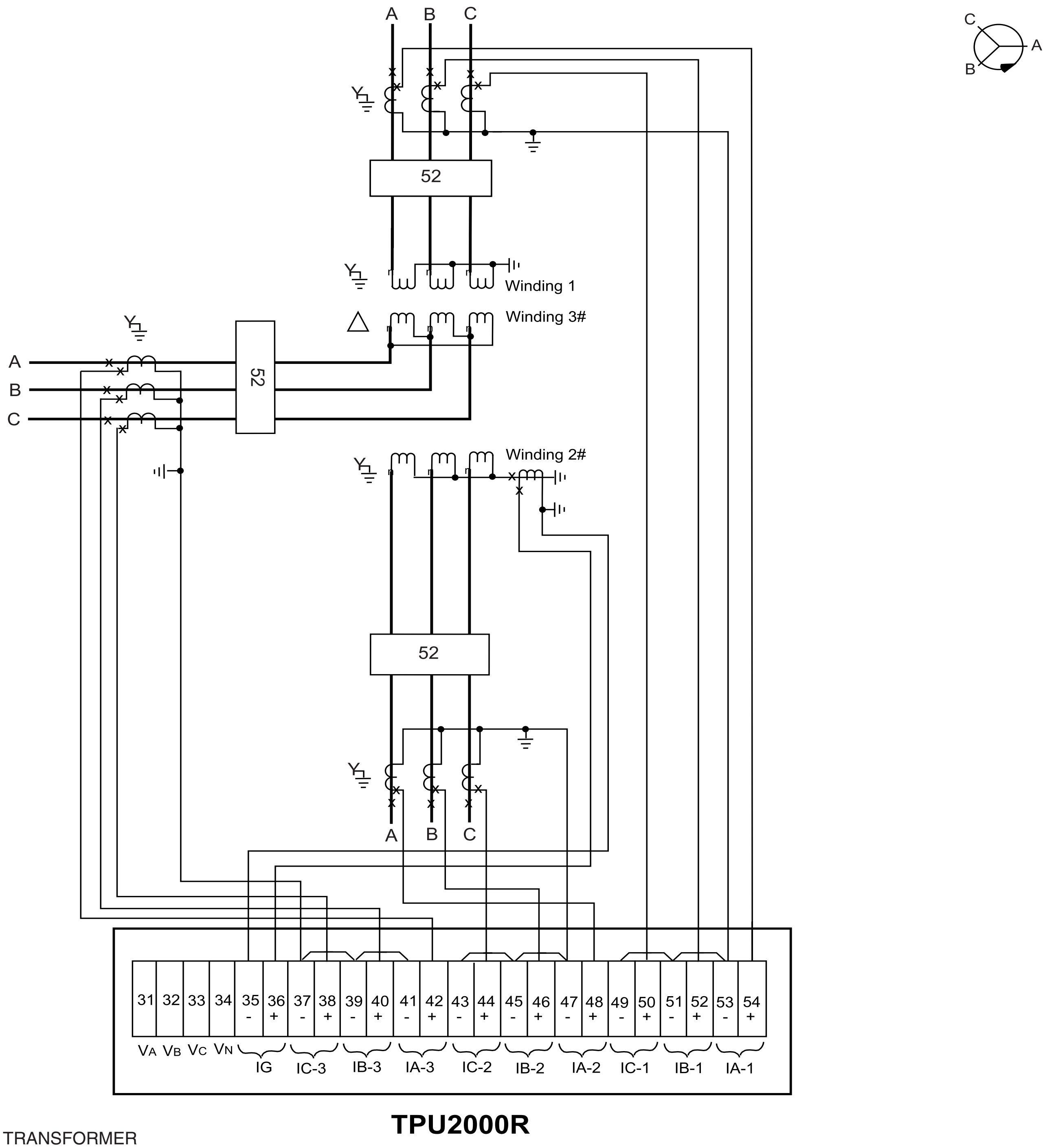


Figure 11-7. Wye 1 - Delta 2 - Wye 3 Transformer Configuration (3 Winding Relay)



3 WINDING TRANSFORMER
WYE 1 - WYE 2 - DELTA 3
PHASE COMP (1-2) = 0°
PHASE COMP (1-3) = 30°

Figure 11-8. Wye1 - Wye 2 - Delta 3 Transformer Configuration (3 Winding Relay)

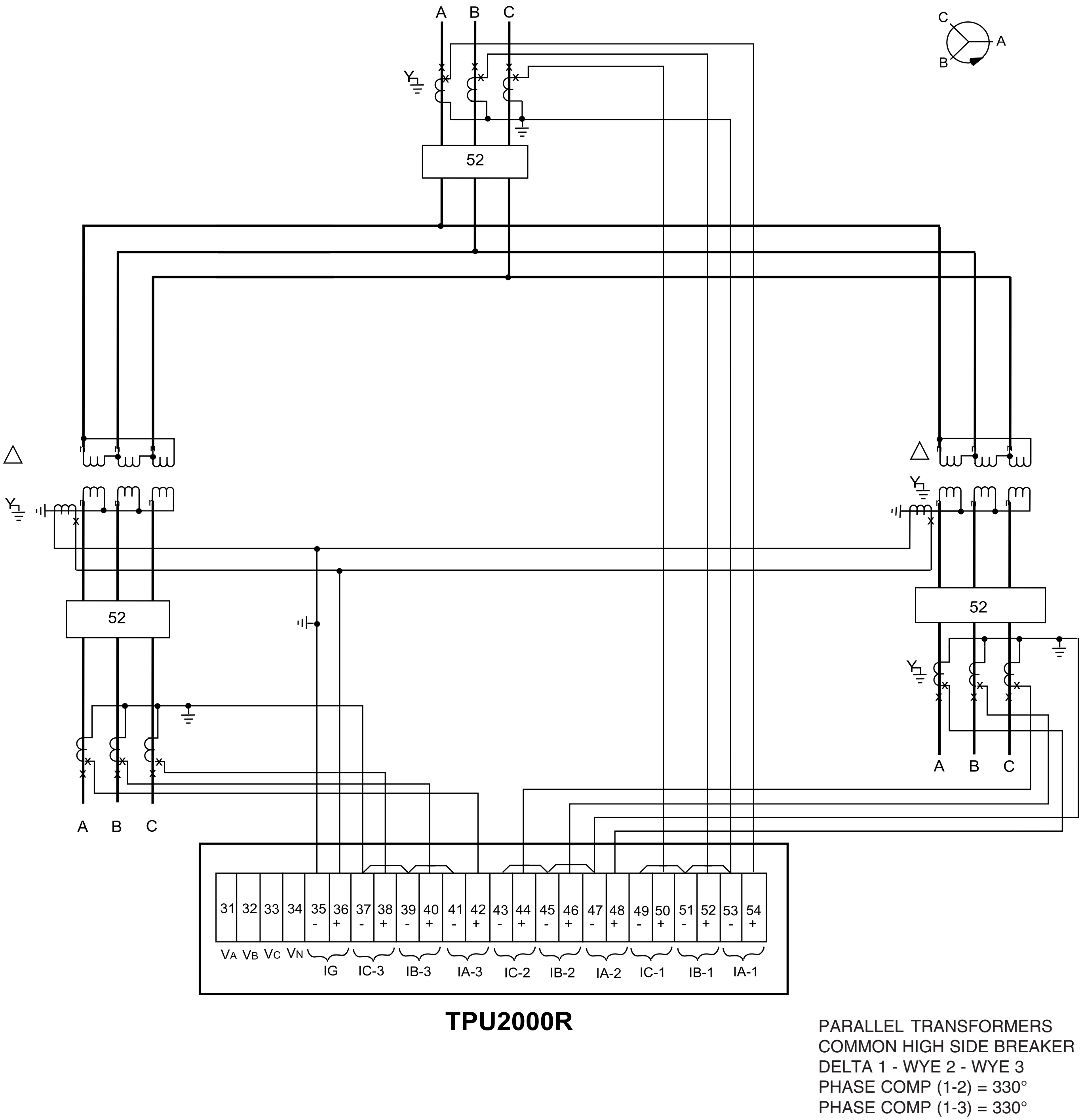


Figure 11-9. Parallel Delta-Wye Transformer Configuation (3 Winding Relay)

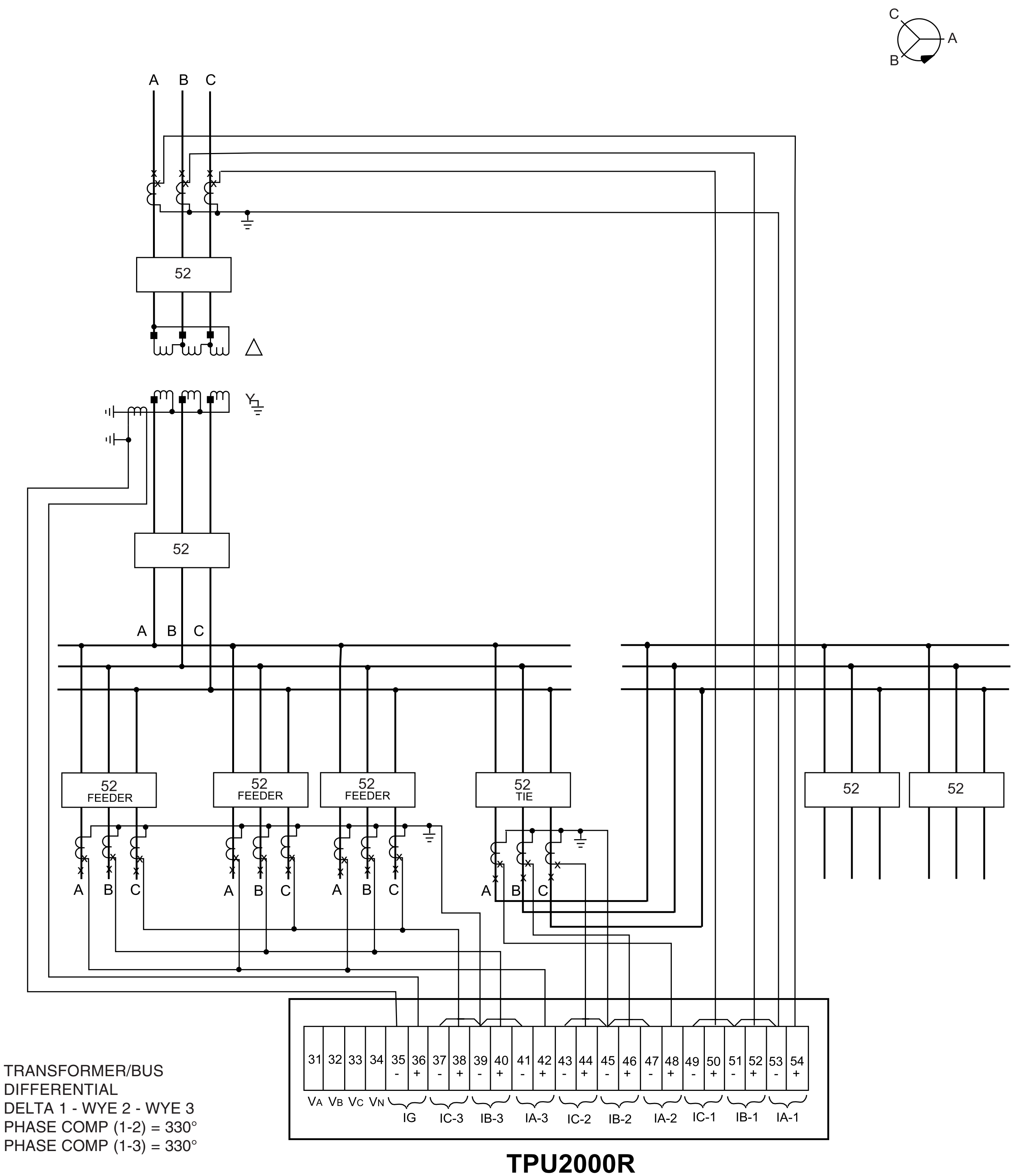


Figure 11-10. Delta 1 – Wye 2 – Wye 3
(3 Winding Relay)

