PCD2000
Power Control Device

Instruction Book
IB38-737-3

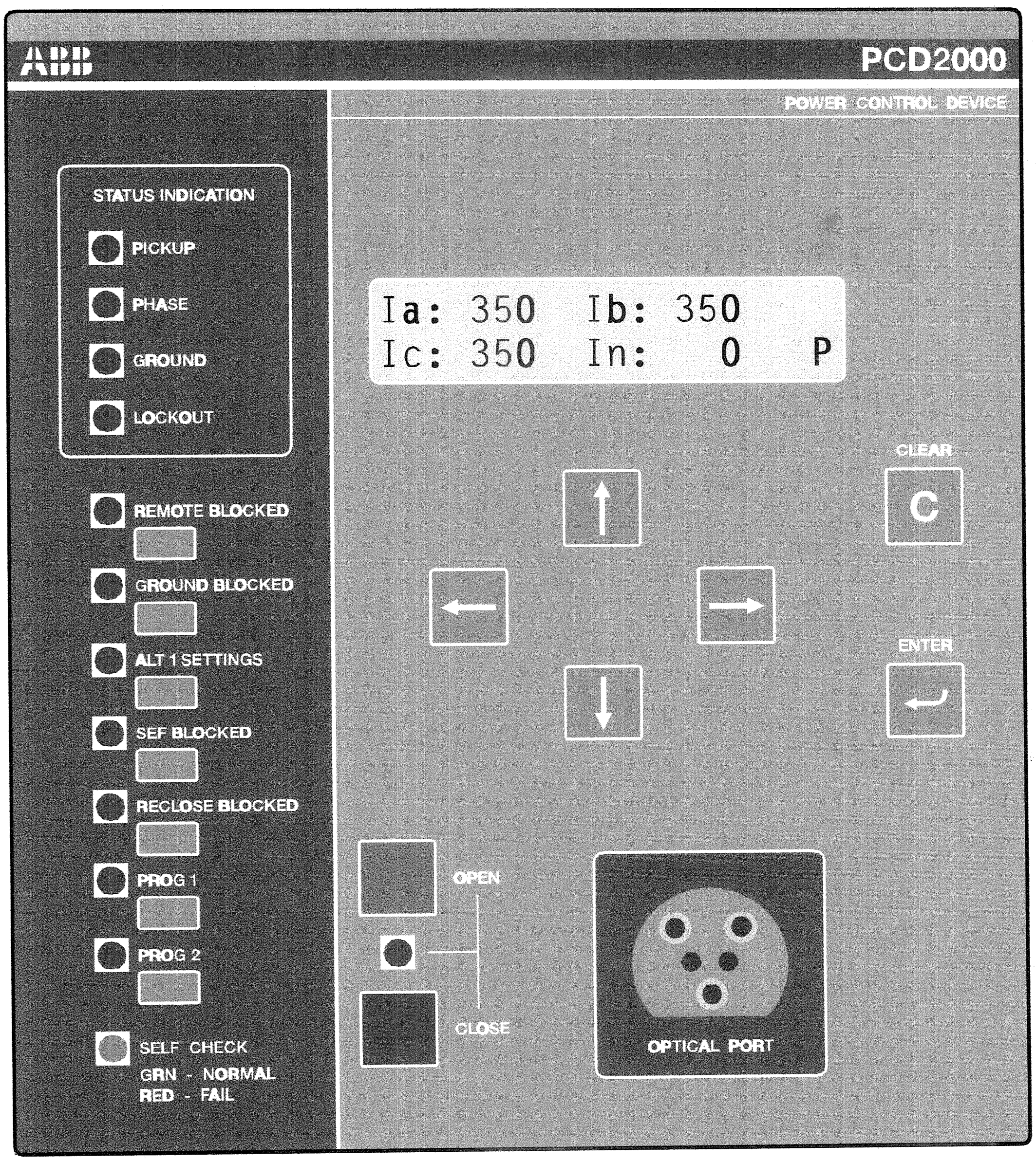

ABB Power Distribution

Precautions

Take the following precautions when using the Power Control Device 2000 (PCD2000):

1. Connect the current and voltage transformers for proper phase rotation and polarity to ensure correct measurement of kilowatts and kiloVARs, and for the proper operation of the 46, 67P, and 67N protection elements.
2. Incorrect wiring may result in damage to the PCD2000 and the recloser and/or electrical hardware connected to the recloser. Be sure the wiring on the PCD2000 and the recloser agrees with the electrical connection diagram before energizing.
3. Apply only the rated control voltage as marked on the PCD2000 nameplate.
4. High-potential tests are not recommended. If a control wire insulation test is required, only perform a DC high-potential test. Surge capacitors installed in the unit do not allow AC high-potential testing.
5. 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.
6. When the self-checking function detects a system failure, the protective elements are disabled and the alarm contacts are activated. Replace the unit as soon as possible.

WARNING: Removal of the modules from the case while the unit is energized 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 PCD2000 but does not purport to cover all details or variation 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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1 Overview

The Power Control Device 2000 (PCD2000) is an easy to use, very powerful microprocessor-based control unit providing extensive recloser protection elements designed for distribution automation systems. The environmentally hardened unit combines monitoring, control, protection, reclosing elements and communication in one economical package. Power quality, accurate metering, load profiling, and condition monitoring provide crucial system information for managing today's competitive distribution systems. Available for 5- or 1-ampere secondary current transformers (cts), the PCD2000 uses circuit breaker 52a and 52b auxiliary contacts for logic input signals. The PCD2000 can be applied with voltage transformers (vts) connected for operation at 69 or 120 volts ac phase-to-ground (wye), 120 volts ac phase-to-phase (delta or open delta with phase B grounded) or 208 volts ac phase-to-phase (delta).

The PCD2000 empowers the user to develop distribution automation solutions for the electric power system without the need of a remote terminal unit (RTU) since it is equipped with DNP 3.0, Modbus® RTU and Modbus® ASCII communication protocols. The PCD2000 can be operated remotely to allow system reconfiguration, fault analysis, and transfer of protection settings to make any distribution system more efficient. In addition, the PCD2000 is equipped with powerful data gathering capability to allow analysis of system loading, planning and future upgrading. The integrated battery charger monitors and maximizes battery life, remote battery testing and fault interruption accumulation makes maintenance planning simple and eliminates time-based maintenance procedures. All of these features save the user time and resources.

The PCD2000 is packaged in a metal case suitable for conventional flush mounting in a pole mounted cabinet. All connections to the PCD2000 are made at clearly identified terminals on the rear of the unit. The PCD200 uses a 6-slot card case with the slots defined as follows:

Slot A: Power Supply or UPS Module

Slot B: VR-3S Recloser Actuator Module (Type 2) or Digital I/O Module (Type 1)

Slot C: Digital I/O Module

Slot D: CPU Module

Slot E: Communications Module

Slot F: PT/CT Inputs Module

Because of its microprocessor capability, the PCD2000 provides the following features in one integrated package:

- Local human-machine interface (HMI)
- Simple menu-driven programming using four arrow, Enter, and Clear keys
- Lighted liquid crystal display (LCD) displays phase currents (I_A, I_B, I_C, and I_N) during normal operation, and fault information after a trip
- Front panel LED status indicators for type of fault: Pickup, Phase, Ground, Lockout
- Front panel Open and Close pushbuttons with LED recloser/breaker status indicator
- Front panel pushbuttons and LED status indicators: Remote Blocked, Ground Blocked, Alternate 1 Settings, SEF Blocked, Reclose Blocked, PROG 1, PROG2
- Front-mounted optically isolated data port for easy download and upload of data on-site
- Password protected settings and controls

- Expanded operating temperature range, from -40°C to 70°C
- AC or DC powered for flexibility
- Integrated battery charging and monitoring for AC-powered units
- Metering: currents, voltages, watts, VARs, watt and VAR-hours, power factor, frequency
- Peak demand currents, watts and VARs with time stamp
- Load profile capability: watts, VARs and voltage for 40, 80 or 160 days
- Summation of recloser interrupting duty and recloser operation counter
- Three selectable settings groups: Primary, Alternate 1, and Alternate 2
- Phase time and instantaneous overcurrent protection: 51P, 50P-1, 50P-2, 50P-3 (ANSI, IEC, Recloser and User-Programmable Curves)
- Ground time and instantaneous overcurrent protection: 51N, 50N-1, 50N-2, 50N-3 (ANSI, IEC, Recloser and User-Programmable Curves)
- Negative sequence (I2) time overcurrent protection: 46
- Multishot reclosing: 79M
- Positive sequence phase directional time overcurrent protection: 67
- Negative sequence ground directional time overcurrent protection: 67N
- Two load shed, two restoration and two overfrequency elements: 81S-1/2, 81R-1/2, 81O-1/2
- Single- and three-phase undervoltage and single-phase overvoltage elements: 27-1P, 27-3P, 59-1P and 59-3P
- Breaker failure detection
- Cold load pickup element
- Zone sequence coordination element
- Fault locator algorithm estimates fault resistance and distance to fault
- Oscillographic data storage captures 64 cycles of current and voltage waveform data
- Fault summary and detailed fault records for last 32 trips
- Operations (sequence of events) record for last 128 operations
- Up to 16 user-programmable binary contact-inputs (depending on configuration ordered)
- Up to 15 user-programmable binary contact-outputs (depending on configuration ordered)
- Continuous self-diagnostics on power supply, memory elements and microprocessors
- Battery backed-up clock maintains date and time during control power interruptions
- Isolated dual rear port RS-232 and RS-485 ports (only one active at a time)
- Optional fiber optic communications card for superior noise-free communications
- ANSI or IEC formatted metering and protection displays
- ANSI or IEC configured HMI

1.1 Internal Design

The PCD2000 design incorporates a 32-bit microprocessor and a 16-bit microprocessor, which together create a multi-tasking environment. The capabilities of the microprocessor allow the PCD2000 to perform many protection, control and monitoring elements.

1.1.1 Processor Specifications

The processing power of the PCD2000 provides a true multi-tasking environment that combines protection, metering, and control. The hardware components of the unit include:

- CPU - 32-bit 68332 Motorola microprocessor, 16 MHz (Type 1) or 20MHz (Type 2)
- CPU RAM - 64K of temporary storage for CPU
- DSP - a 16-bit analog device 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 element settings
- 16-bit analog-to-digital (A/D) converter
- CPU EPROM stores the CPU's programming
- DSP EPROM - 3K of memory store the DSP operating algorithm
- DSP RAM - 16K of memory provide temporary storage of DSP arithmetic values
- Real-time battery backed-up clock

1.1.2 Battery Backed-Up Clock

An internal clock time tags the faults in the Fault Record, events in the Operations Record, and values in the Load Profile record. In normal operation, this clock is powered by the PCD2000. When the CPU is withdrawn from the PCD2000 case a battery powers the clock. For prolonged storage, stop the PCD2000 clock to assure long battery life. Turn off the battery backed-up clock through the front human-machine interface by entering a "0" for the day.