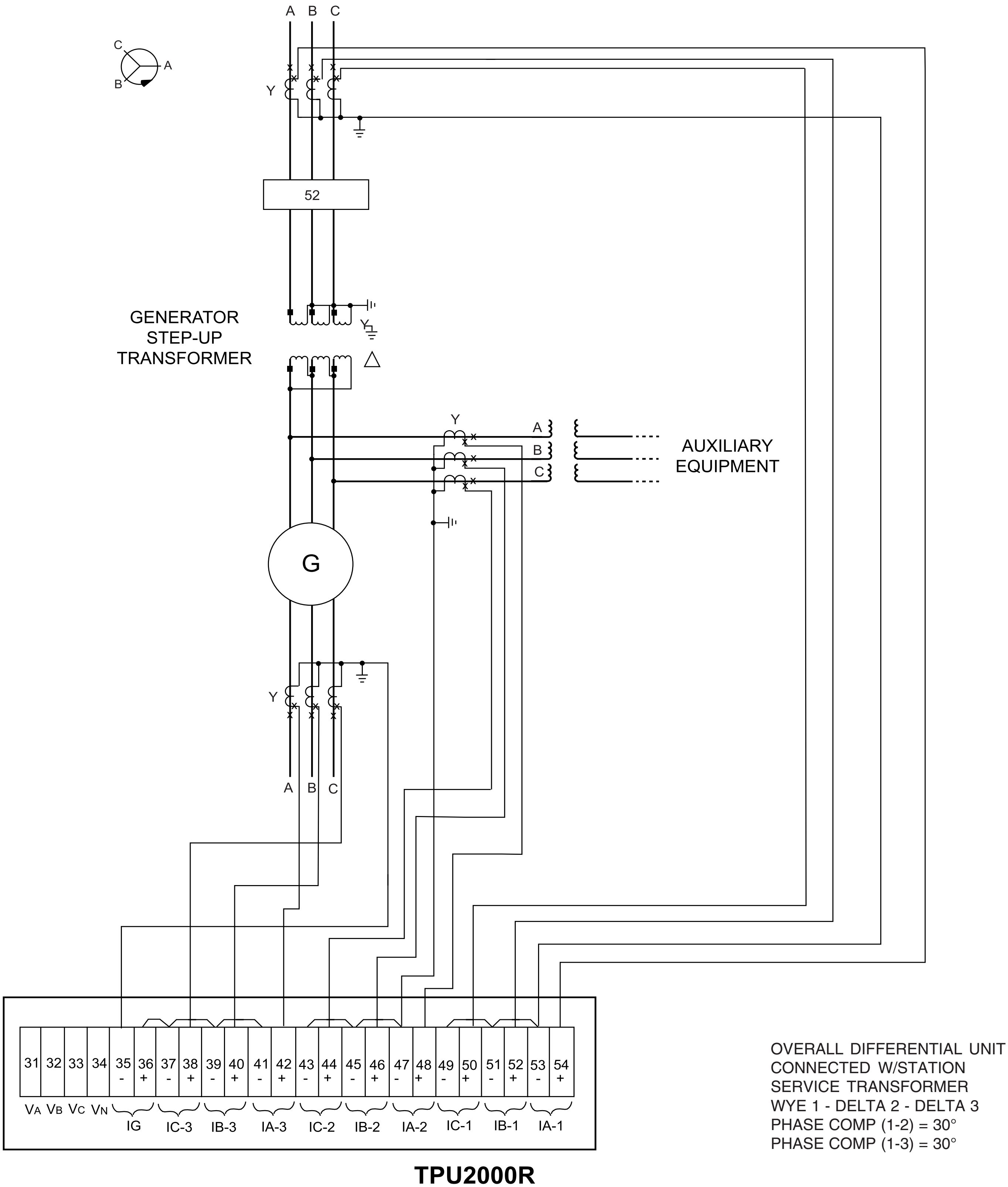
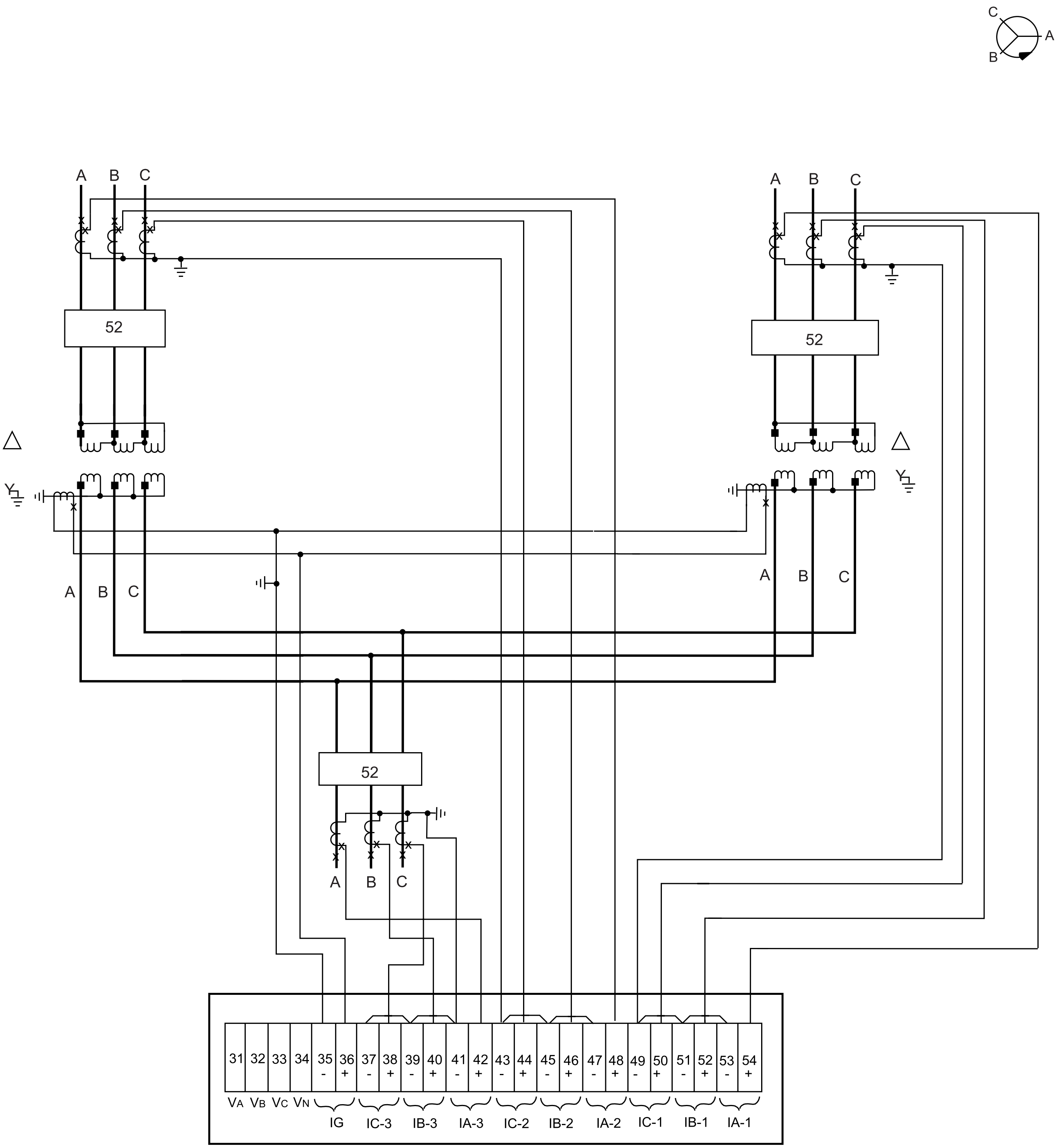


Figure 11-11. Wye 1 – Delta 2 – Delta 3
(3 Winding Relay)



PARALLEL TRANSFORMERS
COMMON LOW SIDE BREAKER
DELTA 1 - DELTA 2 - WYE 3
PHASE COMP (1-2) = 330°
PHASE COMP (1-3) = 330°

Figure 11-12. Delta – Delta 2 – Wye 3 (3 Winding Relay)

Table 11-1. Minimum Required Connections for 2 Winding TPU2000R

Required Connections	Terminals
Control Voltage Input	Positive: 1; Negative: 2; Common Negative: 3*
Current Input Winding 1 Phase A	IA-1: 54(+) and 53(–)
Current Input Winding 1 Phase B	IB-1: 52(+) and 51(–)
Current Input Winding 1 Phase C	IC-1: 50(+) and 49(–)
Current Input Winding 1 Neutral	IN-1: 48(+) and 47(–)
Current Input Winding 2 Phase A	IA-2: 46(+) and 45(–)
Current Input Winding 2 Phase B	IB-2: 44(+) and 43(–)
Current Input Winding 2 Phase C	IC-2: 42(+) and 41(–)
Current Input Winding 2 Ground	IG-2: 40(+) and 39(–)
TRIP Output Contact	29 and 30 (N.O./N.C. jumper # J6 on mother board)
SELF-CHECK ALARM Contacts	15 and16 N.O.; 15 and 14 N.C. (TPU-2000R powered down)

Table 11-2. Minimum Required Connections for 3 Winding TPU2000R

	Required Connections	Terminals
	Control Voltage Input	Positive: 1; Negative: 2; Common Negative: 3*
	Current Input Winding 1 Phase A	IA-1: 54(+) and 53(-)
	Current Input Winding 1 Phase B	IB-1: 52(+) and 51(-)
	Current Input Winding 1 Phase C	IC-1: 50(+) and 49(-)
	Current Input Winding 2 Phase A	IA-2: 48(+) and 47(-)
	Current Input Winding 2 Phase B	IB-2: 46(+) and 45(-)
	Current Input Winding 2 Phase C	IC-2: 44(+) and 43(-)
#	Current Input Winding 3 Phase A	IA-3: 42(+) and 41(-)
#	Current Input Winding 3 Phase B	IB-3: 40(+) and 39(-)
#	Current Input Winding 3 Phase C	IC-3: 38(+) and 37(-)
	Current Input Ground	IG : 36(+) and 35(-)
	TRIP Output Contact	29 and 30 (N.O./N.C. jumper # J6 on mother board)
	SELF-CHECK ALARM Contacts	15 and 16 N.O.; 15 and 14 N.C. (TPU-2000R powered down)

NOTE: A three winding TPU2000R can be used as a two winding unit by not wiring CT connections to the third winding.

Table 11-3. Other Connections

Connection	Terminal
Programmable Inputs (Default Assignments)	
Contact Input Number 1	IN 1; 4(+)
Contact Input Number 2	IN 2; 5(+)
Contact Input Number 3	IN 3; 6(+)
Contact Input Number 4	IN 4; 7(+)
Contact Input Number 5	IN 5; 8(+)
ALT1 (Alternate 1) Settings	IN 6; 9(+)
ALT2 (Alternate 2) Settings	IN 7; 10 & 11
Contact Input Number 8	IN 8; 12 & 13
Programmable Outputs (Default Assignments)	
Overcurrent Winding 1 Trip 51/50/150P/N and 46	Output 1, 27 and 28 (N.O./N.C., jumper # J7 on mother board
Overcurrent Winding 2 Trip 51/50/150P/G and 46	Output 2, 25 and 26 (N.O./N.C.; jumper # J8 on mother board
DIFF TRIP 87T/87H	Output 3; 23 and 24
2nd Harmonic Restraint Alarm 2HROA	Output 4; 21 and 22
Trip Failure Alarm (TFA)	Output 5; 19 and 20
Pickup and Through Fault Alarm (PUA/THRUFA)	Output 6; 17 and18

Maintenance and Testing

Because of its continuous self-testing, the TPU-2000R requires no routine maintenance. However, you can conduct testing to verify proper operation. ABB recommends that an inoperative unit be returned to the factory for repair. If you need to return a unit, contact your local ABB sales office for a return authorization number.

High-Potential Tests

High-potential tests are not recommended. If a control wire insulation test is required, completely withdraw the TPU-2000R from its case and perform only a DC high-potential test.

Withdrawing the TPU-2000R Electronics from the Case

The TPU-2000R can be disassembled to install optional equipment or to change jumper settings of the selectable output contacts, between normally open (NO) and normally closed (NC).

With exception of the CTs and burden board, you can totally withdraw the TPU-2000R from its case.

Follow these steps to disassemble the unit:

WARNING: Removal of the relay from the case exposes the user to dangerous voltages. Use extreme care. Do not insert hands or other foreign objects into the case.

1. Loosen the knurled screws on the face of the TPU-2000R and gently remove the face and attached circuit board by grasping the knurled screws and pulling the unit straight forward. Pulling the board out at an angle or otherwise stressing the board on extraction may damage the unit. Once removed from the case, position the unit face down on a static secured mat.
2. Install the desired options according to the instructions provided with those options. The output relays are on the top-left-rear section of the board (when viewed from the front) under the metal shield. Movable jumper links alongside the output relays set the selectable output contacts to normally open (NO) or normally closed (NC). To access the jumper links it is necessary to remove the shield, which is secured by a screw and 1/4" PCB mounting stud. If an AUX COM board is installed, it will be necessary to remove the board completely to allow access to the shield.
3. To reinstall the unit into the case, carefully align and insert the lips on both sides of the board into the guide rails on the inside walls of the case and gently push the unit straight inward until it fully seats in the case. Secure the knurled screws.

Routine System Verification Tests

Besides continuously monitoring a Self-Check output contact, perform routine hardware tests to verify that the TPU-2000R is functioning properly. Run these tests via the MMI or via the communications port and the External Communications Program. The tests are:

1. Confirm pass/fail status of each Self-Check element by using the Test Menu.
2. Confirm continuity of current and voltage through each input sensor by using the Meter Menu.
3. Confirm continuity through each optically isolated contact input for both the opened and closed condition by using the Test Menu.
4. Verify operation of each output contact by using the Test Menu.
5. Confirm that all relay settings are correct by using the Show Settings Menu.
6. Check the Fault and Operation Records for proper sequential operation.

TPU-2000R Acceptance Tests

Required Equipment

- Active 2 phase AC voltage and high current source with timer.
- IBM or equivalent computer with available serial port and null modem communications cable.

Settings

The following tests were written to verify proper relay operation after it is received from the factory. They are assumed to be performed on the factory default settings. Table 12-1 lists the factory default settings to be tested. Some settings in the TPU-2000R will not be listed in the table and are not needed for testing purposes. The values shown in parentheses (x.xx) are the values for 1 ampere rated units.

to download factory settings to an in service unit for testing, follow the procedure below:

Saving and Downloading Settings

Saving Factory Settings to a File:

1. With an IBM PC or compatible computer, load and execute the TPU-2000R External Communication Program (ECP). Do not connect the PC to the TPU-2000R at this time.
2. Select the monitor type and press “Enter”.
3. Press “Enter” after reading header.
4. The “Communications Options” menu should appear. It should read:

Serial Communications Port:	COM1	(or whichever will be used on your PC)
Baud Rate:	9600	
Frame	N-8-1	
TPU Address	001	

5. Highlight “Return to Main Menu” and press “Enter”.
6. The “Communications Status” menu should appear. Select “Continue Without Connecting” and press “Enter”.
7. Enter the relay catalog number and press “Enter”.
8. Select “Change Settings” and press “Enter”.
9. Select “*Primary Settings” and press “Enter”.
10. Select “Get Data From Disk” and press “Enter”.
11. Select “Don’t Read From Disk” and press “Enter”.
12. The default settings should appear. Press the “Esc” key to exit.
13. Select “Save Data to Disk” and press “Enter”.
14. Enter the desired file name for the factory default settings such as DEFAULT.PRI.
15. Select “Save on Disk” and press “Enter”.
16. Press the “Esc” key until the main menu appears.
17. Select “Quit Program” and press “Enter”.

Saving Existing (in-service) Settings to a File:

1. Connect the TPU-2000R to the PC at this time. Load and execute the TPU-2000R External Communication Program (ECP).
2. Select the monitor type and press “Enter”.
3. Press “Enter” after reading header.

4. The “Communications Options” menu should appear. It should read:

Serial Communications Port:	COM1	(or whichever will be used on your PC)
Baud Rate:	9600	
Frame	N-8-1	
TPU Address	001	

5. Highlight “Return to Main Menu” and press “Enter”.
6. The “Successful Connection to TPU-2000R” screen should appear. This contains the relay information including: division code, ID, catalog number, serial number and prom versions.
7. Press “Enter”.
8. Select “Change Settings” and press “Enter”.
9. Select “*Primary Settings” and press “Enter”.
10. Select “Get Data From TPU-2000R” and press “Enter”.
11. The TPU-2000R settings should appear. Press the “Esc” key.
12. Select “Save Data to Disk” and press “Enter”.
13. Enter the desired file name for the actual settings such as ACTUAL.PRI.
14. Select “Save on Disk” and press “Enter”.
15. Press the “Esc” key until the main menu appears and select “Quit Program” to exit.

Sending Settings to the Relay From a File:

1. Connect the TPU-2000R to the PC at this time. Load and execute the TPU-2000R External Communication Program (ECP).
2. Select the monitor type and press “Enter”.
3. Press “Enter” after reading header.
4. The “Communications Options” menu should appear. It should read:

Serial Communications Port:	COM1	(or whichever will be used on your PC)
Baud Rate:	9600	
Frame	N-8-1	
TPU Address	001	

5. Highlight “Return to Main Menu” and press “Enter”.
6. The “Successful Connection to TPU-2000R” screen should appear. This contains the relay information including: division code, ID, catalog number, serial number and prom versions.
7. Press “Enter”.
8. Select “Change Settings” and press “Enter”.
9. Select “*Primary Settings” and press “Enter”.
10. Select “Get Data From Disk” and press “Enter”.
11. Enter the filename, select “Read from Disk” and press “Enter”. The file settings should appear.
12. Press the “Esc” key and select “Send Data to TPU-2000R” and press “Enter”.
13. Enter the relay password (factory password = four spaces) and press “Enter”.
14. The ECP will display “Communicating with TPU-2000R Please Wait” then return to the Change settings menu.
15. Press the “Esc” key until the main menu appears and select “Quit Program” to exit.

Table 12-1. Primary Settings (Factory Default)

Function	Primary Setting	Default Setting
87T	Curve Selection	% Slope
	Minimum Operating Current	0.2 per unit
	Percent Slope	30%
	Restraint Mode	2nd Harmonic
	Percent Slope	15%
	% 2nd Harmonic Restraint	
87H	Pickup Setting	6.0 per unit
	Winding 1 Settings	
87T-1	Winding 1 Tap	6.0 (1.2) amps
51P-1	Curve Selection	Extremely Inverse
	Pickup Amps	6.0 (1.2) amps
	Time Dial	5.0
50P-1	Curve Selection	Standard
	Pickup Multiple of 51P-1	3.0
150P-1	Selection	Disable
46-1	Curve Selection	Disable
51N-1	Curve Selection	Extremely Inverse
	Pickup Amps	6.0 (1.2) amps
	Time Dial	5.0
50N-1	Curve Selection	Standard
	Pickup Multiple of 51P-2	3.0
150N-1	Selection	Disable
Level Detector-1	Pickup Multiple of 51P-1	Disable
Winding 2 Settings		
87T-2	Winding 2 Tap	6.0 (1.2) amps
51P-2	Curve Selection	Extremely Inverse
	Pickup Amps	6.0 (1.2) amps
	Time Dial	5.0
50P-2	Curve Selection	Standard
	Pickup Multiple of 51P-2	3.0
150P-2	Selection	Disable
46-2	Curve Selection	Disable
51G-2 (2w) 51N-2 (3w)	Curve Selection	Extremely Inverse
	Pickup Amps	6.0 (1.2) amps
	Time Dial	5.0
50G-2 (2w) 50N-2 (3w)	Curve Selection	Standard
	Pickup Multiple of 51P-2	3.0
50G-2 (2w) 50N-2 (3w)	Selection	Disable
Distrubance-2	Pickup Multiple of 51P-2	3.0
Level Detector-2	Pickup Multiple of 51P-2	Disable

Table 12-1. Primary Settings (Factory Default) continued

Winding 3 Settings (if applicable)		
87T-3	Winding 3 Tap	6.0 (1.2) amps
51P-3	Curve Selection	Extremely Inverse
	Pickup Amps	6.0 (1.2) amps
	Time Dial	5.0
50P-3	Curve Selection	Standard
	Pickup Multiple of 51P-3	3.0
	Time Dial	5.0
150P-3	Selection	Disable
46-3	Curve Selection	Disable
51N-3	Curve Selection	Extremely Inverse
	Pickup Amps	6.0 (1.2) amps
	Time Dial	5.0
50N-3	Curve Selection	Standard
	Pickup Multiple of 51P-3	3.0
	Time Dial	2.0
150N-3	Selection	Disable
Disturbance-3	Pickup Multiple of 51P-3	3.0
Level Detector-3	Pickup Multiple of 51P-3	Disable
Ground Settings (3 winding TPU2000R only)		
51G	Curve Selection	Extremely Inverse
	Pickup Amps	6.0 (1.2) amps
	Time Dial	5.0
50G	Curve Selection	Standard
	Pickup Multiple of 51P-3	3.0
150G	Selection	Disable

Testing The 2 Winding TPU-2000R

Change the following CONFIGURATION settings from the factory default for all tests:

- Transformer Configuration Tnfr Cfg = Delta1-Delta 2
- Phase Compensation Phase Comp = 0

Differential Tests

Test 1: Testing the 87T Differential Unit Minimum Pickup:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	6.0
87T-2 Tap Selection	87T-2	=	6.0

Make the test connections as shown in Figure 12-1 for the 87T phase pairs to be tested. Set the primary and secondary currents to 0.50 (0.10) amperes RMS. Set the primary and secondary current source angles to 0 degrees.

Apply the currents. Slowly **raise** only the secondary current from 0.50 (0.10) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the secondary current reaches 0.70 (0.14) amperes RMS ± 3%.

Test 2: Testing the 87T Differential Unit With Adjustable Percent Slope Setting:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0

Make the test connections as shown in Figure 12-1 for the 87T phase pairs to be tested. Set the primary and secondary currents to 6.00 (1.20) amperes RMS. Set the secondary current source angle to 180 degrees.

Apply the currents. Slowly **raise** only the secondary current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the secondary current reaches 7.80 (1.56) amperes RMS ± 3% .

Tests 3: Testing the 87T Differential Unit With Fixed 25% Slope Setting:

87T Selection	87T Select	=	25 % Tap
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0

Make the test connections as shown in Figure 12-1 for the 87T phase pairs to be tested. Set the primary and secondary currents to 6.00 (1.20) amperes RMS. Set the secondary current source angle to 180 degrees.

Apply the currents. Slowly **raise** only the secondary current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the secondary current reaches 7.60 (1.52) amperes RMS ± 3% .

Tests 4: Testing the 87T Differential Unit With HU 30% Slope Setting:

87T Selection	87T Select	=	HU 30%
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0

Make the test connections as shown in Figure 12-1 for the 87T phase pairs to be tested. Set the primary and secondary currents to 6.00 (1.20) amperes RMS. Set the secondary current source angle to 180 degrees.

Apply the currents. Slowly **lower** only the secondary current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the secondary current reaches 4.70 (0.94) amperes RMS ± 3% .

Test 5: Testing the 87T Differential Unit With Harmonic Restraint:

(This test requires a current source with synchronized adjustable frequency sources.)

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0

Make the test connections as shown in Figure 12-1 for the 87T HARM phase pairs to be tested (both sources synchronized and in parallel). Set current source 1 to 6.00 (1.20) amperes RMS at 0 degrees 60 Hz. Set current source 2 to 1.00 (0.20) amperes RMS at 0 degrees 120 Hz.

Apply the currents. The TPU-2000R display should read “Trip Restrained”. Slowly lower only current source 2 from 1.00 (0.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The “Differential” target along with the phase target should light. This should occur when current source 2 is between 0.90 (0.18) and 0.80 (0.16) amperes RMS.

Test 6: Testing the 87H Differential Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
51P-1 Selection	51P-1	=	Disable
51P-2 Selection	51P-2	=	Disable
51N-1 Selection	51N-1	=	Disable
51G-2 Selection	51G-2	=	Disable

Make the test connections as shown in Figure 12-1 for the 87H phase pairs to be tested. Set current source 1 to 11.0 (2.2) amperes RMS at 60 Hz. Set current source 2 to 11.0 (2.2) amperes RMS at 120 Hz (both sources synchronized and in parallel).

Suddenly apply the current for 1 second. The TPU2000R Relay should read “Trip Restrained.”

Set the current source 1 to 13.0 (2.6) amperes RMS at 60 Hz. Set current source 2 to 13.0 A at 120 Hz. Suddenly apply the current for 1 second. The relay should trip. The contact monitor should indicate a closed contact. The “Differential” target along with the phase target light. Go to the fault records and verify that the last trip was initiated by the 87H unit.

Repeat the test for all of the phase pairs listed in Table 12-2.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Phase Overcurrent Tests

Test 7: Testing the Winding 1 51P-1 Phase Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-1 Selection	51P-1	=	Extreme Inv
50P-1 Selection	50P-1	=	Disable

Make the test connections as shown in Figure 12-1 for the 51P-1 phase pairs to be tested. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51P-1 unit should trip in 15.6 seconds ± 7%. The Time and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-2.

Test 8: Testing the Winding 2 51P-2 Phase Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:]

87T Selection	87T Select	=	Disable
51P-2 Selection	51P-2	=	Extreme Inv
50P-2 Selection	50P-2	=	Disable

Make the test connections as shown in Figure 12-1 for the 51P-2 phase pairs to be tested. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51P-2 unit should trip in 15.6 seconds ± 7%. The Time and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-2.

Test 9: Testing the Winding 1 150P-1 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-1 Selection	51P-1	=	Extreme Inv
50P-1 Selection	50P-1	=	Disable
150P-1 Selection	150P-1	=	Enable

Make the test connections as shown in Figure 12-1 for the 150P-1 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150P-1 unit should trip in 0.10 ±.016 seconds. The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-2.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 10: Testing the Winding 2 150P-2 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-2 Selection	51P-2	=	Extreme Inv
50P-2 Selection	50P-2	=	Disable
150P-2 Selection	150P-2	=	Enable

Make the test connections as shown in Figure 12-1 for the 150P-2 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150P-2 unit should trip in 0.10 ±.016 seconds. The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-2.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 11: Testing the Winding 1 50P-1 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50P-1 Selection	50P-1	=	Standard
150P-1 Selection	150P-1	=	Disable

Make the test connections as shown in Figure 12-1 for the 50P-1 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50P-1 unit should trip instantaneously (minimal delay). The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-2.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 12: Testing the Winding 2 50P-2 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50P-2 Selection	50P-2	=	Standard
150P-2 Selection	150P-2	=	Disable

Make the test connections as shown in Figure 12-1 for the 50P-2 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50P-2 unit should trip instantaneously (minimal delay). The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-2.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Ground Overcurrent Tests

Test 13: Testing the Winding 1 50N-1 Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
150N-1 Selection	150N-1	=	Disable

Make the test connections as shown in Figure 12-1 for the 50N-1 unit. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50N-1 unit should trip instantaneously (minimal delay). The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 14: Testing the Winding 2 50G-2 Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
150G-2 Selection	150G-2	=	Disable

Make the test connections as shown in Figure 12-1 for the 50G-2 unit. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50G-2 unit should trip instantaneously (minimal delay). The Instantaneous and Ground (G-2) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 15: Testing the Winding 1 51N-1 Neutral Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-1 Selection	50N-1	=	Disable
150N-1 Selection	150N-1	=	Disable

Make the test connections as shown in Figure 12-1 for the 51N-1 unit. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51N-1 unit should trip in 15.6 seconds ± 7%. The Time and Neutral (N-1) targets should light.

Test 16: Testing the Winding 2 51G-2 Ground Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50G-2 Selection	50G-2	=	Disable
150G-2 Selection	150G-2	=	Disable

Make the test connections as shown in Figure 12-1 for the 51G-2 unit. Set the current source to 12.00 (2.4) amperes RMS (2*pickup). Set the timer to start upon application of current.

Apply the current. The 51G-2 unit should trip in 15.6 seconds ± 7%. The Time and Ground (G) targets should light.

Test 17: Testing the Winding 1 150N-1 Neutral Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-1 Selection	50N-1	=	Disable
150N-1 Selection	150N-1	=	Enable

Make the test connections as shown in Figure 12-1 for the 150N-1 test. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150N-1 unit should trip in 0.10 ±.01 seconds. The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 18: Testing the Winding 2 150G-2 Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50G-2 Selection	50G-2	=	Disable
150G-2 Selection	150G-2	=	Enable

Make the test connections as shown in Figure 12-1 for the 150G-2 test. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150G-2 unit should trip in 0.10 ±.01 seconds. The Instantaneous and Ground (G) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Negative Sequence Tests

Test 19: Testing the Winding 1 46-1 Negative Sequence Time-Overcurrent Unit:
(This test requires a current test source capable of at least 40 (8.0) amperes RMS.)

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
46-1 Selection	46-1	=	Extreme Inv
51P-1 Selection	51P-1	=	Disable
150N-1 Selection	150N-1	=	Disable

Make the test connections as shown in Figure 12-1 for the 46-1 unit. Set the current source to 36.0 (7.2) amperes RMS (2 x pickup single phase mode). Set the timer to start upon application of current.

Apply the current and remove it as soon as the relay trips. The 46-1 unit should trip in 15.6 seconds ± 7%. The Negative Sequence target should light. Allow the relay to cool for 3 minutes before proceeding.

Repeat the tests for all of the phase pairs listed in Table 12-2.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 20: Testing the Winding 2 46-2 Negative Sequence Time-Overcurrent Unit:

(This test requires a current test source capable of at least 40 (8.0) amperes RMS.)

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
46-1 Selection	46-2	=	Extreme Inv
51P-1 Selection	51P-2	=	Disable
150N-1 Selection	150N-2	=	Disable

Make the test connections as shown in Figure 12-1 for the 46-2 unit. Set the current source to 36.0 (7.2) amperes RMS (2 x pickup single phase mode). Set the timer to start upon application of current.