Note: Removal of the battery resets the PCD2000 to factory default settings stored in the CPU ROM.

1.2 Dimensions

Figure 1-1. PCD 2000 Dimensions

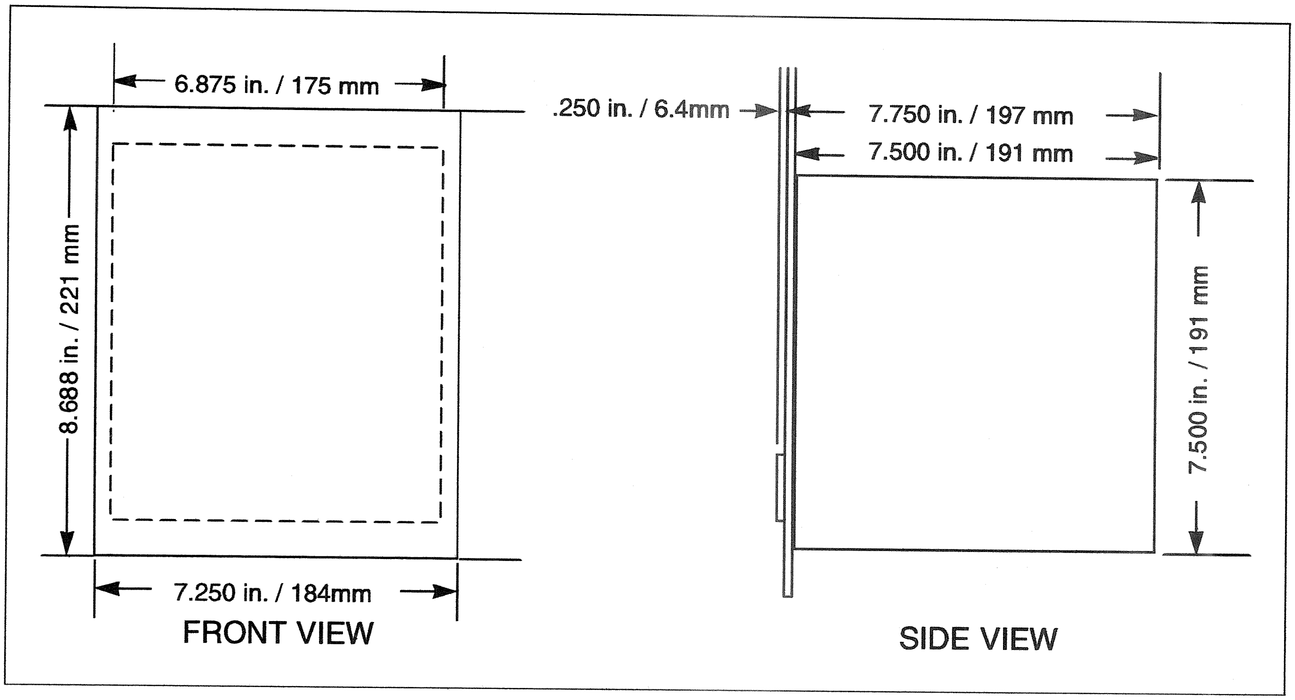
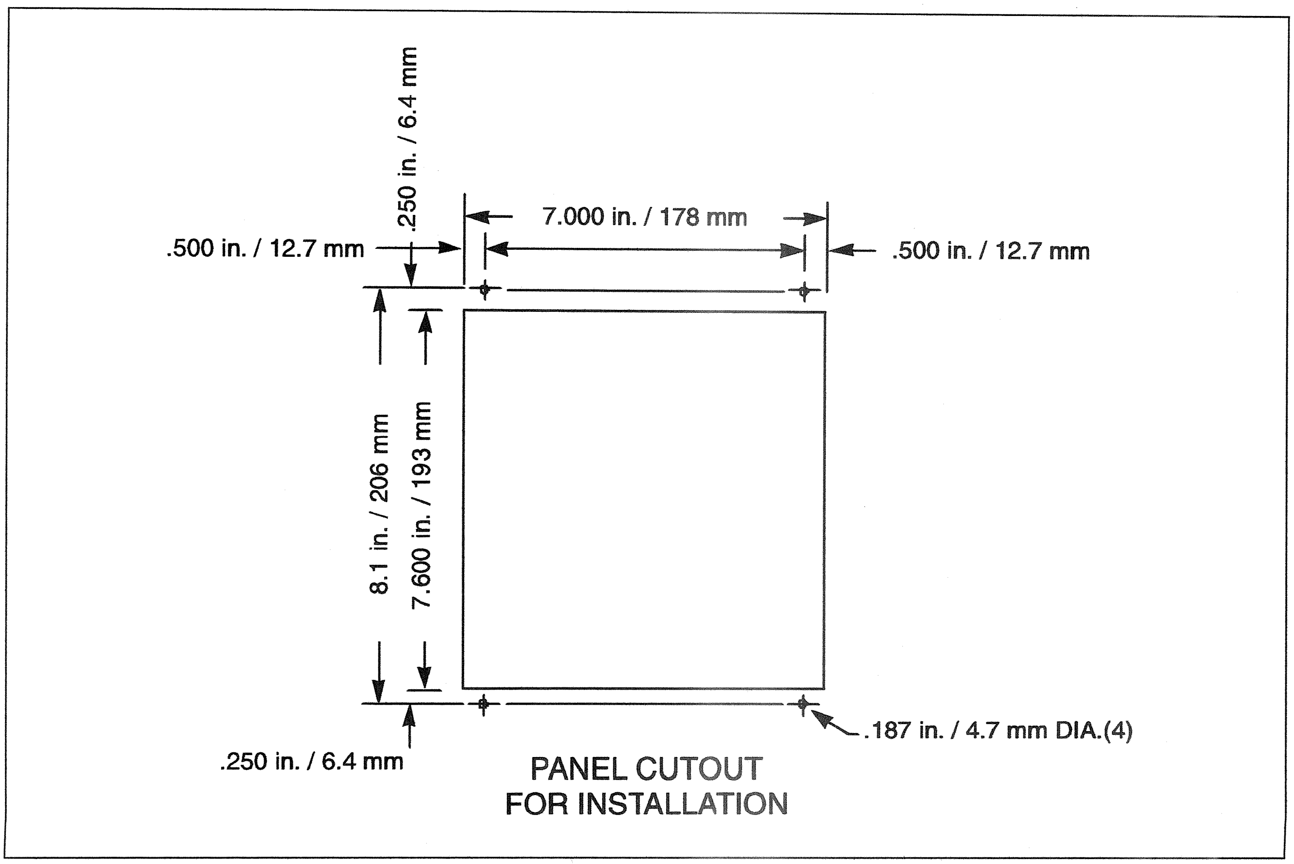


Figure 1-2. PCD2000 Panel Cutout



1.3 Ratings and Tolerances

Table 1-1. Ratings and Tolerances

Parameter	Value		
Current Input Circuits			
Input Rating	5 A (16 A continuous, and 450A for 1 second) 1 A (3 A continuous, and 100A for 1 second)		
Input Burden	Less than 0.1 VA @ 5 A		
Frequency	50 or 60 Hz		
Voltage Input Circuit	Voltage rating based on the VT connection setting		
Burden	0.04 VA for V_{PH-N} at 120 VAC		
69/120 V Wye	160 V continuous and 480 V for 10 s		
120/208 V Delta	260 V continuous and 480 V for 10 s		
Frequency	50 or 60 Hz		
Binary (Contact) Input Circuits			
Burden	0.075 VA at 24 VDC 0.140 VA at 48 VDC 0.360 VA at 125 VDC 0.730 VA at 250 VDC		
Control Power Burden	120 VAC at 0.17 A, Range = 102 to 132 VAC 24 VDC at 0.70 A, Range = 19 to 28 VDC 48 VDC at 0.35 A, Range = 38 to 56 VDC 125 VDC at 0.16 A, Range = 70 to 150 VDC 250 VDC at 0.8 A, Range = 200 to 280 VDC		
Binary Contacts Output Rating			
Each Contact At	120 VAC	125 VDC	250VDC
Tripping	30 A	30 A	30 A
Continuous	5 A	5 A	5 A
Break (Inductive)	2 A	0.3 A	0.1 A
Operating Temperature Range	–40 °C to +70 °C (operating temperatures below –20 °C may reduce LCD display visibility)		
Tolerances Over Temperature Range of –30 °C to +70 °C			
Element	Pickup	Dropout	Timing (whichever is greater)
51P/51N	± 3% of setting	98% of setting	± 7% or ±16 milliseconds
50P/50N	± 7% of setting	98% of setting	± 7% or ±16 milliseconds
46/67P	± 3% of 51P setting	98% of setting	± 7% or ±16 milliseconds
67N	± 3% of 51N setting	98% of setting	± 7% or ±16 milliseconds
27/59/81V/79V	± 3% of setting	99.5% of setting	± 7% or ±16 milliseconds
81	± 0.01 Hz	± 0.01 Hz	± 1 cycle
Ammeter	± 1% of 51P and 51N time overcurrent pickup setting		
Voltmeter	± 1% of the VT connection setting		
Power Meter	± 2% of I x V, 51P pickup setting x VT connection setting		
Frequency	± 0.01 Hz from 30-90 Hz, at 120 VAC input on VA		

Parameter	Value
Transient Immunity	Surge withstand capability SWC and fast transient tests per ANSI C37.90.1 and IEC80255-22-1 class III for all connections except communication or AUX ports Isolated communication ports and AUX ports per ANSI C37.90 using oscillatory SWC Test Wave only and per IEC80255-22-1 class III and 80255-22-4 class III Impulse voltage withstand test per IEC80255-5 EMI test per trial use standard ANSI C37.90.2
Humidity	Per ANSI C37.90, up to 95% without condensation
Dielectric	3150 VDC for 1 s all circuits to ground except communication ports per IEC80255-5 2333 VDC for 1 s for isolated communication ports