Apply the current and remove it as soon as the relay trips. The 46-2 unit should trip in 15.6 seconds ± 7%. The Negative Sequence target should light. Allow the relay to cool for 3 minutes before proceeding.

Repeat the tests for all of the phase pairs listed in Table 12-2.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 21: Metering Tests:

Set the current source to 1.00 amperes RMS. Apply the current to each current input on the TPU-2000R and watch the metering on the front panel display or ECP program. The values seen should be 100 ± 6 amperes RMS.

Restoration of Settings:

Verify or change the PRIMARY settings to return to the factory defaults listed in Table 12-1.

Change the following CONFIGURATION settings to return to the factory default:

Transformer Configuration	Tnfr Cfg	=	Del1-Wye2
Phase Compensation	Phase Comp	=	30

IMPORTANT: To return the unit to service, the settings must be restored to the in-service values. Follow the procedure outlined at the beginning of this section. If the unit is not to be placed into service, the factory default settings should be restored. This can be down by downloading a previously saved default file or by manually checking each setting.

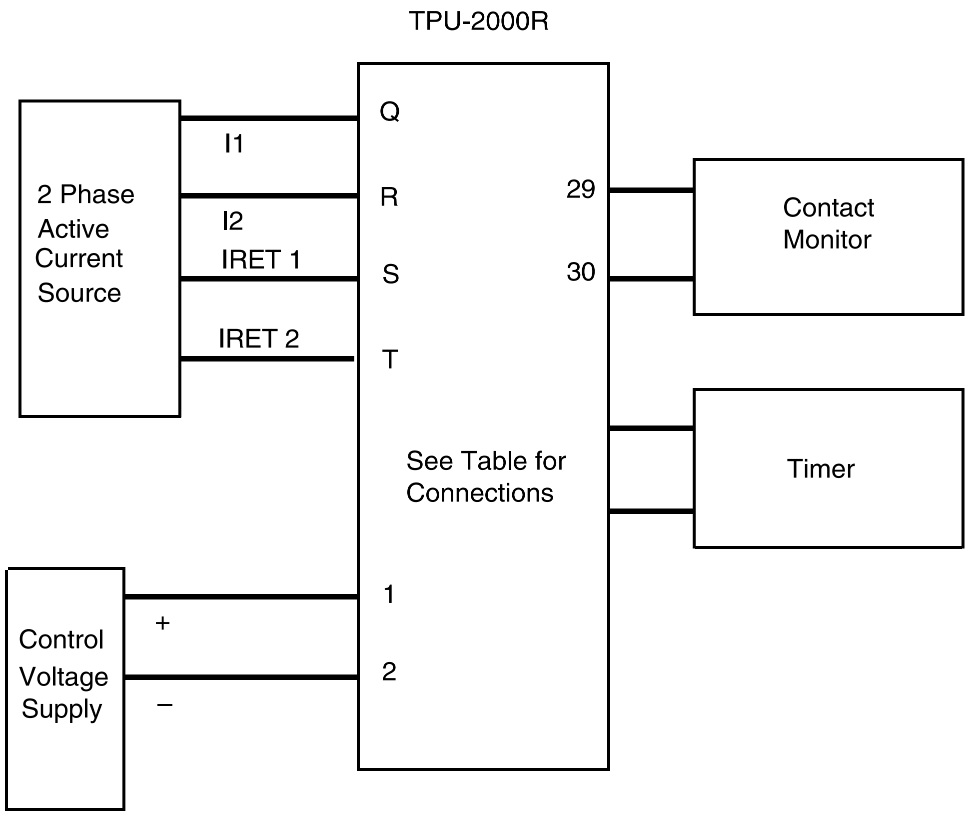


Figure 12-1. TPU-2000R Test Connections

Test Number	Function Under Test	Phase Inputs Under Test		Connections						Expected Value	Tested Value
				Q	R	S	T	TIMER			
#1	87T Minimum Operate	IA-1	IA-2	54	46	53	45	—	—	0.7 (0.14) amperes	± 3%
		IB-1	IB-2	52	44	51	43	—	—	0.7 (0.14) amperes	± 3%
		IC-1	IC-2	50	42	49	41	—	—	0.7 (0.14) amperes	± 3%
#2	87T % Slope	IA-1	IA-2	54	46	53	45	—	—	7.8 (1.56) amperes	± 3%
		IB-1	IB-2	52	44	51	43	—	—	7.8 (1.56) amperes	± 3%
		IC-1	IC-2	50	42	49	41	—	—	7.8 (1.56) amperes	± 3%
#3	87T Fixed 25%	IA-1	IA-2	54	46	53	45	—	—	7.6 (1.52) amperes	± 3%
		IB-1	IB-2	52	44	51	43	—	—	7.6 (1.52) amperes	± 3%
		IC-1	IC-2	50	42	49	41	—	—	7.6 (1.52) amperes	± 3%
#4	87T HU 30%	IA-1	IA-2	54	46	53	45	—	—	4.7 (0.94) amperes	± 3%
		IB-1	IB-2	52	44	51	43	—	—	4.7 (0.94) amperes	± 3%
		IC-1	IC-2	50	42	49	41	—	—	4.7 (0.94) amperes	± 3%
#5	87T HARM	IA-1		54	54	53	53	—	—	0.72 (0.144) - 1.08 (0.216)	
		IB-1		52	52	51	51	—	—	0.72 (0.144) - 1.08 (0.216)	
		IC-1		50	50	49	49	—	—	0.72 (0.144) - 1.08 (0.216)	
		IA-2		46	46	45	45	—	—	0.72 (0.144) - 1.08 (0.216)	
		IB-2		44	44	43	43	—	—	0.72 (0.144) - 1.08 (0.216)	
		IC-2		42	42	41	41	—	—	0.72 (0.144) - 1.08 (0.216)	
#6	87H	IA-1		54	54	53	53	—	—	12 (2.4) ± 0.84 (0.17)	
		IB-1		52	52	51	51	—	—	12 (2.4) ± 0.84 (0.17)	
		IC-1		50	50	49	49	—	—	12 (2.4) ± 0.84 (0.17)	
		IA-2		46	46	45	45	—	—	12 (2.4) ± 0.84 (0.17)	
		IB-2		44	44	43	43	—	—	12 (2.4) ± 0.84 (0.17)	
		IC-2		42	42	41	41	—	—	12 (2.4) ± 0.84 (0.17)	

Table 12-2. Test Connections

Test Number	Function Under Test	Phase Inputs Under Test	Connections Q	R	S	T	TIMER		Expected Value	Tested Value
7	51P-1	IA-1	54	—	53	—	27	28	15.6 sec. ± 7%	
		IB-1	52	—	51	—	27	28	15.6 sec. ± 7%	
		IC-1	50	—	49	—	27	28	15.6 sec. ± 7%	
8	51P-2	IA-2	46	—	45	—	25	26	15.6 sec. ± 7%	
		IB-2	44	—	43	—	25	26	15.6 sec. ± 7%	
		IC-2	42	—	41	—	25	26	15.6 sec. ± 7%	
9	150P-1	IA-1	54	—	53	—	27	28	0.10 ± 0.016 sec.	
		IB-1	52	—	51	—	27	28	0.10 ± 0.016 sec.	
		IC-1	50	—	49	—	27	28	0.10 ± 0.016 sec.	
10	150P-2	IA-2	46	—	45	—	25	26	0.10 ± 0.016 sec.	
		IB-2	44	—	43	—	25	26	0.10 ± 0.016 sec.	
		IC-2	42	—	41	—	25	26	0.10 ± 0.016 sec.	
11	50P-1	IA-1	54	—	53	—	27	28	Instantaneous	
		IB-1	52	—	51	—	27	28	Instantaneous	
		IC-1	50	—	49	—	27	28	Instantaneous	
12	50P-2	IA-2	46	—	45	—	25	26	Instantaneous	
		IB-2	44	—	43	—	25	26	Instantaneous	
		IC-2	42	—	41	—	25	26	Instantaneous	
13	50N-1	IN-1	48	—	47	—	27	28	Instantaneous	
14	50G-2	IG-2	40	—	39	—	25	26	Instantaneous	
15	51N-1	IN-1	48	—	47	—	27	28	15.6 sec. ± 7%	
16	51G-2	IG-2	40	—	39	—	25	26	15.6 sec. ± 7%	
#17	150N-1	IN-1	48	—	47	—	27	28	0.10 ± 0.016 sec	
#18	150G-2	IG-2	40	—	39	—	25	26	0.10 ± 0.016 sec.	
19	46-1	IA-1	54	—	53	—	27	28	15.6 sec. ± 7%	
		IB-1	52	—	51	—	27	28	15.6 sec. ± 7%	
		IC-1	50	—	49	—	27	28	15.6 sec. ± 7%	
20	46-2	IA-2	46	—	45	—	25	26	15.6 sec. ± 7%	
		IB-2	44	—	43	—	25	26	15.6 sec. ± 7%	
		IC-2	42	—	41	—	25	26	15.6 sec. ± 7%	
21	Metering	IA-1	54	—	53	—	—	—	100 ± 6 amperes	
		IB-1	52	—	51	—	—	—	100 ± 6 amperes	
		IC-1	50	—	49	—	—	—	100 ± 6 amperes	
		IN-1	48	—	47	—	—	—	100 ± 6 amperes	
		IA-2	46	—	45	—	—	—	100 ± 6 amperes	
		IB-2	44	—	43	—	—	—	100 ± 6 amperes	
		IC-2	42	—	41	—	—	—	100 ± 6 amperes	
		IG-2	40	—	39	—	—	—	100 ± 6 amperes	

Table 12-2. Test Connections (continued)

Testing The 3 Winding TPU-2000R

Change the following CONFIGURATION settings from the factory default for tests 1-4:

• Transformer Configuration	Tnfr Cfg	=	Delta1-Delta 2-Delta3
• Phase Compensation	Phase Comp 1-2	=	0°
	Phase comp 1-3	=	0°

Differential Tests

Test 1: Testing the 87T Differential Unit Minimum Pickup:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	6.0
87T-2 Tap Selection	87T-2	=	6.0
87T-3 Tap Selection	87T-3	=	6.0

Make the test connections as shown in Figure 12-2 for the 87T phase pairs to be tested. Set the winding 1 and winding 2 currents to 0.50 (0.10) amperes RMS. Set the winding 1 and winding 2 current source angles to 0 degrees.

Apply the currents. Slowly **raise** only the winding 2 current from 0.50 (0.10) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The “Differential” target along with the phase target should light. This should occur when the winding 2 current reaches 0.70 (0.14) amperes RMS ± 3%.

Repeat this test for all phase pairs listed in Table 12-3.

Tests 2: Testing the 87T Differential Unit With Adjustable Percent Slope Setting:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0

Make the test connections as shown in Figure 12-2 for the 87T phase pairs to be tested. Set winding 1 and winding 2 currents to 6.00 (1.20) amperes RMS. Set the winding 2 current source angle to 180 degrees.

Apply the currents. Slowly **raise** only the winding 2 current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The “Differential” target along with the phase target should light. This should occur when winding 2 current reaches 7.80 (1.56) amperes RMS ± 3% .

Repeat this test for all phase pairs listed in table 12-3.

Tests 3: Testing the 87T Differential Unit With Fixed Setting:

87T Selection	87T Select	=	25% Tap
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0

Make the test connections as shown in Figure 12-2 for the 87T phase pairs to be tested. Set winding 1 and winding 2 currents to 6.00 (1.20) amperes RMS. Set the winding 2 current source angle to 180 degrees.

Apply the currents. Slowly **raise** only the winding 2 current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The “Differential” target along with the phase target should light. This should occur when the winding 2 current reaches 7.60 (1.52) amperes RMS ± 3% .

*Repeat this test for all phase pairs listed in Table 12-3.

Tests 4: Testing the 87T Differential Unit With HU30% Setting:

87T Selection	87T Select	=	HU 30%
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0

Make the test connections in as shown in Figure 12-2 for the 87T phase pairs to be tested. Set winding 1 and winding 2 currents to 6.00 (1.20) amperes RMS. Set the winding 2 current source angle to 180 degrees.

Apply the currents. Slowly **lower** only the winding 2 current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the winding 2 current reaches 4.70 (0.94) amperes RMS ± 3% .

*Repeat this test for all phase pairs listed in Table 12-3.

Test 5: Testing the 87T Differential Unit With Harmonic Restraint:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	6.0
87T-2 Tap Selection	87T-2	=	6.0
87T-3 Tap Selection	87T-3	=	6.0

Make the test connections as shown in Figure 12-2 for the 87T phase pairs to be tested. Set winding 1 and winding 3 currents to 0.50 (0.10) amperes RMS. Set the winding 1 and winding 3 current source angles to 0 degrees.

Apply the currents. Slowly **raise** only the winding 3 current from 0.50 (0.10) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the winding 3 current reaches 0.70 (0.14) amperes RMS ± 3%.

*Repeat this test for all phase pairs listed in Table 12-3.

Test 6: Testing the 87T Differential Unit With Adjustable Percent Slope Setting:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0

Make the test connections as shown in Figure 12-2 for the 87T phase pairs to be tested. Set the winding 1 and winding 3 currents to 6.00 (1.20) amperes RMS. Set the winding 3 current source angle to 180 degrees.

Apply the currents. Slowly **raise** only the winding 3 current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the winding 3 current reaches 7.80 (1.56) amperes RMS ± 3% .

*Repeat this test for all phase pairs listed in Table 12-3.

Test 7: Testing the 87T Differential Unit With Fixed Setting:

87T Selection	87T Select	=	25% Tap
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0

Make the test connections as shown in Figure 12-2 for the 87T phase pairs to be tested. Set the winding 1 and winding 3 currents to 6.00 (1.20) amperes RMS. Set the winding 3 current source angle to 180 degrees.

Apply the currents. Slowly **raise** only the winding 3 current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the winding 3 current reaches 7.60 (1.52) amperes RMS ± 3%.

*Repeat this test for all phase pairs listed in Table 12-3.

Test 8: Testing the 87T Differential Unit With HU30% Setting:

87T Selection	87T Select	=	HU 30%
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0

Make the test connections as shown in Figure 12-2 for the 87T phase pairs to be tested. Set the winding 1 and winding 3 currents to 6.00 (1.20) amperes RMS. Set the winding 3 current source angle to 180 degrees.

Apply the currents. Slowly **lower** only the winding 3 current from 6.00 (1.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when the winding 3 current reaches 4.70 (0.94) amperes RMS ± 3%.

*Repeat this test for all phase pairs listed in Table 12-3.

Test 9: Testing the 87T Differential Unit With Harmonic Restraint:

(This test requires a current source with synchronized adjustable frequency sources.)

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0

Make the test connections as shown in Figure 12-2 for the 87T HARM phase pairs to be tested (both sources synchronized and in parallel). Set current source 1 to 6.00 (1.20) amperes RMS at 0 degrees 60 Hz. Set current source 2 to 1.00 (0.20) amperes RMS at 0 degrees 120 Hz.

Apply the currents. The TPU-2000R display should read "Trip Restrained". Slowly lower only current source 2 from 1.00 (0.20) amperes RMS until the relay trips. The contact monitor should indicate a closed contact. The "Differential" target along with the phase target should light. This should occur when current source 2 is between 0.90 (0.18) and 0.80 (0.16) amperes RMS.

*Repeat this test for all phase pairs listed in Table 12-3.

Test 10: Testing the 87H Differential Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	% Slope
87T-1 Tap Selection	87T-1	=	2.0
87T-2 Tap Selection	87T-2	=	2.0
87T-3 Tap Selection	87T-3	=	2.0
51P-1 Selection	51P-1	=	Disable
51P-2 Selection	51P-2	=	Disable
51P-3 Selection	51P-3	=	Disable
51N-1 Selection	51N-1	=	Disable
51N-2 Selection	51N-2	=	Disable
51N-3 Selection	51N-3	=	Disable

Make the test connections as shown in Figure 12-2 for the 87H phase pairs to be tested. Set the current source 1 to 11.0 (2.2) amperes RMS at 60 Hz. Set current source 2 to 11.0 A at 120 Hz (both sources synchronized and in parallel).

Suddenly apply the current for 1 second. The TPU2000R Relay should read “Trip Restrained.”

Set the current source 1 to 13.0 (2.6) amperes RMS at 60 Hz. Set current source 2 to 13.0 A at 120 Hz. Suddenly apply the current for 1 second. The relay should trip. The contact monitor should indicate a closed contact. The “Differential” target along with the phase target light. Go to the fault records and verify that the last trip was initiated by the 87H unit.

Repeat the test for all of the phase pairs listed in Table 12-3.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Phase Overcurrent Tests

In the programmable outputs menu in ECP, map 51P-1, 50P-1, 150P-1, 46-1, 51N-1, 50N-1, 150N-1 to OUT 1. Map 51P-2, 50P-2, 150P-2, 46-2, 51N-2, 50N-2, 150N-2 to OUT 2. Map 51P-3, 50P-3, 150P-3, 46-3, 51N-3, 50N-3, 150N-3 to OUT 3. Map 51G, 50G, 150G, to OUT 4.

Test 11: Testing the Winding 1 51P-1 Phase Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-1 Selection	51P-1	=	Extreme Inv
50P-1 Selection	50P-1	=	Disable

Make the test connections as shown in Figure 12-2 for the 51P-1 phase pairs to be tested. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51P-1 unit should trip in 15.6 seconds ± 7%. The Time and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

Test 12: Testing the Winding 2 51P-2 Phase Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-2 Selection	51P-2	=	Extreme Inv
50P-2 Selection	50P-2	=	Disable

Make the test connections as shown in Figure 12-2 for the 51P-2 phase pairs to be tested. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51P-2 unit should trip in 15.6 seconds ± 7%. The Time and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

Test 13: Testing the Winding 3 51P-3 Phase Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-3 Selection	51P-3	=	Extreme Inv
50P-3 Selection	50P-3	=	Disable

Make the test connections as shown in Figure 12-2 for the 51P-3 phase pairs to be tested. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51P-3 unit should trip in 15.6 seconds ± 7%. The Time and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

Test 14: Testing the Winding 1 150P-1 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-1 Selection	51P-1	=	Extreme Inv
50P-1 Selection	50P-1	=	Disable
150P-1 Selection	150P-1	=	Enable

Make the test connections as shown in Figure 12-2 for the 150P-1 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150P-1 unit should trip in 0.10 ±.01 seconds. The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Figure 12-3.

CAUTION: Do not allow high currents to persist. If tripping is not obtained within specified time, shut off the current and review your set up.

Test 15: Testing the Winding 2 150P-2 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-2 Selection	51P-2	=	Extreme Inv
50P-2 Selection	50P-2	=	Disable
150P-2 Selection	150P-2	=	Enable

Make the test connections as shown in Figure 12-2 for the 150P-2 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150P-2 unit should trip in 0.10 ±.01 seconds. The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

CAUTION: Do not allow high currents to persist. If tripping is not obtained within specified time, shut off the current and review your set up.

Test 16: Testing the Winding 3 150P-3 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51P-3 Selection	51P-3	=	Extreme Inv
50P-3 Selection	50P-3	=	Disable
150P-3 Selection	150P-3	=	Enable

Make the test connections as shown in Figure 12-2 for the 150P-3 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150P-3 unit should trip in 0.10 ±.01 seconds. The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

CAUTION: Do not allow high currents to persist. If tripping is not obtained within specified time, shut off the current and review your set up.

Test 17: Testing the Winding 1 50P-1 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50P-1 Selection	50P-1	=	Standard
150P-1 Selection	150P-1	=	Disable

Make the test connections as shown in Figure 12-2 for the 50P-1 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50P-1 unit should trip instantaneously (minimal delay). The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 18: Testing the Winding 2 50P-2 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50P-2 Selection	50P-2	=	Standard
150P-2 Selection	150P-2	=	Disable

Make the test connections as shown in Figure 12-2 for the 50P-2 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50P-2 unit should trip instantaneously (minimal delay). The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 19: Testing the Winding 3 50P-3 Phase Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50P-3 Selection	50P-3	=	Standard
150P-3 Selection	150P-3	=	Disable

Make the test connections as shown in Figure 12-2 for the 50P-3 phase pairs to be tested. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50P-3 unit should trip instantaneously (minimal delay). The Instantaneous and Phase targets should light.

Repeat the test for all of the phase pairs listed in Table 12-3.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Neutral Overcurrent Tests

Test 20: Testing the Winding 1 50N-1 Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51N-1 Selection	51N-1	=	Enable
50N-1 Selection	50N-1	=	Standard
150N-1 Selection	150N-1	=	Disable
51P-1 Selection	51P-1	=	Disable

Make the test connections as shown in Figure 12-2 for the 50N-1 unit. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50N-1 unit should trip instantaneously (minimal delay). The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 21: Testing the Winding 2 50N-2 Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51N-2 Selection	51N-2	=	Enable
50N-2 Selection	50N-2	=	Standard
150N-2 Selection	150N-2	=	Disable
51P-2 Selection	51P-2	=	Disable

Make the test connections as shown in Figure 12-2 for the 50N-2 unit. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50N-2 unit should trip instantaneously (minimal delay). The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 22: Testing the Winding 3 50N-3 Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
51N-3 Selection	51N-3	=	Enable
50N-3 Selection	50N-3	=	Standard
150N-3 Selection	150N-3	=	Disable
51P-3 Selection	51P-3	=	Disable

Make the test connections as shown in Figure 12-2 for the 50N-3 unit. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50N-3 unit should trip instantaneously (minimal delay). The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 23: Testing the 50G Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
150G-1 Selection	150G	=	Disable

Make the test connections as shown in Figure 12-2 for the 50G unit. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 50G unit should trip instantaneously (minimal delay). The Instantaneous and Ground targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 24: Testing the Winding 1 51N-1 Neutral Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-1 Selection	50N-1	=	Disable
150N-1 Selection	150N-1	=	Disable
51P-1 Selection	51P-1	=	Disable

Make the test connections as shown in Figure 12-2 for the 51N-1 unit. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51N-1 unit should trip in 15.6 seconds ± 7%. The Time and Neutral (N) targets should light.

Test 25: Testing the Winding 2 51N-2 Ground Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-2 Selection	50N-2	=	Disable
150N-2 Selection	150N-2	=	Disable
51P-2 Selection	51P-2	=	Disable

Make the test connections as shown in Figure 12-2 for the 51N-2 unit. Set the current source to 12.00 (2.4) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51N-2 unit should trip in 15.6 seconds ± 7%. The Time and Neutral (N) targets should light.

Test 26: Testing the Winding 3 51N-3 Neutral Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-3 Selection	50N-3	=	Disable
150N-3 Selection	150N-3	=	Disable
51P-3 Selection	51P-3	=	Disable

Make the test connections as shown in Figure 12-2 for the 51N-3 unit. Set the current source to 12.0 (2.40) amperes RMS (2 x pickup). Set the timer to start upon application of current.

Apply the current. The 51N-3 unit should trip in 15.6 seconds ± 7%. The Time and Neutral (N) targets should light.

Test 27: Testing the 51G Ground Time-Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50G Selection	50G	=	Disable

Make the test connections as shown in Figure 12-2 for the 51G unit. Set the current source to 12.00 (2.4) amperes RMS (2*pickup). Set the timer to start upon application of current.

Apply the current. The 51G unit should trip in 15.6 seconds ± 7%. The Time and Ground (G) targets should light.

Test 28: Testing the Winding 1 150N-1 Neutral Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-1 Selection	50N-1	=	Disable
150N-1 Selection	150N-1	=	Enable
51P-1 Selection	51P-1	=	Disable

Make the test connections as shown in Figure 12-2 for the 150N-1 test. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150N-1 unit should trip in 0.10 ±.016 seconds. The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained within specified time, shut off the current and review your set up.

Test 29: Testing the Winding 2 150N-2 Neutral Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-2 Selection	50N-2	=	Disable
150N-2 Selection	150N-2	=	Enable
51P-2 Selection	51P-2	=	Disable

Make the test connections as shown in Figure 12-2 for the 150N-2 test. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150N-2 unit should trip in 0.10 ±.016 seconds. The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained within specified time, shut off the current and review your set up.

Test 30: Testing the Winding 3 150N-3 Neutral Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50N-3 Selection	50N-3	=	Disable
150N-3 Selection	150N-3	=	Enable
51P-3 Selection	51P-3	=	Disable

Make the test connections as shown in Figure 12-2 for the 150N-3 test. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150N-3 unit should trip in 0.10 ±.016 seconds. The Instantaneous and Neutral (N) targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained instantaneously, shut off the current and review your set up.

Test 31: Testing the 150G Ground Instantaneous Overcurrent Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
50G Selection	50G	=	Disable
150G Selection	150G	=	Enable

Make the test connections as shown in Figure 12-2 for the 150G test. Set the current source to 20.0 (4.0) amperes RMS. Set the timer to start upon application of current.

Apply the current for 1 second. The 150G unit should trip in 0.10 ±.016 seconds. The Instantaneous and Ground targets should light.

CAUTION: Do not allow high currents to persist. If tripping is not obtained within specified time, shut off the current and review your set up.

Negative Sequence Tests

Test 32: Testing the Winding 1 46-1 Negative Sequence Time Over-current Unit:

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
46-1 Selection	46-1 Curve	=	Extreme Inv
46-1 Selection	46-1 Pickup	=	2.0
46-1 Selection	46-1 Time Dial	=	5.0
51P-1 Selection	51P-1	=	Disable
51N-1 Selection	51N-1	=	Disable

Make the test connections as shown in Figure 12-2 for the 46-1 unit. Set the current source to 12.0 (2.4) amperes RMS (2 x pickup single phase mode). Set the timer to start upon application of current.

Apply the current and remove it as soon as the relay trips. The 46-2 unit should trip in 15.6 seconds ± 7%. The Negative Sequence target should light. Allow the relay to cool for 3 minutes before proceeding.

Repeat the tests for all of the phase pairs listed in Table 12-3.

Test 33: Testing the Winding 2 46-2 Negative Sequence Time Over-current Unit:

(This test requires a current test source capable of at least 40 amperes RMS.)

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
46-2 Selection	46-2 Curve	=	Extreme Inv
46-2 Selection	46-2 Pickup	=	2.0
46-2 Selection	46-2 Time Dial	=	5.0
51P-2 Selection	51P-2	=	Disable
51N-2 Selection	51N-2	=	Disable

Make the test connections as shown in Figure 12-2 for the 46-2 unit. Set the current source to 12.0 (2.4) amperes RMS (2 x pickup single phase mode). Set the timer to start upon application of current.

Apply the current and remove it as soon as the relay trips. The 46-2 unit should trip in 15.6 seconds ± 7%. The Negative Sequence target should light.

Repeat the tests for all of the phase pairs listed in Table 12-3.

Test 34: Testing the Winding 3 46-3 Negative Sequence Time-Overcurrent Unit:

(This test requires a current test source capable of at least 40 (8.0) amperes RMS.)

Verify or change the following PRIMARY settings for this test:

87T Selection	87T Select	=	Disable
46-3 Selection	46-3 Curve	=	Extreme Inv
46-3 Selection	46-3 Pickup	=	2.0
46-3 Selection	46-3 Time Dial	=	5.0
51P-3 Selection	51P-3	=	Disable
51N-3 Selection	51N-3	=	Disable

Make the test connections as shown in Figure 12-2 for the 46-3 unit. Set the current source to 12.0 (2.4) amperes RMS (2 x pickup single phase mode). Set the timer to start upon application of current.

Apply the current and remove it as soon as the relay trips. The 46-3 unit should trip in 15.6 seconds ± 7%. The Negative Sequence target should light.

Repeat the tests for all of the phase pairs listed in Table 12-3.

Test 35: Metering Tests:

Set the current source to 1.00 amperes RMS. Apply the current to each current input on the TPU-2000R and watch the metering on the front panel display or ECP program. The values seen should be 100 ± 6 amperes RMS.