1.4 Modules

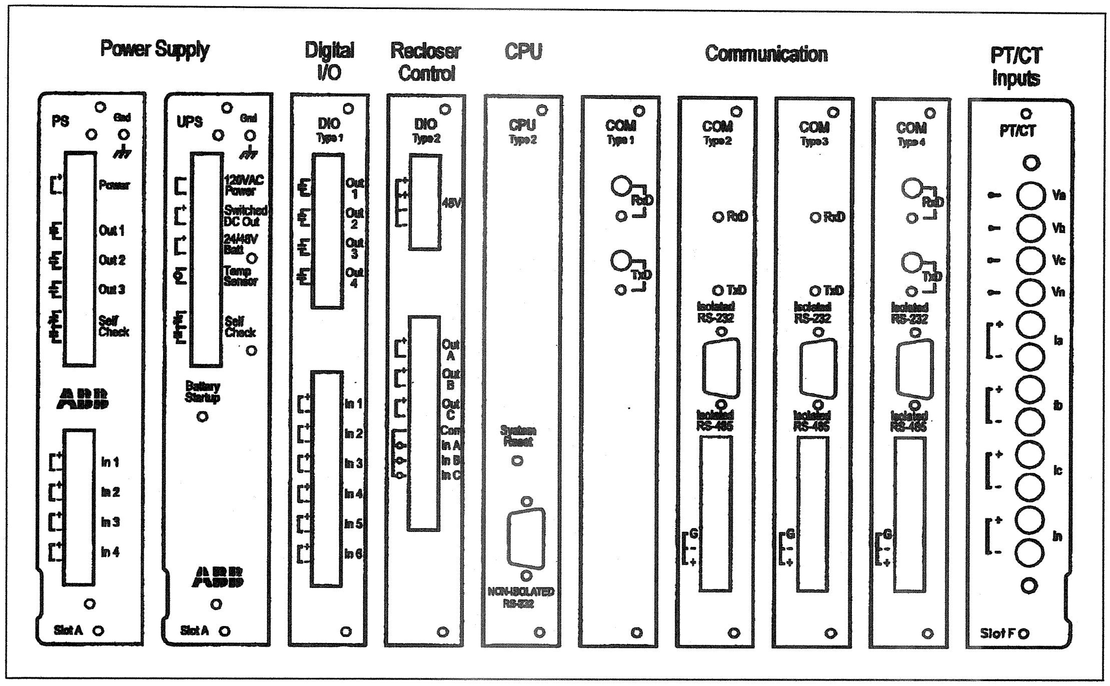
1.4.1 Rear Terminal Block Connections

Apply rated control voltage as indicated by the catalog number and nameplate of the PCD2000 to the appropriate terminals. Connect a ground wire from the PS or UPS module ground stud to the equipment ground bus with at least #12 AWG gauge wire.

If the PCD2000 is installed in a control cabinet, verify that the terminals are correctly connected as indicated on the enclosed wiring diagram.

Figure 1-3 shows the terminal block layouts.

Figure 1-3. Rear Terminal Block View



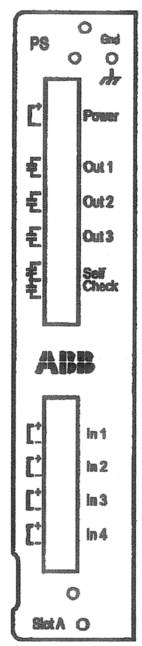
1.4.2 PS – Power Supply Module

The PS Power Supply module accepts only DC voltage and it must be installed in Slot A of the PCD2000 case.

Depending upon the product catalog number, the PS module is available for operation with three different voltage levels: 24 VDC, 48 VDC, and 125 VDC. An additional feature of the PS module is the ability to distribute auxiliary DC voltage from the PS module to other modules connected within the PCD2000 powering all the binary input and binary output contacts and an externally mounted radio transceiver. Also, the PS module provides 3 binary output contacts, a self-check (Form C) relay output, and 4 binary input contacts. Each of the 3 binary output contacts have factory default settings for normally open (NO). Binary output 1 (Out 1) however can be configured to be a normally close (NC) contact.

To change Out 1 from a NO to NC configuration, ensure that the PCD2000 is de-energized. Label and disconnect all wires from the PS module terminal block. Remove the two screws securing the PS module to the PCD2000 housing. Firmly grasp both terminal blocks and slide the PS module out of the PCD2000 housing. With the PS module removed locate an orange jumper labeled J1 on the printed circuit board. Looking at the printed circuit board the orange jumper is vertically orientated. Carefully remove the orange jumper and re-insert it with a horizontal orientation. Out 1 is now configured for NC output. Reinsert the PS module into the PCD2000 housing following the procedure in reverse order. Energize the PCD2000 and verify Out 1 is now a NC contact.

Figure 1-4. PS - Power Supply Module



1.4.3 UPS – Uninterruptible Power Supply Module

The UPS Uninterruptible Power Supply module accepts only AC voltage, and must be installed in Slot A of the PCD2000.

Depending upon the product catalog number PCD2000 is available for operation with two different voltage levels: 120 VAC or 240 VAC. When 240 VAC is specified a step-down transformer from 240 VAC to 120 VAC is required in the control cabinet and is connected to the control voltage input. The UPS module is used primarily in applications with a backed-up battery system mounted in the Recloser Control Cabinet and maintains a charge on the battery system for uninterruptible operation in case of main power failure.

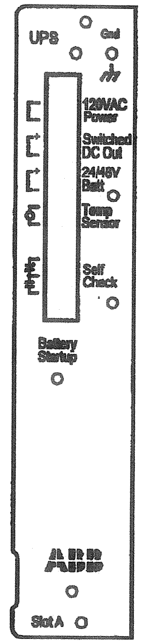
An auxiliary Switched DC Out voltage is distributed from the UPS module to other externally connected devices within the recloser control cabinet. The maximum output of the Switched DC Out is rated for 5 amps. A recommended connection should be limited to ≤ 0.25 A to allow the UPS module too properly maintain an adequate charge on the battery system. A typical application for the Switched DC voltage from the UPS module is to provide power to all the binary input and binary output contacts, a radio transmitter or dial-up modem.

The battery connection terminals provide a connection point for connection of a battery system to the PCD2000. For optimum performance the battery system should be a sealed lead-acid type battery. If the battery system connected to the UPS module discharges below 40 VDC for a 48 VDC battery and 20 VDC for a 24 VDC battery the Switched DC output will be disconnected from the battery to prevent a potentially damaging deep discharge condition on the battery.

Temperature sensor terminals provide a connection point for a thermistor to monitor the battery temperature. For accurate battery monitoring this thermistor should have a rating of 10KΩ, -4.40%/°C. To achieve accurate temperature measurement the thermistor should be mounted as close to the battery as possible. If using an ABB control cabinet, the thermistor can be mounted directly to the PCD2000 terminal block.

The UPS Module is designed to operate with a nominal AC supply voltage of 120 VAC. The actual range is 102 to 132 VAC. A 120/240V isolation transformer is required for isolating the DC ground from the AC and can be used to supply a 120/240 selectable input.

Figure 1-5. UPS - Uninterruptible Power Supply Module



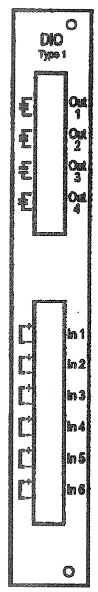
1.4.4 DI/O Type 1 – Digital I/O Module

The DI/O Type 1 Module provides 4 binary (contact) outputs and 6 binary (contact) inputs. These binary inputs and outputs can be mapped to regulate a variety of logic functions using WinPCD configuration software. DI/O module is typically used in retrofit recloser applications with the UPS module. The DI/O module and UPS module are very well suited for battery systems. The 4 binary (contact) outputs have a factory default configuration of normally open (NO).

Binary (contact) outputs 2, 3 and 4 can be configured as normally closed (NC) outputs. To change the configuration from a NO to NC configuration, ensure that the PCD2000 is de-energized. Label and disconnect all wires from the Digital I/O module terminal blocks. Remove the two screws securing the DI/O module to the PCD2000 housing. Firmly grasp both terminal blocks and slide the DI/O module out of the PCD2000 housing. With the DI/O module removed locate three orange jumpers labeled J1, J2 and J3 on the printed circuit board. Looking at the printed circuit board the orange jumper is vertically orientated. Carefully remove the orange jumpers and re-insert them with a horizontal orientation. Out 2, 3 and 4 are now configured for NC output. Reinsert the DI/O module into the PCD2000 housing following the procedure in reverse order. Energize the PCD2000 and verify Out 2, 3 and 4 are now a NC contacts.

The DI/O Type 1 module must be installed in either Slot B or Slot C in the PCD2000 case.

Figure 1-6. DI/O Type 1 - Digital I/O Module



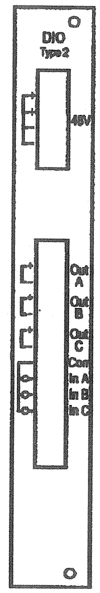
1 OVERVIEW

1.4.5 DI/O Type 2 – Recloser Actuator Module

The DI/O Type 2 Recloser Actuator Module is specifically designed for use with the VR-3S recloser. It provides 3 binary (contact) outputs and 3 binary (contact) inputs from the VR-3S. This Recloser Actuator Module is configured for optimal operation with the PS Module.

The DI/O Type 2 module must be installed in Slot B in the PCD2000 case.

Figure 1-7. DI/O Type 2 - Recloser Actuator Module



1.4.6 CPU Module

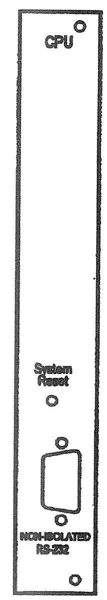
The CPU Module is the control center for the PCD2000.

Located on the back panel of the CPU Module is a System Reset pushbutton and a non-isolated RS-232 communications port. Depressing the System Reset pushbutton resets the PCD2000 microprocessor and re-initiates the internal start-up program. Whenever a system reset is performed all stored information and settings are saved.

The non-isolated RS-232 port is provided for temporary communication with a local device such as a laptop PC being used to update the PCD2000 firmware. For permanent connections use a communications module (Type 3 or Type 4) which can provide an isolated RS-232 or RS-485 and/or fiber optic interface loop communication port. When a communication module is installed, the non-isolated RS-232 port on the CPU module will be disabled.

The CPU module must be installed in Slot D in the PCD2000 case.

Figure 1-8. CPU Module



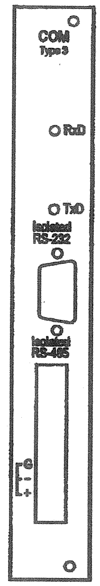
1.4.7 COM Type 3 – Communications Module

The COM Type 3 Communications Module provides an isolated RS-232 port with selectable RTS/CTS handshaking and RS-485 port on the back panel of the PCD2000.

Please refer to Section 9 for detailed information on the communication ports available on the PCD2000.

The COM Type 3 module must be installed in Slot E on the PCD2000 platform.

Figure 1-9. COM Type 3 - Communications Module



1 OVERVIEW

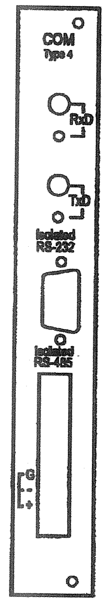
1.4.8 COM Type 4 – Communications Module

The COM Type 4 Communications Module provides an isolated RS-232 port, RS-485 port and fiber optic port on the back panel of the PCD2000.