IMPORTANT: To return the unit to service, the settings must be restored to the in-service values. Follow the procedure outlined at the beginning of the testing section, Sending Settings to the Relay. If the unit is not to be placed into service, the factory default settings should be restored. This can be down by downloading a previously saved default file or by manually checking each setting.

When applying current to one phase at a time, neutral current on the winding will also be present.

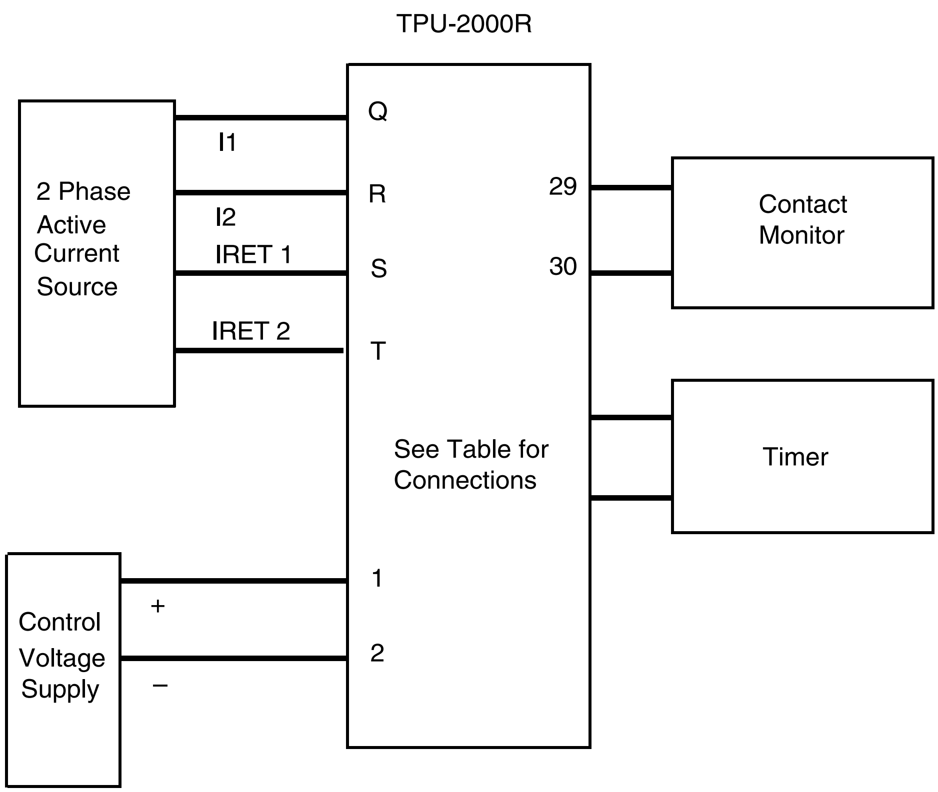


Figure 12-2. TPU-2000R Test Connections

Test Number	Function Under Test	Phase Inputs Under Test		Connections Q	R	S	T	TIMER		Expected Value	Tested Value
#1	87T Minimum Operate	IA-1	IA-2	54	48	53	47	-	-	0.7 (0.14) amperes ± 3%	
		IB-1	IB-2	52	46	51	45	-	-	0.7 (0.14) amperes ± 3%	
		IC-1	IC-2	50	44	49	43	-	-	0.7 (0.14) amperes ± 3%	
#2	87T % Slope	IA-1	IA-2	54	48	53	47	-	-	7.8 (1.56) amperes ± 3%	
		IB-1	IB-2	52	46	51	45	-	-	7.8 (1.56) amperes ± 3%	
		IC-1	IC-2	50	44	49	43	-	-	7.8 (1.56) amperes ± 3%	
#3	87T Fixed 25%	IA-1	IA-2	54	48	53	47	-	-	7.6 (1.52) amperes ± 3%	
		IB-1	IB-2	52	46	51	45	-	-	7.6 (1.52) amperes ± 3%	
		IC-1	IC-2	50	44	49	43	-	-	7.6 (1.52) amperes ± 3%	
#4	87T HU 30%	IA-1	IA-2	54	48	53	47	-	-	4.7 (0.94) amperes ± 3%	
		IB-1	IB-2	52	46	51	45	-	-	4.7 (0.94) amperes ± 3%	
		IC-1	IC-2	50	44	49	43	-	-	4.7 (0.94) amperes ± 3%	
#5	87T Minimum Operate	IA-1	IA-3	54	42	53	41	-	-	0.7 (0.14) amperes ± 3%	
		IB-1	IB-3	52	40	51	39	-	-	0.7 (0.14) amperes ± 3%	
		IC-1	IC-3	50	38	49	37	-	-	0.7 (0.14) amperes ± 3%	
#6	87T % Slope	IA-1	IA-3	54	42	53	41	-	-	7.8 (1.56) amperes ± 3%	
		IB-1	IB-3	52	40	51	39	-	-	7.8 (1.56) amperes ± 3%	
		IC-1	IC-3	50	38	49	37	-	-	7.8 (1.56) amperes ± 3%	
#7	87T Fixed 25%	IA-1	IA-3	54	42	53	41	-	-	7.6 (1.52) amperes ± 3%	
		IB-1	IB-3	52	40	51	39	-	-	7.6 (1.52) amperes ± 3%	
		IC-1	IC-3	50	38	49	37	-	-	7.6 (1.52) amperes ± 3%	
#8	87T HU30%	IA-1	IA-3	54	42	45	41	-	-	4.7 (0.94) amperes ± 3%	
		IB-1	IB-3	52	40	43	39	-	-	4.7 (0.94) amperes ± 3%	
		IC-1	IC-3	50	38	41	37	-	-	4.7 (0.94) amperes ± 3%	
#9	87T HARM	IA-1		54	54	53	53	-	-	0.72 (0.144) - 1.08 (0.216)	
		IB-1		52	52	51	51	-	-	0.72 (0.144) - 1.08 (0.216)	
		IC-1		50	50	49	49	-	-	0.72 (0.144) - 1.08 (0.216)	
		IA-2		48	48	47	47	-	-	0.72 (0.144) - 1.08 (0.216)	
		IB-2		46	46	45	45	-	-	0.72 (0.144) - 1.08 (0.216)	
		IC-2		44	44	43	43	-	-	0.72 (0.144) - 1.08 (0.216)	
		IA-3		42	42	41	41	-	-	0.72 (0.144) - 1.08 (0.216)	
		IB-3		40	40	39	39	-	-	0.72 (0.144) - 1.08 (0.216)	
		IC-3		38	38	37	37	-	-	0.72 (0.144) - 1.08 (0.216)	

Table 12-3. Test Connections

Test Number	Function Under Test	Phase inputs Under Test	Connections						Expected Value	Tested Value
			Q	R	S	T	TIMER			
#10	87H	IA-1	54	54	53	53	-	-	12 (2.4) ± 0.84	
		IB-1	52	52	51	51	-	-	12 (2.4) ± 0.84	
		IC-1	50	50	49	49	-	-	12 (2.4) ± 0.84	
		IA-2	48	48	47	47	-	-	12 (2.4) ± 0.84	
		IB-2	46	46	45	45	-	-	12 (2.4) ± 0.84	
		IC-2	44	44	43	43	-	-	12 (2.4) ± 0.84	
		IA-3	42	42	41	41	-	-	12 (2.4) ± 0.84	
		IB-3	40	40	39	39	-	-	12 (2.4) ± 0.84	
		IC-3	38	38	37	37	-	-	12 (2.4) ± 0.84	
11	51P-1	IA-1	54	-	53	-	27	28	15.6 ± 7%	
		IB-1	52	-	51	-	27	28	15.6 ± 7%	
		IC-1	50	-	49	-	27	28	15.6 ± 7%	
12	51P-2	IA-2	48	-	47	-	25	26	15.6 ± 7%	
		IB-2	46	-	45	-	25	26	15.6 ± 7%	
		IC-2	44	-	43	-	25	26	15.6 ± 7%	
13	51P-3	IA-3	42	-	41	-	23	24	15.6 ± 7%	
		IB-3	40	-	39	-	23	24	15.6 ± 7%	
		IC-3	38	-	37	-	23	24	15.6 + 7%	
14	150P-1	IA-1	54	-	53	-	27	28	0.10 ± 0.016 sec.	
		IB-1	52	-	51	-	27	28	0.10 ± 0.016 sec.	
		IC-1	50	-	49	-	27	28	0.10 ± 0.016 sec.	
15	150P-2	IA-2	48	-	47	-	25	26	0.10 ± 0.016 sec.	
		IB-2	46	-	45	-	25	26	0.10 ± 0.016 sec.	
		IC-2	44	-	43	-	25	26	0.10 ± 0.016 sec.	
16	150P-3	IA-3	42	-	41	-	23	24	0.10 ± 0.016 sec.	
		IB-3	40	-	39	-	23	24	0.10 ± 0.016 sec.	
		IC-3	38	-	37	-	23	24	0.10 ± 0.016 sec.	
17	50P-1	IA-1	54	-	53	-	27	28	Instantaneous	
		IB-1	52	-	51	-	27	28	Instantaneous	
		IC-1	50	-	49	-	27	28	Instantaneous	
18	50P-2	IA-2	48	-	47	-	25	26	Instantaneous	
		IB-2	46	-	45	-	25	26	Instantaneous	
		IC-2	44	-	43	-	25	26	Instantaneous	

Table 12-3. Test Connections (continued)

Test Number	Function Under Test	Phase Inputs Under Test	Connections						Expected Value	Tested Value
			Q	R	S	T	TIMER			
19	50P-3	IA-3	42	—	41	—	23	24	Instantaneous	
		IB-3	40	—	39	—	23	24	Instantaneous	
		IC-3	38	—	37	—	23	24	Instantaneous	
20	50N-1	IA-1	54	—	53	—	27	28	Instantaneous	
21	50N-2	IA-2	48	—	47	—	25	26	Instantaneous	
22	50N-3	IA-3	42	—	41	—	23	24	Instantaneous	
23	50G	IG	36	—	35	—	22	21	Instantaneous	
24	51N-1	IA-1	54	—	53	—	27	28	15.6 sec. ± 7%	
25	51N-2	IA-2	48	—	47	—	25	26	15.6 sec. ± 7%	
26	51N-3	IA-3	42	—	41	—	23	24	15.6 sec. ± 7%	
27	51G	IG	36	—	35	—	21	22	15.6 sec. ± 7%	
28	150N-1	IA-1	54	—	53	—	27	28	0.10 ± 0.01 sec.	
29	150N-2	IA-2	48	—	47	—	25	26	0.10 ± 0.01 sec.	
30	150N-3	IA-3	42	—	41	—	23	24	0.10 ± 0.01 sec.	
31	150G	IG	36	—	35	—	22	21	0.10 ± 0.01 sec.	
32	46-1	IA-1	54	—	53	—	27	28	15.6 sec. ± 7%	
		IB-1	52	—	51	—	27	28	15.6 sec. ± 7%	
		IC-1	50	—	49	—	27	28	15.6 sec. ± 7%	
33	46-2	IA-2	48	—	47	—	25	26	15.6 sec. ± 7%	
		IB-2	46	—	45	—	25	26	15.6 sec. ± 7%	
		IC-2	44	—	43	—	25	26	15.6 sec. ± 7%	
34	46-3	IA-3	42	—	41	—	23	24	15.6 sec. ± 7%	
		IB-3	40	—	39	—	23	24	15.6 sec. ± 7%	
		IC-3	38	—	37	—	23	24	15.6 sec. ± 7%	
35	Metering	IA-1	54	—	53	—	—	—	100 ± 6 amperes	
		IB-1	52	—	51	—	—	—	100 ± 6 amperes	
		IC-1	50	—	49	—	—	—	100 ± 6 amperes	
		IA-2	48	—	47	—	—	—	100 ± 6 amperes	
		IB-2	46	—	45	—	—	—	100 ± 6 amperes	
		IC-2	44	—	43	—	—	—	100 ± 6 amperes	
		IA-3	42	—	41	—	—	—	100 ± 6 amperes	
		IB-3	40	—	39	—	—	—	100 ± 6 amperes	
		IC-3	38	—	37	—	—	—	100 ± 6 amperes	
		IG	36	—	35	—	—	—	100 ± 6 amperes	

Table 12-3. Test Connections (continued)

Testing Programmable Logic

The TPU-2000R contains features to help verify the correct operation of the Programmable Logic. These features are found under the “Operations Menu” and are used to force the physical I/O and Logical Inputs to a particular logic state. In this way, the outputs of the logic function can then be examined, using the “Show Logical Outputs” command in the Test Menu, and the logic modified if necessary to produce the desired result.

Be aware that protection function inputs to the Programmable Logic cannot be forced. In order to produce the active state of a protection function, currents and/or voltages must be applied to simulate the appropriate fault condition. Refer to the Acceptance Test procedure earlier in this section.

Forced Physical Inputs and Outputs

To force a physical input, use ECP and the following procedure:

- From the ECP Main Menu, select “Operations Menu.” The Operations Menu appears.
- Select “Force Physical Input.” The Force Phys. Input screen appears.
- Select “Open” or “Close” to force the input or “Normal” to return it to its normal, non-forced state.

To force a physical output, use ECP and the following procedure:

- From the ECP Main Menu, select “Operations Menu.” The Operations Menu appears.
- Select “Force Physical Output.” The Force Phys. Out screen appears.
- Select “Assert” or “De-Assert” to force the output or “Normal” to return the contact to its normal, non forced state.

Forced Logical Inputs

To force a logical input, use ECP and the following procedure:

From the ECP Main Menu, select “Operations Menu.” The Operations Menu appears.

Select “Force Logical Input.” The Forced Logical Inputs screen appears.

Select “Open” or “Close” to force the ULI to a 0F (disabled) state or a 1F (enabled) state, respectively. Select “Normal” to return it to its normal, non-forced state. The ULI will remain in the same state that it was forced, but can now change depending on the logic.

Test Example

The same logic as in the Programmable I/O "Multilevel Programmable Logic" section example will be used to demonstrate using Forced I/O to test the logic designed to seal in a trip from a differential fault until the breaker opens. In operation, the process would start with the relay detecting a differential fault and asserting 87T and/or 87H. The high level output of OR gate A inputs to OR gate C which outputs a high level and operates the trip contact. Gate A also activates AND gate B which already sees a high level from the closed 52a contact. The output of gate B inputs a high level back to gate A to seal in the trip signal for when the 87 functions are no longer asserted. When the breaker opens, the 52a contact opens and outputs a low level disabling gate B. Because there is a low level from gate B and the 87 function is no longer asserted, gate C outputs a low level and de-energizes the trip contact.

1) Before testing the logic, use the items under the Test Menu to examine the states of all affected Logical and Physical I/O. Specifically, confirm that:

    - IN-4 is Open
    - OUT-2 is De-Energized
    - ULI1 and ULI2 are Disabled
    - ULO1 and ULO2 are Not Energized

2) If it is not convenient to apply current to the relay to create an 87 condition, another connected ULI/ULO pair can be used to act as the initial input to gate A. Use ULI3 and ULO3 for this purpose. Map ULO3 to an input of gate A just like ULO1 and ULO2. Use "Force Logical Input" in the Operations Menu to force ULI3 active (1F). Also, use "Force Physical Input" to force IN-4 closed to indicate a closed breaker.

    Use the Test Menu to confirm that:

    - IN-4 is Closed
    - OUT-2 is Asserted
    - ULI1 and ULI2 are Asserted
    - ULO1 and ULO2 are Asserted

3) Again use "Force Logical Input" to disable ULI3 (0F). Use the Test Menu to confirm that all signals listed in step 2 have not changed; the trip has sealed in.

4) Force IN-4 inactive to simulate the breaker opening. Use the Test Menu to confirm that:

    - IN-4 is Open
    - OUT-2 is De-Energized
    - ULI1 and ULI2 are Not Asserted
    - ULO1 and ULO2 are Not Asserted

5) Return all forced signals to their "Normal" state.

WARNING: When any signal is in the "Forced" state, the green Normal LED blinks on and off. Make certain that all forced signals have been returned to "Normal" before putting the relay back into service.

Parts and Assemblies

The following table lists the parts and assemblies involved in the TPU-2000R.

Table 13-1. TPU-2000R Parts and Assemblies Table

Part and Assembly Description	Part Number
125-Vdc Power Supply Assembly	613806-K2
48-Vdc Power Supply Assembly	613806-K1
24-Vdc Power Supply Assembly	613806-K1
RS-232 Port Front or Rear Comm 1	613800-T2
RS-232 Card (non isolated Comm 2)	613811-T1
RS-232 Card (isolated Comm 3)	613630-T10
Aux Comm & RS-232 Card (isolated comm 3)	613624-T8
INCOM (isolated)	613624-T6
Aux Comm & INCOM (isolated)	613624-T7
RS-485 (isolated)	613630-T6
Modbus Plus & RS-232 (non isolated comm 2)	613628-T3
Modbus Plus & RS-485 (isolated)	613628-T4
Horizontal Panel Mount Kit	604513-K1
Vertical Panel Mount Kit	604513-K2
Bezel/gasket assembly only	604513-K3
Horizontal lens cover only	613724-K1
Vertical lens cover only	613724-K2

Replacing Power Supplies

To replace an exisiting power supply with a power supply of the same voltage, simply remove the TPU2000R relay from its case. the power supply board is located on the underside of the relay. Remove the four (4) mounting screws and the two (2) white plastic connectors. Reinstall with new board.

If the user is replacing the power supply with a power supply with a different voltage, follow the above procedure and note the following:

1. When going from a 125 VDC supply to a 48 or 24 VDC supply, Jumper J3 should be installed. On some newer relays, the jumper should be moved to the LOW position.
2. When going from a 24 or 48 VDC supply to a 125 VDC supply, Jumper J3 should be removed. On some newer relays, the jumper should be moved to the HIGH position.

Jumper J3 is located on the CPU Board near the two (2) rear RS-232 ports.

Please note that the unit catalog number will not be affected by changing the power supplies. Therefore, when changing power supply voltages, the sixth digit in the catalog number will be wrong. If the user wants this remedied, please contact the factory.

Panel Mounting Kit

The complete kit will include a bezel, its associated hardware and gasket, as well as a lens cover with its associated hardware. This kit will provide a means for panel mounting and dustproofing.

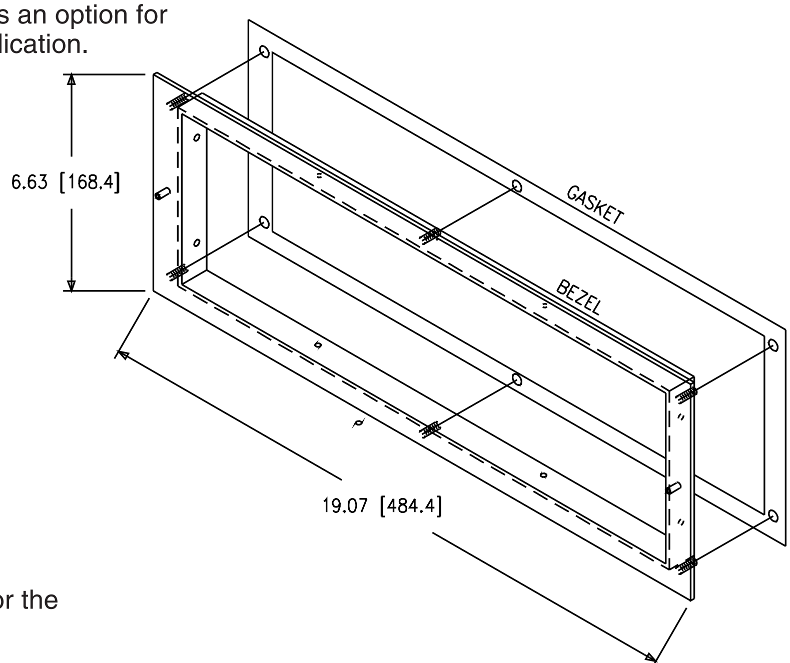
Ordering Information:

Horizontal Panel Mounting Kit	604513-K1
Vertical Panel Mounting Kit	604513-K2

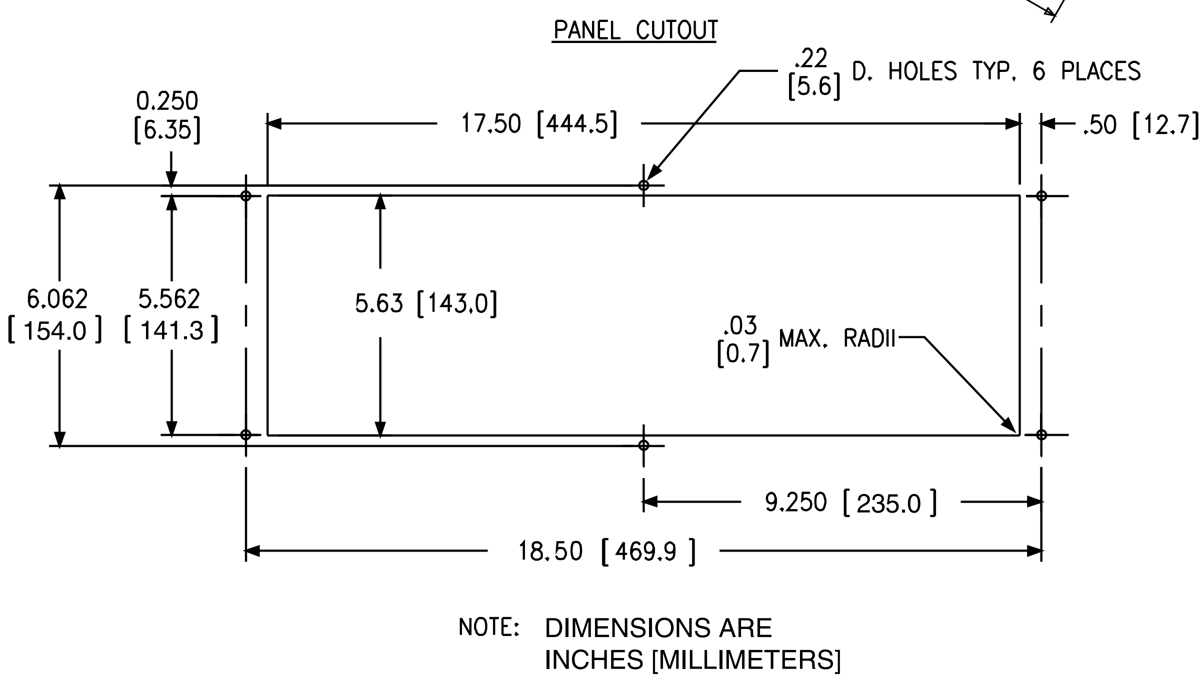
Spare Parts List:

Bezel/gasket assembly only	604513-K3
Horizontal lens cover assembly	613724-K1
Vertical lens cover assembly	613724-K2

Note: The Bezel Assembly is available as an option for mounting the 2000R units in a panel application.



Note: Below is the panel drilling cutout for the TPU-2000R unit and the bezel assembly.



Communications Ports

The TPU-2000R has a standard 9-pin RS-232C interface on the front for serial port communications. Connect a 9-pin RS-232C cable from this port to your personal computer to have direct point-to-point communications through the ECP. Refer to the External Communications section of this manual, for the proper communications parameters.

As an option, a serial port termination can be provided at the rear of the TPU-2000R. This rear port, called the Auxiliary Communications port, can be a 9-pin RS-232C, 3-wire RS-485, 2-wire INCOM, IRIG-B or SCADA Interface Unit (SIU) connection. Because the hardware termination for all these options is on every TPU-2000R, you must refer to the catalog number on the front of the unit or to the software communications menu to know which rear port option is implemented. An IRIG-B input for precision real-time setting is furnished with the rear communications port catalog options 2, 3 or 4 (see "Ordering Selections" on the last page of this instruction book). The rear RS-232C port can interface with a modem and a remotely connected computer or you can attach a computer directly to the rear RS-232C port. The RS-232C ports are configured as data terminal equipment.

The TPU-2000R supports various byte-oriented protocols. The command message structure and substructures for these protocols are available upon request. Contact the nearest ABB sales office or ABB at its Allentown, PA factory for information about the emulation of SCADA protocols via the rear Auxiliary Communications port (SIU). Use the External Communications Program (ECP) shipped with the relay to communicate with the TPU-2000R via the following protocols:

- STANDARD~~–A~~BB 2000 series-specific ASCII oriented 10 byte communication protocol available through all ports
- SPACOM~~–a~~ protocol available through the Auxiliary Communications port
- INCOM®~~–a~~ two-wire communications system and protocol
- DNP 3.0 (IEC870-5)~~–a~~ protocol available through the Auxiliary Communications port
- Modbus Plus™~~–a~~ token ring network capable of high speed communication (1 Mb/sec)

Pin Connections

The pin connections for the various communications ports are shown in Tables 13-2 and 13-3.

Table 13-2. RS-232 Pin Connections for 2 Winding TPU2000R

Pin Number	Pin Number
2	Receive data–Relay receives data through this pin.
3	Transmit data–Relay transmit data through this pin.
5	Signal ground–Front port has signal ground tied to the chasis; rear port signal ground is fully isolated.

Table 13-3. RS-485, INCOM, SIU and IRIG-B Pin Connections

Pin Number	Pin Number
64	IRIG-B Minus
63	IRIG-B Positive
62	INCOM
61	INCOM
60	+5 VDC at 100 milliamperes
59	Direction minus
58	Direction positive
57	RS-485 common/VDC return
56	RS-485 minus or SIU minus (aux. comm. port)
55	RS-485 positive or SIU positive (aux. comm. port)

RS-485 Port

For all communications hardware options with a single RS485 port, that port is provided at terminals 55(+), 56 (-), and 57 (com). See Table 13-3.

For communications hardware option #8, dual RS485 ports, terminals 55, 56, and 57 are designated RS485 Rear Port #2, and pins 1(+), 2 (-), and 7(com) of the Com #3 DB-9 connector represent RS485 Rear Port #1.

The RS485 port on the TPU2000R has three associated resistors and jumper links that allow insertion or removal of these resistors, depending on the location of the relay in the network. Jumper link J6 on the communications card is for the termination resistor. A termination resistor should be inserted at the first and last devices on the network. Typically J6 would be set for “IN” for the last relay on the RS485 network; and, J6 would be set in the “OUT” position for all other relays in the loop. The first unit on the network, typically an ABB 245X series convertor, has the terminating resitor built-in. For communication hardware option “8,” dual RS485 ports, J6 is for Port #2 and a similar jumper, J16 is provided for RS485 Port #1.

Jumper links J7 and J8 insert or remove “pull-up” resistors. These resistors establish a known voltage level on the RS485 bus when no units are transmitting, in order to reduce noise. These jumpers should be set to the “IN” position on only one relay at either end of the RS485 loop. If an ABB communications convertor, catalog series 245X, is used on the network, it has these resistors built-in, and all relays can have J7 and J8 in the out position. For communications hardware option “8”, dual RS485 ports, J7 and J8 are for Port #2, and J17 and J18 are for Port #1.

The RS485 cable should be shielded 3 conductor twisted cable. The shield should be grounded at one end of the communications circuit, preferably where the RS485 circuit begins; eg: at the convertor unit. A typical RS485 connection diagram, drawing 604765, is available on request from the factory.

Communications Settings

Change communications settings via the man-machine interface (MMI) on the front of the TPU-2000R or through the ECP. When you use the MMI, the communications ports are blocked from downloading settings but can still retrieve data. Similarly, when a communications port is downloading new settings, the MMI and other communications ports are blocked from changing or downloading settings but not from retrieving data.

Use the MMI to change all communications settings, such as baud rate, data bits, parity and stop bits. You can change settings locally or remotely. If you use a computer or modem to change the settings, be certain that the communications settings on your equipment match those of the TPU-2000R.

Set the communications settings (baud rate, [parity, data bits, stop bits]) for the front and rear ports as follows:

- Front port: 300, 1200, 2400, 4800 or 9600 [n, 8, 1 or n, 8, 2]
- Rear port: 300, 1200, 2400, 4800, 9600 or 19,200 [n, 8, 1 or n, 8, 2 or e, 8, 1 or odd, 8, 1 or e, 7, 1 or n, 7, 2 or odd, 7, 1].