Please refer to Section 9 for detailed information on the communication ports available on the PCD2000.

The COM Type 4 module must be installed in Slot E on the PCD2000 platform.

Figure 1-10. COM Type 4 - Communications Module



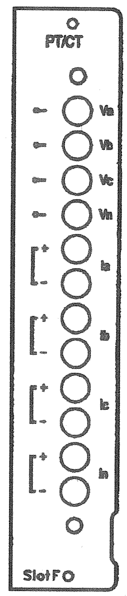
1.4.9 PT/CT Module

The PT/CT Module accepts 4 voltage inputs and 4 current inputs as shown in Figure 1-11.

The PT/CT Module is available for use with three CT ratios: 1000:1 and 600:1.

The PT/CT Module must be installed in Slot F on the PCD2000 platform.

Figure 1-11. PT/CT Module



The PCD2000 PT/CT Module can be configured for two tap settings: HIGH tap and LOW tap. See Table 1-2 for the pickup range and tap settings.

Table 1-2. CT Module Tap Settings for Phase and Neutral Currents

CT Module	Tap Setting	Range for Phases	Range for Neutral
600:1 (Type 1 or 2)	Low High	50 to 800A Primary 100 to 1600A Primary	25 to 400A Primary 50 to 800A Primary
1000:1 (Type 3 or 4)	Low High	50 to 800A Primary 100 to 1600A Primary	25 to 400A Primary 50 to 800A Primary
Recloser (Type 5 or 6)	Low High	0.2 to 3.2A Secondary 1 to 16A Secondary	0.2 to 3.2A Secondary 1 to 16A Secondary
600:1 (Type 7 or 8)	Low High	20 to 320A Primary 100 to 1600A Primary	10 to 160A Primary 50 to 800A Primary
1000:1 (Type 9 or A)	Low High	20 to 320A Primary 100 to 1600A Primary	10 to 160A Primary 50 to 800A Primary

To change the pickup range:

1. Remove the module from the PCD2000 housing and identify four red jumpers as shown in Figure 1-12. For each phase and neutral you will notice an "L" for low tap and an "H" for high tap. Insert the jumper across the "H" to configure each phase for high tap and across the "L" for low tap.
2. For correct operation each phase must be configured with the same setting; however, the neutral setting can be different.
3. After you are comfortable with your configuration locate the jumper labeled "J1" and insert the phase and neutral jumpers to match your configuration.

Figure 1-12. PT/CT Sensor Module Jumper Locations

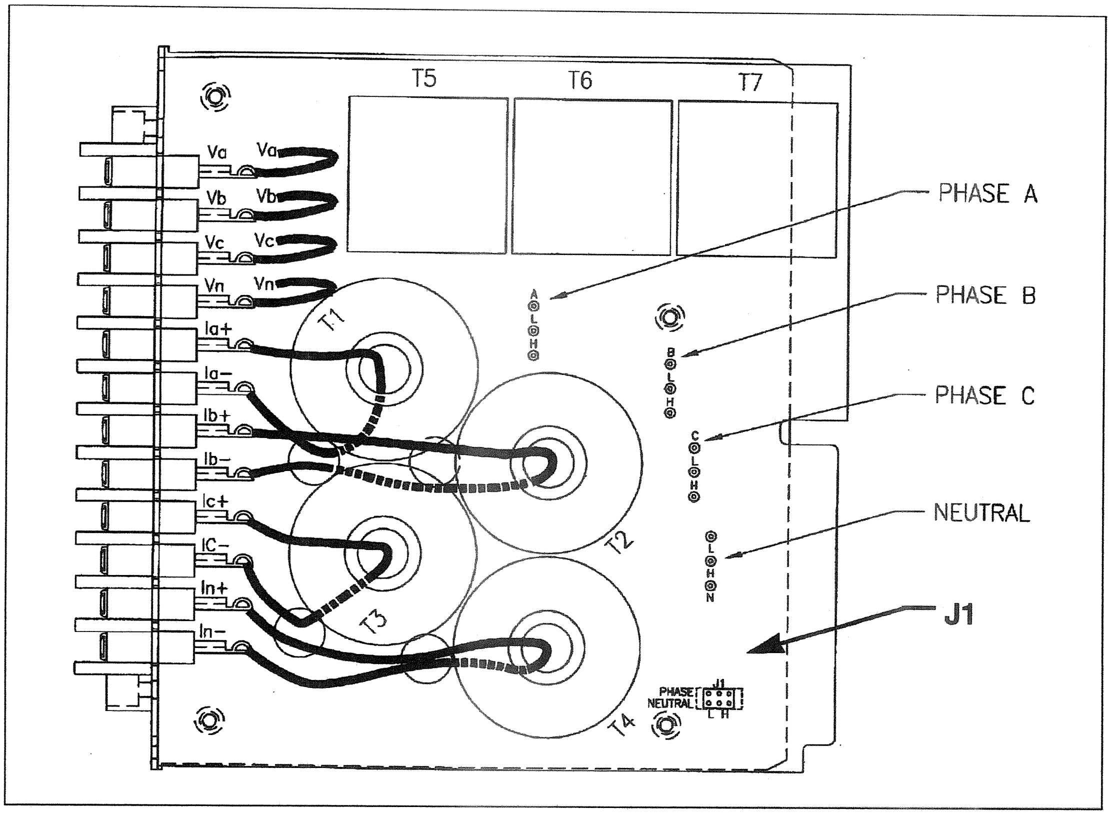
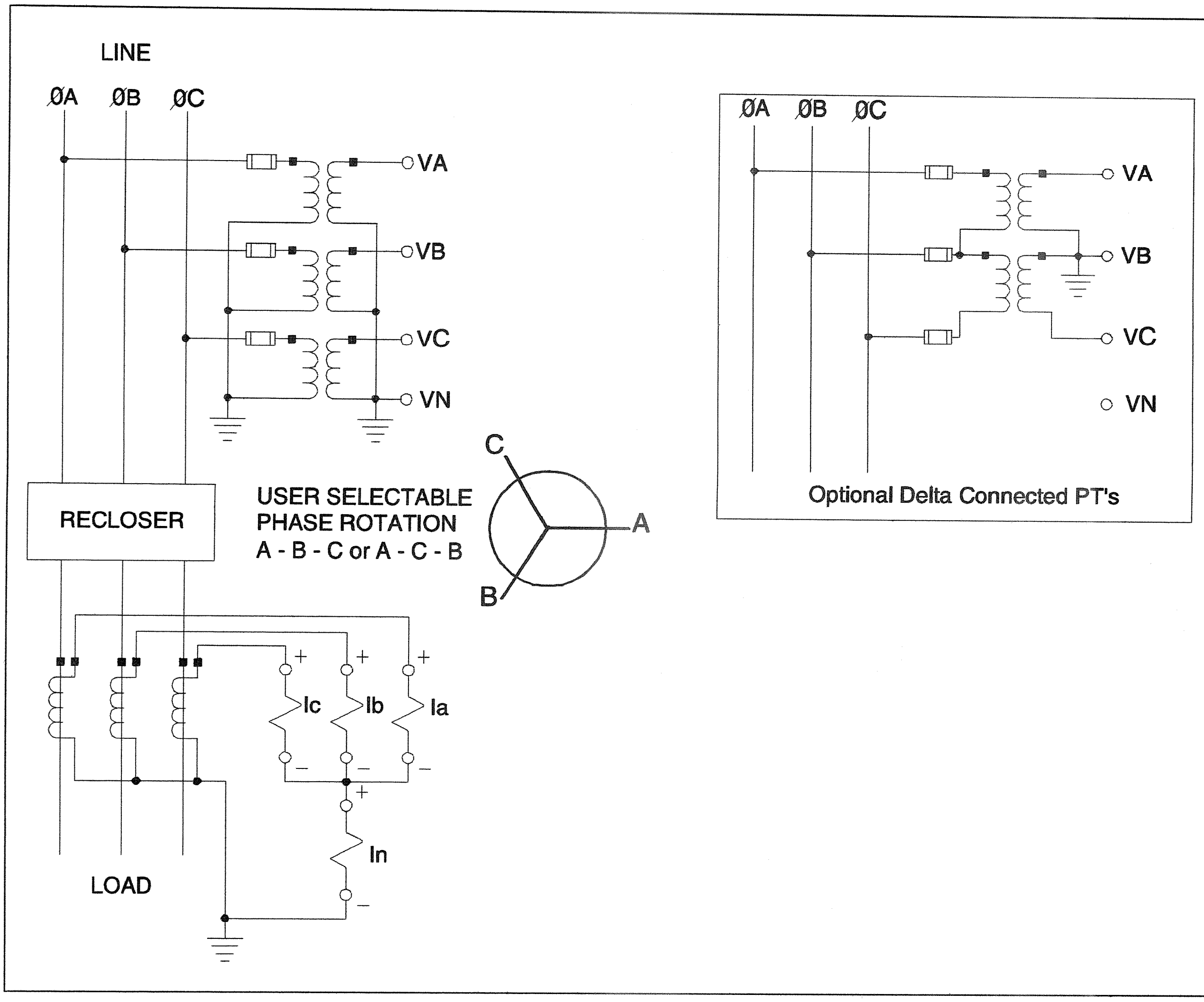


Table 1-3. Settings Describing the Protected Line and CT/PT Connections

HMI Abbreviation	WinPCD Name and Description
SE CT Ratio	Specification of the ratio of the current transformer (CT) monitoring the ground current (for units ordered with the Sensitive Earth Fault option). The setting range is 1 to 2000 with an increment of 1. The default is 100.
VT Ratio	VT Ratio Specification of the ratio of the potential transformers (VT's or PT's) connected to the voltage inputs on the CT/CT module. The setting range is 1 to 2000 with an increment of 1. The default is 100.
VT Conn:	VT Connection Specification of the wiring configuration of the potential transformers (VT's or PT's) connected to the voltage inputs on the CT/CT module. The choices are 69V or 120V Wye (phase-to-ground); or 120V or 208V Delta (phase-to-phase). The default is 120V Wye.
Pos Seq X/M	Positive Sequence Reactance/Mile The setting range is 0.001 to 4 Ohms primary with an increment of 0.001. The default is 0.001.
Pos Seq R/M	Positive Sequence Resistance/Mile The setting range is 0.001 to 4 Ohms primary with an increment of 0.001. The default is 0.001.
Zero Seq X/M	Zero Sequence Reactance/Mile The setting range is 0.001 to 4 Ohms primary with an increment of 0.001. The default is 0.001.
Zero Seq R/M	Zero Sequence Resistance/Mile The setting range is 0.001 to 4 Ohms primary with an increment of 0.001. The default is 0.001.
Line Length	Line Length (Miles) The setting range is 0.1 to 50 miles. The default is 0.1.
Phase Rotate:	Phase Rotation Specification of phase rotation in use on the protected line. The choices are ABC (default) or ACB.
Frequency	Frequency Specification of frequency in use on the protected line. The choices are 50Hz or 60Hz (default).

Figure 1-13. Typical External Connections



1.5 Uninterruptible Power Supply Module

1.5.1 UPS Features

The Uninterruptible Power Supply (UPS) Module provides battery backup and maintenance functions for the PCD2000. Features include:

- Operation from a 120 VAC input
- Supports 24 VDC or 48 VDC lead acid batteries
- Battery float voltage is temperature compensated for maximum battery capacity
- Battery temperature, voltage and charger current are available for display via the PCD2000 HMI
- A battery test can be performed on request from the PCD2000 front panel or via WinPCD software
- Switched DC Output voltage supports external devices
- Provides a status check single-pole-double-throw (SPDT) relay output

1.5.2 UPS Application and Operation

1.5.2.1 AC Input and Isolation

The AC input requires a nominal supply of 120 VAC at 80 VA maximum. The operating voltage range is -15 % to +10 %, or 102 to 132 VAC.

The AC power input is not internally isolated from the Switched DC Output, Battery, or Temperature Sense terminals. Any connection between the AC power inputs and the other UPS terminals (except for the status check relay outputs, which are fully isolated) will damage the UPS module. Unwanted connections can occur via a grounded battery, grounded load on the Switched DC Output, or during testing.

Note: The UPS module AC input should therefore be fed through an isolation transformer. Use of a 120/240 V dual-primary transformer affords the additional option of 240 VAC operation.

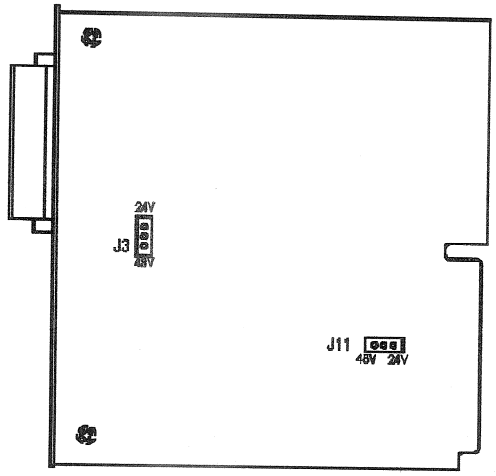
1.5.2.2 Battery and Temperature Sensing Thermistor

The UPS charging voltage is optimized for lead acid chemistry and temperature compensated to maintain full battery charge and life. The UPS module must only be used with lead acid batteries, preferably of sealed construction.

The UPS module supports 24 and 48 VDC batteries only. To configure the board for the correct voltage, carefully remove the module from the housing and locate two jumpers, J3 and J11. Both jumpers must be set to the same position for proper operation. Figure 1-14 shows the approximate location of these jumpers.

Note: For VR-3S recloser applications the UPS must be configured for 48VDC.

Figure 1-14. UPS Module Jumper Locations



The UPS module float voltage temperature compensation scheme results in a higher battery charging voltage at lower temperatures. For a 48 VDC battery, the nominal float voltage is 54 VDC at 25°C. Over temperature, the voltage will vary from 64.8 VDC at -40°C to 52.8 VDC above 50°C. The voltages for 24 VDC batteries are half of the 48 VDC values (32.4 to 26.4 VDC). Any device connected to the battery or the Switched DC Output terminals must accommodate the entire temperature compensated voltage range.

Battery temperature is sensed via a 10K Ohm thermistor connected to the "Temp Sensor" input terminals. For proper operation, the thermistor must be a Keystone Thermometrics type KC003T or equivalent. Operation without a thermistor installed will cause the UPS to set maximum output voltage, resulting in possible over-charging of the battery.

The thermistor should be positioned to reflect the temperature of the battery. If the thermistor is mounted on a cable, twisted shielded pair should be used. The cable shield should be connected to chassis ground. If the thermistor is mounted directly to the UPS input plug, care should be taken to avoid damaging the fragile thermistor leads.

1.5.3 Battery Charging and Capacity

Available operation time on battery is affected by the battery's capacity rating, charge state, temperature and age. A fully charged 8 A-h 48 V battery should support an average PCD2000 configuration for one day at room temperature, excluding the effects of additional accessory loads and breaker operations.

The UPS Module's battery charger function directly supplies the battery, PCD2000 internal load, and all other battery loads (including any load connected to the Switched DC Output). The available battery charging current is therefore the battery charger's 1 A maximum output minus all other system loads. An average PCD2000 draws around 0.2 A at 48 V or 0.4 A at 24 V. Care must therefore be exercised in connecting loads to the battery or to the Switched DC Output. Additional loads will lengthen battery charging time. Excessive loading will result in battery discharge even with AC on and eventual system shutdown.

To protect the battery from deep discharge during extended operation without AC input, the UPS module shuts down the PCD2000 and turns off the Switched DC Output when the battery voltage falls to 40 V for a 48 V battery (20 V on a 24 V battery). However, any loads that are externally connected directly to the battery will continue to discharge the battery. For this reason, loads should not be connected directly to the battery in systems that can experience extended outages. Extended discharge below the UPS cutoff voltage will reduce the battery's capacity and life.

1.5.4 Operation without a Battery

The PCD2000 with UPS module may be safely operated without a battery connected for testing and configuration purposes. However, the proper battery should always be connected when the system is in service.

Note: Do not operate the PCD2000 connected to a VR3S recloser without a battery.

1.5.5 Switched DC Output

The Switched DC Output is provided to power certain PCD2000 accessory loads that benefit from battery backup power. Examples include wetting of breaker sensing contacts and powering of a communication radio.

However, since loads connected to Switched DC Output reduce the available current for battery charging, Switched DC Output loading must be carefully limited. It is recommended that the total Switched DC Output current be limited to a long time average of 0.35 A. Higher currents up to 2.5 A are allowed for short periods. These ratings will support one MDS-2310A radio or the equivalent using a DC to DC converter to power 12/24V accessories. A 48/12V DC to DC converter `is available from ABB, contact your ABB sales office for this information.

The Switched DC Output is not protected against short circuits. It is therefore recommended that an external limiting resistor and fuse be installed in series with the Switched DC Output. The resistor should be as close to the Switched DC Output terminal as is practical. The recommended parts are:

Resistor: 3 Ohm, 10%, 25 W wirewound—Ohmite L25J3R0 or equivalent

Fuse: 2.5 A Fast Acting

1.5.6 Startup

When the proper voltage is applied to the UPS AC input, the UPS module automatically begins operation. However, if an unpowered UPS is connected to a charged battery, the UPS does not start automatically. This is a safety feature designed to avoid unexpected startups.

1.5.7 Status Check Relay Output

A SPDT status check relay output is provided to signal proper operation of the PCD2000. When the PCD2000 is operating normally, the top two terminals will be open. If the PCD2000 is unpowered or experiences a failure, the bottom two terminals will be open.

The contact ratings of the status check relay are 10 A maximum at 240 VAC and 8 A maximum at 24 VDC. The minimum recommended load is 12 V and 100 mA.

1.5.8 Battery Monitoring and Test

The PCD2000 UPS module provides battery monitoring and test functions to facilitate battery management.

Battery monitoring information is available through the PCD2000 menu system and via the DNP 3.0 or Modbus® communication protocol analog inputs object type. The data includes: battery temperature, battery voltage and charger current.

1.5.8.1 Battery Temperature

This is the temperature (Celsius) computed from the temperature sensing thermistor.

1.5.8.2 Battery Voltage

This is the battery bus voltage at the UPS module. The status of the UPS AC input must be considered in interpreting this voltage. If the AC input is on, the battery is under charge. With AC on, the battery will eventually charge to the float voltage determined by the battery temperature.

If the AC input is off, the battery is being discharged to support the PCD2000 and accessory loads. The battery's discharge voltage is generally lower than the voltage under charge. The battery is considered completely discharged at 40 V for a 48 V battery or 20 V for a 24 V unit. The PCD2000 is shut down and the Switched DC Output turned off when battery voltage falls to the "discharged" point.

1.5.8.3 Charger Current

This is the total current delivered by the UPS charger to the battery, PCD2000 internal circuits, and any other battery loads (including loads on Switched DC output and any loads directly applied to the battery). The maximum available current is 1.0 A for either battery voltage setting.

The internal PCD2000 circuits consume approximately 0.2 A at 48 V or 0.4 A at 24 V. The charging current to the battery is the total indicated current minus the PCD2000 current minus any accessory current loads.

The status of the AC input is easily determined from the UPS charger current. If AC is off, the indicated current will be near zero. When AC is on, the current is the amount required to support the PCD2000.

A battery test function is additionally provided to gauge battery capacity and health. The battery test function is initiated at the PCD2000 front panel or through the communication protocols. To initiate the battery test from the HMI, press the PROG 1 pushbutton on the PCD2000.

The battery test function applies a 1-ohm load to the battery for a short time (up to 100 milliseconds). The change in battery voltage during the test (no-load voltage minus loaded voltage) is reported as "Delta V." If the battery test fails for any reason, "Delta V" is reported as 99 V.

A valid battery test will return a "Delta V" less than 99 V. Since "Delta V" is proportional to the battery's internal impedance, lower "Delta V" results are indicative of healthier batteries. As a battery ages, the internal impedance gradually increases.

The allowable "Delta V" varies with PCD2000 installation and application. However, it is suggested that the installation be inspected whenever "Delta V" exceeds 20 % of the nominal battery voltage (9.6 V for a 48 V battery, 4.8 V for a 24 V battery).