Communication Port Configurations

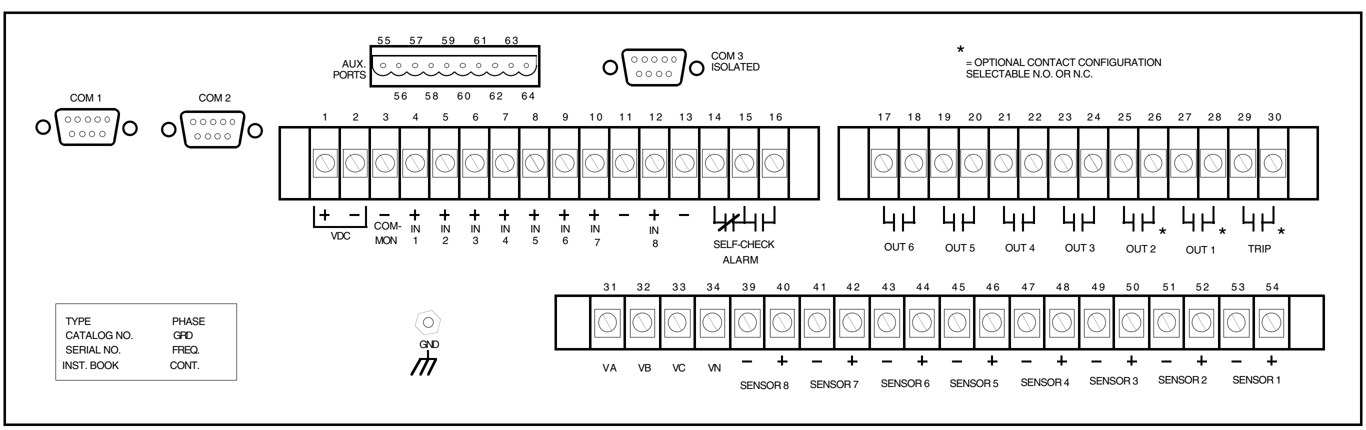
The 2000R platform provides several variations of communication ports, such as a 9-pin RS-232, RS-485, INCOM™ and Modbus Plus™. Also available is a list of factory supported common communication protocols for networking the unit.

RS-232 ports are available in two different configurations, Isolated and Non-Isolated. Isolated ports provide isolation between the communication port and the rest of the relay.

COM 1 port is configured as a non-isolated port only. Units having an MMI display use the RS-232 port on the front panel as COM 1, thereby permanently disabling the RS-232 port marked COM 1 on the rear of the unit. Units not having an MMI Display permit the user to select, via jumper setting, either the front or rear (labeled COM 1) RS-232 connectors to act as COM 1.

COM 2 port is a non-isolated configuration and COM 3 port is an isolated configuration. Refer to the following list of options to select the most suitable configuration.

The 2000R series also features ABB's innovative RS-485 isolated communications capability available when the optional Auxiliary Communication board is installed. This isolated RS-485 configuration provides superior communication quality recommended for applications in areas of high electrical noise or that require connecting cables longer than 10 feet (3m).



Rear Terminal Blocks and Communication Ports

NOTE: Non-isolated RS-232 ports are susceptible to electrical noise. For that reason it is recommended that connecting cables be no longer than 10 feet (3m) when connecting to a non-isolated port. Devices connected to non-isolated ports must have the same ground return as the 2000R unit.

Refer to the Select Communication Options Table when making option selections.

In addition to the standard front or rear non-isolated RS-232 port (COM 1), the following rear communication port options are available:

Option 0

This option provides RS-232 communication via the non-isolated COM 2 port and is suitable only in applications where communication to the unit is local through a direct connection to a PC or remote through an external isolating communication device , such as an RS-232 to fiber optic converter, which is connected to the relay using a short cable.

Options 1 through 8 are provided on an independent communication card installed in the unit.

Option 1

This option provides RS-232 communication via the isolated COM 3 port for transient immunity and isolation and must be used where communication cable lengths are greater than 10 feet (3m) or a common ground is not guaranteed. In general, RS-232 communication is limited to a maximum distance of 50 feet (15m). Aux Com and COM 2 ports are disabled in this configuration.

Option 2

This option provides RS-232 communication via isolated COM 3 port and RS-485 communication via the isolated Aux Com ports. The auxiliary port is an isolated RS-485 configuration that supports several communication protocols (*See Communication Protocol Category On Ordering Sheet*).

Option 3

This option provides INCOM™ availability, via the Aux Com port, in applications where either the Westinghouse INCOM™, or ABB WRELCOM™, network is used.

Option 4

This option provides RS-485 communication and INCOM™ availability, via the isolated Aux Com port. In this configuration, the INCOM™ port provides the same functionality as option 3.

Option 5

This option provides RS-485 communication via the isolated Aux Com port, and is highly recommended for applications requiring communication over distances of up to 300 feet (100m). This option has an advantage over RS-232 by allowing networking of multiple relays via a simple 3 wire connection.

An RS-485 to RS-232 converter (Catalog Number 245X2000) is available to connect the network to an external device such as a modem or a personal computer.

Option 6

This option provides a Modbus Plus™ interface, via the COM 3 port, and RS-232 communication via the non-isolated COM 2 port.

Option 7

This option provides a Modbus Plus™ interface via the COM 3 and RS-485 communication via the isolated Aux Com port.

Option 8

This option provides RS-485 communication via the isolated COM 3 and Aux Com ports.

Communication Protocols

The Select Options Table shows the communication protocols and the respective hardware port assignments that are currently available.

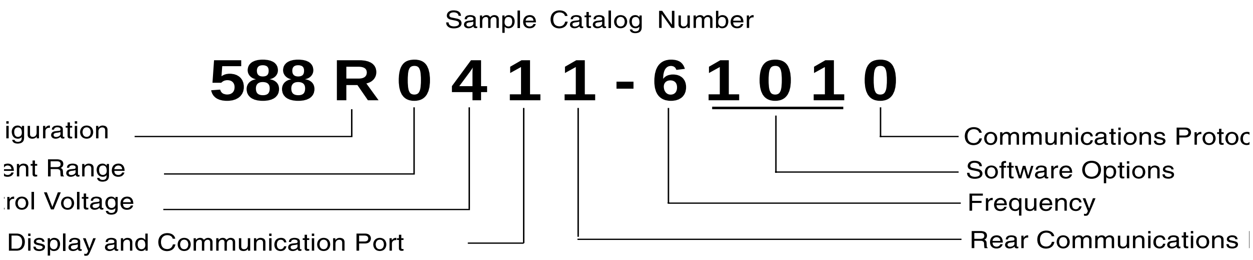
The "Standard" Protocol

The "Standard" protocol referenced throughout this publication refers to an ABB 2000 series-specific 10 byte ASCII oriented communication protocol. This protocol is standard for COM 1 and is selectable for other rear ports as per the Select Options Table. The 2000 series External Communication Program (ECP) provided, at no charge, with the relay uses the standard protocol.

Product specific protocol documents are available from the factory upon request.

Ordering Instructions

The 2000R series of relays have a structured catalog number ordering system. The unit's catalog number is built up from 13 customer-selectable characters. Each character identifies features or functions that can be incorporated into the relay.



How to Order

Using the Ordering Selection sheet, select those special features or options that are required to adapt the 2000R to your specific application. Create the catalog number, as shown above, by selecting the associated number or letter that refers to the desired feature or option from each category.

Software Options

The software options available on the 2000R series include Load Profile, User Programmable Curves, and Oscillograhic Data. Any combination of these options may be selected.

3 character locations in the catalog number define your selection of software options.

- Oscillographics
- User Programmable Curves
- Load Profile

The table below illustrates all possible hardware configurations for the communication ports and the supported protocols. The Catalog Number Select Option columns list every communication option for which the relays can be configured.

The different protocol variations are outlined under the corresponding communication ports that support them. Select the row containing the protocol combination that best suits your communications requirements and use the corresponding catalog number options to fill in the brackets [ ] of the catalog number.

The auxiliary port labelled IRIG-B receives a demodulated IRIG-B signal for 2000R clock synchronization purposes.

For example, if your system requires DNP 3.0 (IEC870-5) protocol, the ordering catalog number would be 588R041[**2**]-6101[**1**] (4th row), 588R041[**4**]-6101[**1**](10th row) or 588R041[**8**]-6101[**1**](18th row) based on your choice for the second port provided.

Select other characteristics of the relay from the following pages.

Catalog Number Select Option

588R041[ ] - 6101[ ]

REAR PORT ASSIGNMENTS

588R041[ ]	6101[ ]	With Display	Without Display* / COM 1 NON ISOLATED RS-232	COM 2 NON ISOLATED RS-232	COM 3 ISOLATED RS-232 unless noted	AUX. PORTS 55–60 RS-485 ISOLATED	61–62 INCOM ISOLATED	63–64 IRIG-B
0	0		Standard	Standard				
1	0		Standard		Standard			
2	0		Standard		Standard	Standard		IRIG-B
2	1		Standard		Standard DNP 3.0	DNP 3.0 Standard		
2	4		Standard		Modbus® or Standard See Note #	Modbus® or Standard See Note #		IRIG-B
3	0		Standard				INCOM	IRIG-B
4	0		Standard			Standard	INCOM	IRIG-B
4	1		Standard			DNP 3.0†	INCOM	
4	4		Standard			Modbus®	INCOM	IRIG-B
5	0		Standard			Standard		
6	4		Standard	Standard	Modbus® (Modbus Plus™)			
7	4		Standard		Modbus® (Modbus Plus™)	Standard		
# 8	0		Standard		Standard	Standard		IRIG-B
# 8	1		Standard		Standard DNP 3.0	DNP 3.0 Standard		
8	4		Standard		Modbus® or Standard (RS-485) See Note #	Modbus® or Standard See Note #		IRIG-B

Select Communication Options Table

An empty selection box indicates communication port is either not provided or is disabled.

Consult factory for availability.

* Main board jumper selectable front or rear.
# Protocol selectable in settings process, all 4 combinations possible.

Ordering Selections

Catalog Number Selection **5 8 8** R 0 4 1 1 – 6 1 0 0 0

Configuration

3 Windings	**T**
3 Windings w/voltage inputs	**Q**
2 Windings	**R**
2 Windings w/voltage inputs	**V**

Current Range

See following page for Current Range Options	**0 - K**

Control Voltage

38 — 58 Vdc	**3**
70 — 280 Vdc	**4**
19 — 29 Vdc	**9**

Man-Machine Interface / Mounting

Horizontal Mount Unit / No Man Machine Interface	**0**
Horizontal Mount Unit / Man Machine Interface	**1**
Vertical Mount Unit / No Man Machine Interface	**5**
Vertical Mount Unit / Man Machine Interface	**6**

Rear Communications Port (see table on previous page for futher explanation) (Front RS-232 port is standard equipment on all units)

RS-232 (non-isolated)	**0**
RS-232 (isolated)	**1**
Auxiliary Port & RS-232 (isolated)	**2**
INCOM™ (isolated)	**3**
Auxiliary Port & INCOM™ (isolated)	**4**
RS-485 (isolated)	**5**
Modbus Plus™ & RS-232 (non-isolated)	**6**
Modbus Plus™ & RS-485 (isolated)	**7**
Dual RS-485 Ports (isolated)	**8**

Frequency

50 Hertz	**5**
60 Hertz	**6**

Software Options

No Oscillographics	**0**
Oscillographics	**1**
No User Programmable Curves	**0**
User Programmable Curves	**1**
No Load Profile	**0**
Load Profile	**1**

Communications Protocol

Standard (10-Byte protocol)	**0**
DNP 3.0 (IEC 870-5)	**1**
SPACOM	**2**
Modbus®	**3**

Current Range Options

	Current Range						**Catalog Digit Selection**	
	Winding 1		Winding 2		Winding 3			
	Phase	Ground	Phase	Ground	Phase	Gound	Ground	No.
	1 – 12	1 – 12	1 – 12	1 – 12	—	—	—	0
	1 – 12	.2 – 2.4	1 – 12	.2 – 2.4	—	—	—	1
	.2 – 2.4	.2 – 2.4	.2 – 2.4	.2 – 2.4	—	—	—	2
	1 – 12	1 – 12	.2 – 2.4	.2 – 2.4	—	—	—	3
	.2 – 2.4	.2 – 2.4	1 – 12	1 – 12	—	—	—	4
	.02 – .24	.02 – .24	1 – 12	1 – 12	—	—	—	5
	.02 – .24	.02 – .24	1 – 12	.2 – 2.4	—	—	—	6
	.02 – .24	.02 – .24	.2 – 2.4	.2 – 2.4	—	—	—	7
	1 – 12	1 – 12	.02 – .24	.02 – .24	—	—	—	8
	1 – 12	.2 – 2.4	.02 – .24	.02 – .24	—	—	—	9
	.2 – .24	.2 – 2.4	.02 – .24	.02 – .24	—	—	—	A
	.02 – .24	.02 – .24	.02 – .24	.02 – .24	—	—	—	B
	1 – 12	—	1 – 12	—	1 – 12	—	1 – 12	C
	1 – 12	—	1 – 12	—	.2 – 2.4	—	1 – 12	D
	1 – 12	—	.2 – 2.4	—	.2 – 2.4	—	1 – 12	E
	.2 – 2.4	—	.2 – 2.4	—	.2 – 2.4	—	1 – 12	F
	1 – 12	—	1 – 12	—	1 – 12	—	.2 – 2.4	G
	1 – 12	—	1 – 12	—	.2 – 2.4	—	.2 – 2.4	H
	1 – 12	—	.2 – .24	—	.2 – 2.4	—	.2 – 2.4	J
	.2 – 2.4	—	.2 – 2.4	—	.2 – 2.4	—	.2 – 2.4	K
#	.2 – 2.4	—	1 – 12	—	1– 12	—	.2 – 2.4	L

Note: .02 – .24 range is for use with ABB Optical CT's.