1.6 Style Number Interpretation Key

Style Number: _ R 1 _ - _ 0 _ _ - _ _ - _ _ 0 _

Faceplate	
ANSI	8
IEC	9

Sensor Module	
600:1 Current Sensor w/o SEF (replaced by option 7)	1
600:1 Current Sensor w/SEF (replaced by option 8)	2
1000:1 Current Sensor w/o SEF (replaced by option 9)	3
1000:1 Current Sensor w/SEF (replaced by option A)	4
Recloser (Current Input 1-16A or 0.2-3.2A) w/o SEF	5
Recloser (Current Input 1-16A or 0.2-3.2A) w/SEF	6
600:1 Current Sensor w/o SEF	7
600:1 Current Sensor w/SEF	8
1000:1 Current Sensor w/o SEF	9
1000:1 Current Sensor w/SEF	A
No PT/CT Input Board	N

Power Supply	
DC	0
AC (120 VAC)	1

Input/Output Module(s)	
One Type 1 Module	1
Two Type 1 Modules	2
One Type 2 Module	3
One Type 1 Module and One Type 2 Module	4

Control Voltage	
24 VDC	0
48 VDC	1
125 VDC	2
250 VDC	3

Rear Communications Port	
None	0
Type 2: Isolated RS-232 & RS-485 w/o Handshaking (replaced by Type 3)	1
Type 1: Radial Fiber Optic Interface (replaced by Type 4)	2
Type 3: Isolated RS-232 & RS-485 with RTS/CTS Handshaking	3
Type 4: Isolated RS-232 & RS-485 with RTS/CTS Handshaking plus Fiber Optic Interface (Radial & Loop)	4

CPU Board Selection	
Type 1 CPU Board	0
Type 2 CPU Board	1

Software Options	
None	0
Load Profile, Programmable Curves (replaced by choice 3)	1
Standard Oscillographics, Load Profile, Programmable Curves (replaced by choice 3)	2
Power Quality, Load Profile, Standard Oscillographics, Programmable Curves	3

Functional Options	
None	0
Single-Phase Tripping	1

Communications Protocol Option	
Standard Modbus® RTU and Modbus® ASCII Protocols (replaced by choice 1)	0
DNP 3.0 (IEC 870-5), Modbus® RTU, and Modbus® ASCII Protocols	1

2 Acceptance

2.1 Precautions

Take the following precautions when using the Power Control Device 2000 (PCD2000):

4. Connect the current and voltage transformers for proper phase rotation and polarity to ensure correct measurement of kilowatts and kiloVARs, and for the proper operation of the 46, 67P, and 67N protection elements.
5. Incorrect wiring may result in damage to the PCD2000 and the recloser and/or electrical hardware connected to the recloser. Be sure the wiring on the PCD2000 and the recloser agrees with the electrical connection diagram before energizing.
6. Apply only the rated control voltage as marked on the PCD2000 nameplate.
7. High-potential tests are not recommended. If a control wire insulation test is required, only perform a DC high-potential test. Surge capacitors installed in the unit do not allow AC high-potential testing.
8. 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.
9. When the self-checking function detects a system failure, the protective elements are disabled and the alarm contacts are activated. Replace the unit as soon as possible.

WARNING: Removal of the modules from the case while the unit is energized 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 PCD2000 but does not purport to cover all details or variation 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.

ABB Power T&D Company Inc. has made every reasonable attempt to guarantee the accuracy of this document, however, the information contained herein is subject to change at any time without notice, and does not represent a commitment on the part of ABB Power T&D Company Inc.

2.2 Handling Electrostatic Susceptible Devices (ESD)

The electronic circuitry on PCD2000 modules is susceptible to damage from electrostatic discharge. When handling a module, observe the following guidelines.

- Keep modules in the static-shielding bag until you are ready to install them. Save the bag for future use.
- Before opening a bag containing electronic circuitry, touch it to a grounded surface to equalize charges.
- Always wear a grounded wrist strap when handling modules. In the field, connect the wrist strap to a non-painted grounded component within the enclosure. The grounded component must be effectively connected to the earth ground for the enclosure.
- When working with modules, use a static dissipating work surface (static mat) connected to the same ground as the wrist strap.
- Do not touch circuitry. Handle printed circuit board modules by the edges or by the mounting bracket.
- Avoid partial connection of semiconductors. Verify that all devices connected to the modules are properly grounded before using them.

2.3 Acceptance Testing

The purpose of this section is to provide the user with all of the necessary information on receipt of the unit, initial power-up, verify settings, initial test, initial tripping and reclose in a new PCD2000. It is structured to answer most of the question frequently asked by users who are not familiar with the device. It is recommended that the initial tests performed be done according to the factory default procedures in this instruction booklet before attempting to test with operational settings.

2.3.1 Receipt of the PCD2000

When you receive the PCD2000, examine it carefully for shipping damage. If any damage or loss is evident, file a claim with the shipping agent and promptly notify the nearest ABB sales office.

2.3.2 Initial Power-up

Before installing the PCD2000 it is suggested that the following procedures be performed:

- Power up the PCD2000. A slight clicking sound should be heard, pressing any arrow key will illuminate the LCD display. The following LED should illuminate Green: G-Normal (Self-check). The following LEDs should illuminate Red: SEF Blocked and the Close LED.
- The Clear (C) pushbutton operates like the [Esc] key on a PC to get back to the previous screen or by continued pressing return to the Meter screen.
- The Enter [↵] pushbutton provides access to the various menus in the PCD it also operates like the Enter [↵] key on a PC to gain access to a menu item or confirm a setting change.
- The Up and Down arrow pushbuttons provide scrolling through the various menu items and change the characters for entering the Password.

- The Right and Left arrow pushbuttons provide moving the cursor from one position to the next for entering the Password and for changing the settings within the unit.

2.3.3 Changing the Password

To verify and test the PCD2000 the correct Password must be known. Otherwise there is no access to the PCD2000. This feature prevents unauthorized users from access to certain metering, settings, operations, and test menus in the unit. The following table identifies which menu items require a Password and which menu items do not require a Password.

Table 2-1. When Password is Required

Password Required	Password Not Required
Change Primary Settings	View Load
Change Alt1 Settings	View Demand
Change Alt2 Settings	View Min/Max Demand
Change Counter Settings	Show Primary Settings
Change Alarm Settings	Show Alt1 Settings
Change Clock Settings	Show Alt2 Settings
Change Communication Settings	Show Configuration Settings
Trip Breaker	Show Alarm Settings
Close Breaker	Show Clock
Force Physical Input	Show Communications
Force Physical Output	View Fault Summary
Set/Clear ULO	View Fault Record
Force Logical Input	View Operations Record
Test Output Contacts	View Operations Summary
Function Test Mode	Perform Self Test
Fault Test Mode	Test Contact Inputs
	Battery Test Mode

The factory preset Password for PCD2000 is four underscore characters.

To set a new Password, write down a 4-digit alphanumeric password that is easy to remember.

1. Press Enter [↵] to go to the Main Menu.
2. Using the Down arrow key scroll to Settings and press Enter [↵].
3. This opens the Setting Menu, scroll down to Change Settings press Enter [↵].
4. Scroll down to Configuration press Enter [↵], at the Enter Password prompt, press Enter [↵] again for the second time. This is the Change Configuration Setting menu.
5. Scroll down to Relay Password, press Enter [↵].
6. This is the Change Password screen. The cursor is at the first digit position. Using the Up or Down arrow pushbuttons change the first digit position (ranging from _ to Z), then use the Right arrow pushbutton to move to the second digit position and again use the Up and Down arrow pushbuttons to change this digit. Continue the same process for the third and fourth digit.
7. When input of the 4-digits for the Password are complete press Enter [↵].

8. A new Verify Screen appears with a prompt to Input Password Again. Input the New Password and press Enter [↵]. A new screen stating Password Verified appears.
9. Press Clear (C) pushbutton. A screen prompt asks to Save Configuration press Enter [↵].
10. Verify the New Relay Password by following the same procedure to change the Test Password.
11. Write both the Relay and Test Passwords down and keep them in a secure place. If you forget the password, contact ABB Power T&D Company Inc.

2.3.4 Verify Settings

1. Using the arrow keys, got to the Main menu, scroll to Setting, press Enter [↵], scroll to Unit Information, press Enter [↵].
2. Record the PCD2000 serial number and CPU ROM for future reference. Use the Catalog Number Interpretation Key (see Section 1.6) to verify the options that apply to this serial number are as ordered.
3. Press Clear [C] to return to the Settings menu, scroll to Show Settings, press Enter [↵]. Check default settings against the tables supplied in this instruction booklet.
4. If a change to the default settings are necessary, press Enter [↵] on the selection to make the appropriate change, enter the new setting change, press Enter [↵] to confirm the change. A prompt will appear asking if you want to save this setting change, select
5. After checking the default settings, press Clear [C] twice to return to the Main menu. Scroll to Settings and press Enter [↵], in the Settings menu, scroll to Change Configuration Settings and press Enter [↵]. In the Change Configuration Settings menu, scroll to Clock and set the unit clock using the arrow keys.
6. Press Enter [↵] to enter the correct time and return to the Change Configuration Settings menu, press Clear [C] twice to return to the Main menu.

2.3.5 Initial Test

The factory default protection elements that are enabled for the PCD2000 are in Primary Settings. Protection elements 50P, 51P, 50N and 51N are enabled. The time overcurrent elements (51P/N) are set for pick-up at 6 amperes and the instantaneous elements (50P/N) are set for pick-up at 3 times the (51P/N setting) or 18 amperes. The default time overcurrent curve is extremely inverse with a time dial setting of 5.0. When the device is tested at 12 amperes (2 times 51P pick-up setting) into one phase and out another phase the PCD2000 should trip the 51P element in approximately 16 seconds. Refer to Figure 10-1 on page 10-5 of this instruction book for test connections and procedure.

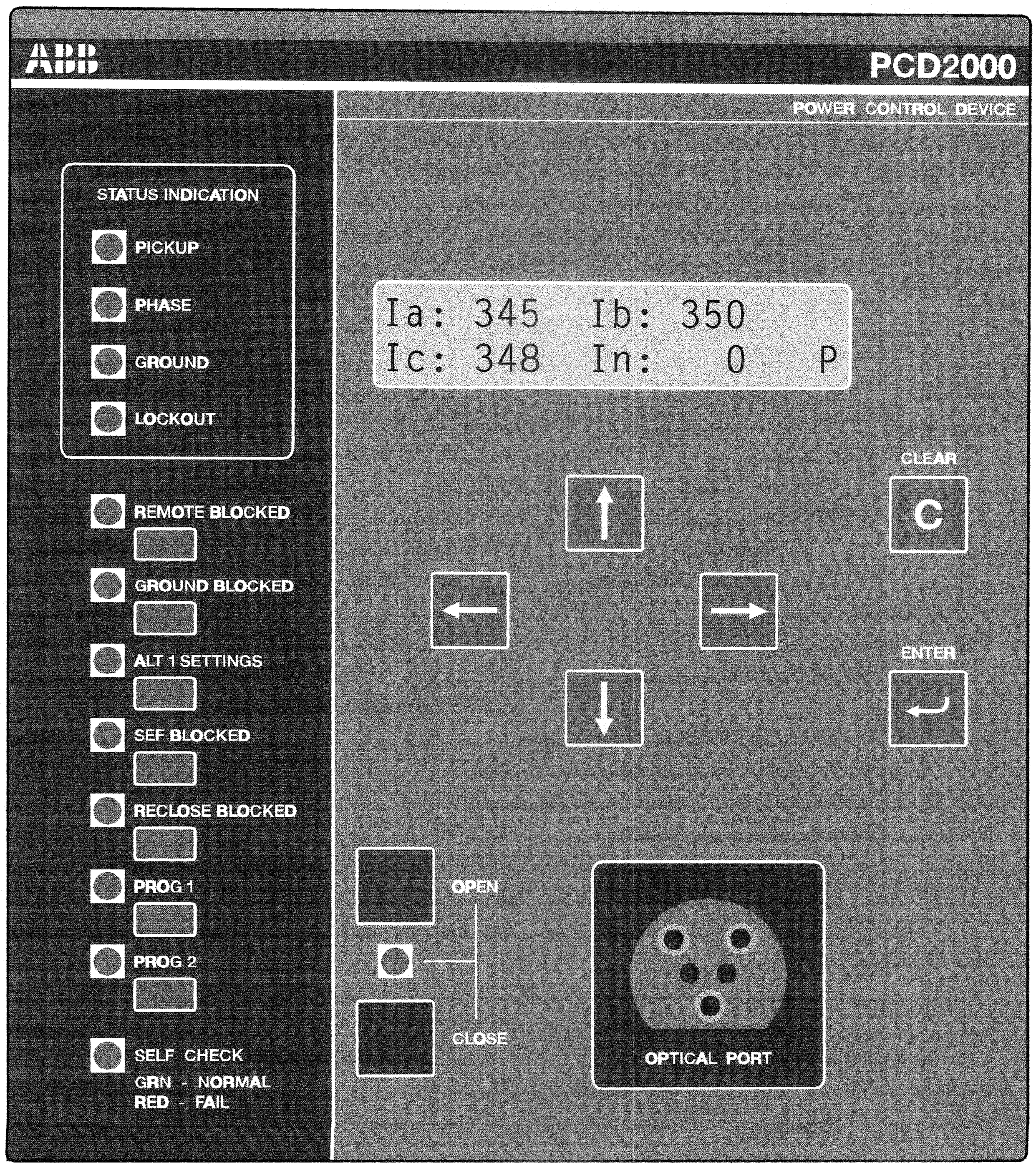
2.3.6 Initial Tripping and Reclose

These factory default settings for the PCD2000 also ensure that the Recloser Trip Elements 79-1 are enabled. With the 79-1 element enabled the PCD2000 can initiate a trip signal to the recloser before the first reclose and lockout. This precautionary setting ensures that the PCD2000 has minimal protection settings prior to being installed into the electric power system. However, this setting alone is not enough. To ensure that the PCD2000 settings are fully enabled, each Recloser Trip Elements should be mapped and enabled in the 79-2 and 79-3 element settings. Only the recloser trip elements that are enabled, or set to lockout, can trip the device during their respective recloser cycle. For example: The 79-1 element is enabled to send a trip signal to the device before the first reclose to lockout. When the 79-2 element is enabled it can send a trip signal to the device between the first and second reclose to lockout. And with the 79-3 element enabled it can send a trip signal between the first, second and third reclose to lockout. Elements that are disabled in any reclose sequence will not operate. Refer to Figure 10-1 in Maintenance and Testing section of this instruction book for test connections and procedure.

3 Human-Machine Interface (HMI)

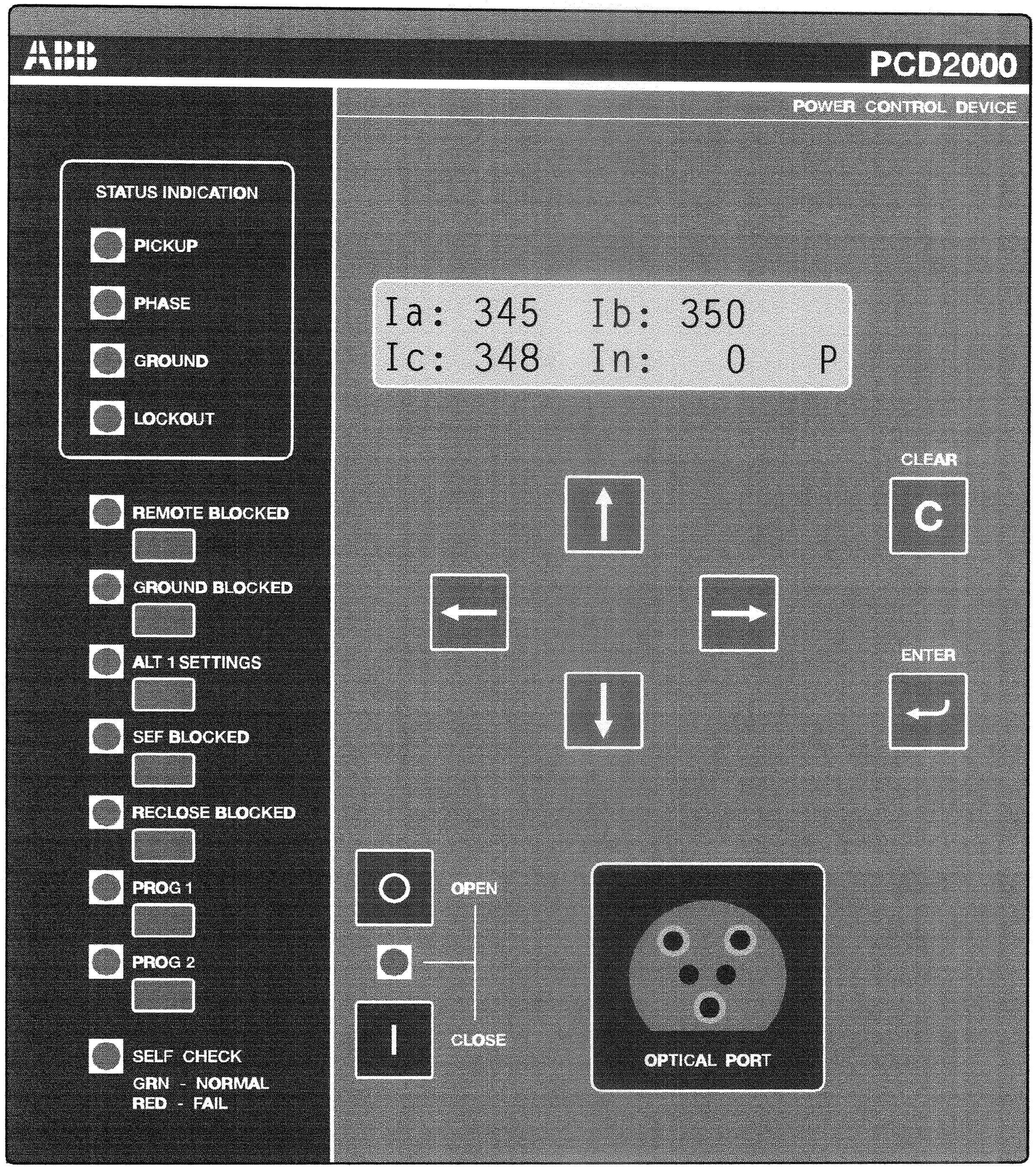
This section describes the front-panel Human-Machine Interface (HMI). The HMI controls can be used to directly control the recloser/breaker or PCD2000, to change the PCD2000 settings, and to view information stored within the PCD2000 unit.

Figure 3-1. Front Panel HMI for ANSI Units



3 HMI

Figure 3-2. Front Panel HMI for IEC Units



3 HMI

Table 3-1. Settings that Affect the Human Machine Interface (HMI)

HMI Abbreviation	WinPCD Name and Description
Target Mode	Target Display Choice of whether the front panel LED targets display information about only the last fault or all faults. This is a Configuration Setting, and so is the same for all three settings sets (Primary, Alternate 1, and Alternate2.
LCD Light	LCD Light Choice of whether to have the LCD light remain on all the time, or shut off five minutes after any key or button has been pressed. This is a Configuration Setting, and so is the same for all three settings sets (Primary, Alternate 1, and Alternate2).
LCD Contrast	LCD Contrast Adjustment Numerical value that specifies the contrast of the LCD display. The range is 0 to 63 with an increment of 1. The default is 60. This is a Configuration Setting, and so is the same for all three settings sets (Primary, Alternate 1, and Alternate2).
Relay Password	Setting to specify the password to access HMI setting menus that require a password. The default is four space-characters. The password cannot be changed using WinPCD. This is a Configuration Setting, and so is the same for all three settings sets (Primary, Alternate 1, and Alternate2).
Test Password	Setting to specify the password to access HMI test menus that require a password. The default is four space-characters. The password cannot be changed using WinPCD. This is a Configuration Setting, and so is the same for all three settings sets (Primary, Alternate 1, and Alternate2).

3.1 Status-Indication LED Targets

3 HMI

3.1.1 Pickup

Indicates current on the phase or neutral lines is above the minimum pickup setting as programmed in any of the PCD2000 overcurrent elements (51P, 51N, 50P-1, 50P-2, 50P-3, 50N-1, 50N-2, 50N-3, 46, 67P or 67N),

3.1.2 Phase

Indicates an overcurrent fault has occurred on one of the phase lines.

3.1.3 Ground

Indicates an overcurrent fault has occurred on the neutral line.

3.1.4 Lockout

Indicates the recloser/breaker has completed its programmed reclosing sequence and has locked out with the recloser/breaker left in the open position.

3.1.5 Self Check

Indicates the functional status of the PCD2000. Green indicates the PCD has successfully passed its internal diagnostic test and is functioning properly. Red indicates the PCD has failed its internal diagnostic test. When the Self Check target is illuminated, all protection elements are disabled, the Self-Test dedicated contact on the rear panel (on the Power Supply or UPS module) will drop out, and alarm contacts are **activated**. Replace the unit as soon as possible.

3.2 Control Buttons with LED Targets

3.2.1 Remote Blocked

When illuminated, all remote commands received through the rear communication port (e.g., from a SCADA system) are being blocked. This includes initiating any contact operations, functional tests and the downloading of settings. Acquisition of informational quantities such as meter values, status, etc., will still be available. The Remote Block condition can be enabled either by pressing the Remote Blocked pushbutton on the front panel OR by using the Remote Blocked logical input (RBI). The front panel LED will illuminate on any source of block. A logical output (RBA) is also generated which can be mapped to a physical output using the programmable I/O (see Section 6). Pressing the Remote Blocked pushbutton will toggle between Enable/Disable.

SCADA control refers to any supported communications protocol such as Modbus® ASCII, Modbus® RTU, or DNP3.0.

3.2.2 Ground Blocked

When illuminated, the following ground overcurrent elements are disabled: 50N-1, 50N-2, 50N-3, 51N and 67N. Also, the SEF element, if available, is blocked. The Remote Block condition can be enabled in any of three ways: (1) pressing the Ground Blocked pushbutton on the front panel, (2) using the Ground Torque Control logical input (GRD), or (3) using the SCADA Ground Block/Unblock points. Any of these sources will turn on the front panel LED and enable the blocking.

Note: The front panel control and SCADA control are mutually resetting. In other words if a block is created by a SCADA block command, a local operator can unblock by pressing the Ground Blocked pushbutton. The opposite is also true; the SCADA Unblock will clear a block enabled using the front panel control. The GRD logical input, however, can never be unblocked by either the SCADA command or by front panel control.

3.2.3 Alt 1 Settings

When illuminated, the Alternate Settings 1 group is active. "A1" will also be displayed in the lower right corner of the LCD display ("P" will be displayed for Primary settings, and "A2" for the Alternate Settings 2 group). Using the Alternate Settings 1 can be enabled either by pressing the Alt 1 Settings pushbutton on the front panel OR by using the Alt Settings 1 logical input (Alt1). This could be used to place "safety" oriented settings in place conveniently during maintenance operations.

3.2.4 SEF Blocked

When illuminated, the Sensitive Earth Fault (SEF) element is blocked. The SEF Blocked control works essentially the same as the Ground Blocked except it effects only the SEF element. The SEF Blocked condition can be enabled either by pressing the SEF Blocked pushbutton on the front panel OR by using the SEF Blocked logical input (SEF). The front panel LED will illuminate on either source of SEF blocking, and also if Ground Blocked is enabled.

3.2.5 Reclose Blocked

The Reclose Blocked control is used to disable the 79 (reclose) element. The Reclose Blocked condition can be enabled in any of three ways: (1) pressing the Reclose Blocked pushbutton, (2) using the recloser enable logical input (43A), or (3) using the SCADA 43A Block/Unblock points. The front panel LED will illuminate for any source of blocking.

Note: The front panel control and SCADA control are mutually resetting. In other words if a block is created by a SCADA block command, a local operator can unblock by hitting the Reclose Blocked control. The opposite is also true; the SCADA Unblock will clear a block due to the front panel control.

The 43A logical input, however, can never be unblocked by either the SCADA command or by front panel control. It is important to note that the blocking affects only the automatic recloser, 79S and 79M. The front panel Close, logical input Close, and HMI menu selection Close are not blocked. The SCADA Close with 43A, however, is blocked by the 43A logical input.

3.2.6 PROG 1

Pressing this pushbutton will initiate a battery test sequence (see page 1-23). The LED target will remain illuminated for the duration of the test.

3.2.7 PROG 2

Pressing this pushbutton will simulate a fault current of 2.0 per unit on all phases and ground. Although the fault is simulated, the PCD2000 will respond as if a real fault current has been applied. When the PCD trips on the simulated fault the fault current will automatically go to zero allowing the breaker to properly clear. When breaker-open is detected, the test mode is exited. Pressing the front panel "C" button will also abort the test. The test will not continue through a reclose sequence since it is a single shot test only. All operation records will be logged as if a real fault were applied, however, fault event records will be suppressed.

Note: Units using firmware version 1.15 or later can no longer initiate this test using the Prog 2 button. Instead, choose "Fault Test Mode" from the Test menu.

CAUTION: The simulated fault test will trip the recloser/breaker.

3.3 Recloser/Breaker Status LED and Direct Controls

3.3.1 Close

Pressing the CLOSE pushbutton sends a close signal to the recloser/breaker. ANSI units have a red close pushbutton; while IEC units have a green close pushbutton. (Whether a unit is ANSI or IEC is designated by the first digit in the PCD2000 catalog number: 8=ANSI, 9=IEC.)

Units operating with firmware version 1.15 or later have a feature that will allow a fixed time delay before closing the recloser/breaker. This setting is accessible via the Configuration Settings menu of the HMI or the WinPCD software. The Close Delay Time setting will allow a delay of 0 to 250 seconds after pressing the close pushbutton before closing the recloser/breaker.

3.3.2 Open

Pressing the OPEN pushbutton sends a trip signal to the recloser/breaker. ANSI units have a green open pushbutton. IEC units have a red open pushbutton. (Whether a unit is ANSI or IEC is designated by the first digit in the PCD2000 catalog number: 8=ANSI, 9=IEC.)

3.3.3 Recloser Position LED Target

Indicates the position of the recloser. For both ANSI and IEC units, green signifies the recloser/breaker is open while red signifies the recloser breaker is closed.

A blinking LED (alternating between red-and-green) indicates that the integrity of the 52a or 52b circuits have been lost, or that the recloser/breaker is in a failed state.

3.4 LCD Display and Control Keys

3.4.1 Liquid Crystal Display (LCD)

The Liquid Crystal Display (LCD) of the PCD2000 displays two lines of twenty characters each.

High or low temperature extremes will affect the illuminated visibility of this display. In the event the display becomes unreadable, increase the LCD contrast by pressing the down-arrow key while the normal LCD display is in view (which displays the present load current values). The normal contrast the LCD can also be changed with a setting on the Configuration Menu.

The following displays and menus are available through the HMI:

- **Continuous Display**—shows currents, voltages and which settings table is enabled
- **Post-Fault Display**—shows faulted elements, phase(s), and fault currents for last fault until targets are reset

Figure 3-3 below shows an outline of all the menus available through the front panel HMI.

3.4.2 Enter Key

Press the Enter key first to enter the menu tree for displaying information or changing settings (see page). To move down the menu tree to a sub-menu, scroll to the sub-menu's name using the up and down arrow keys, then press the Enter key. The Enter key is also used to accept a new setting value or record choice that has been selected using the left and right arrow keys.

3.4.3 Left and Right Arrow Keys

Use the left and right arrow keys to decrease or increase, respectively, a setting value or record number. 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.

3.4.4 Up and Down Arrow Keys

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.

When the normal LCD display is in view (which shows the present load-current values), pressing the down arrow key will increase the contrast of the LCD display, while pressing the up arrow key will reduce the LCD display contrast.

3.4.5 Clear Key

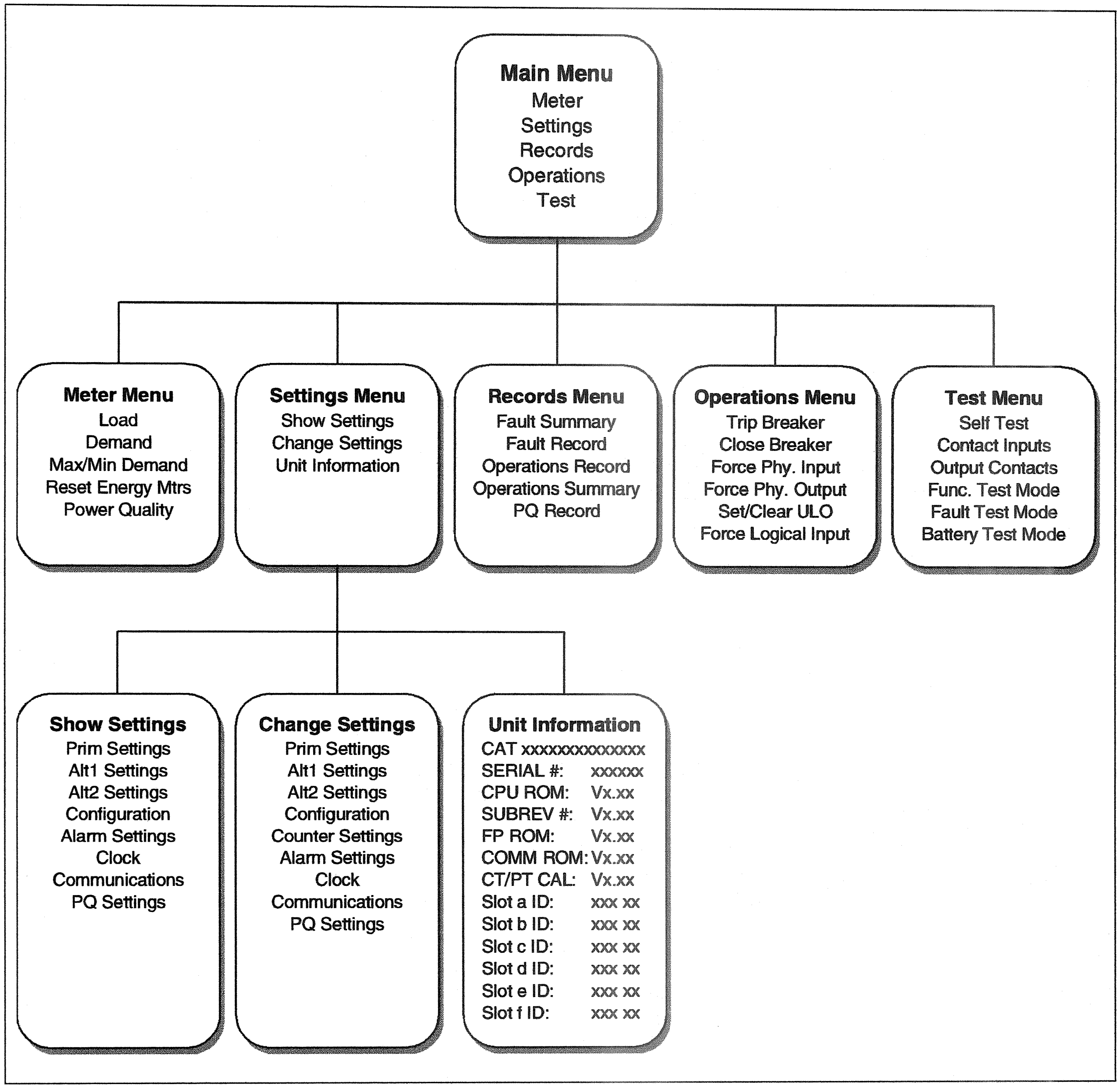
The Clear key can be used to:

- Return to the previous menu (i.e., move up the menu tree)
- Reset LED targets and the LCD display after a fault (push "C" once)
- Scroll through all metered values (push "C" twice)
- Reset the peak demand values (push "C" three times)

3.5 PCD2000 System Reset

You can perform a system reset by simultaneously pressing the "C", "E" and up-arrow keys. A System Reset resets the microprocessor and re-initiates the software program. During a System Reset no information or settings are lost.

Figure 3-3. HMI Menu Map



3.6 Optical Port

The optical port on the front panel can be used to connect a computer to the PCD2000. Additional data ports are located on the rear of the unit (see Section 9).

4 Using WinPCD

WinPCD is a Windows® based program that provides point-to-point communications with the PCD2000. By using WinPCD, you can program the settings for the PCD2000's various functions, map logical inputs and outputs, and monitor the control's activity.

You can also use the software without the PCD2000 control to explore the capabilities and functionality of the control. When your PC is not connected to a PCD2000, the settings and configurations displayed are the factory default values. You can then change the values and save them to a database for later download to a PCD2000. When the PC is connected to a PCD2000, the records can be viewed and printed to a printer or a file. Printing to a file will create a text file containing the information you are viewing on the screen.

For the Fault Summary and the Operations Record, only the screens you view are saved to the database. Therefore, to save all the data, you must view all the screens before exiting the record display.

When changing the Configuration Settings through WinPCD, you must type in the four-digit password (the factory default password is four spaces) followed by a carriage return.

Use a null modem when you connect a terminal directly to the PCD2000.

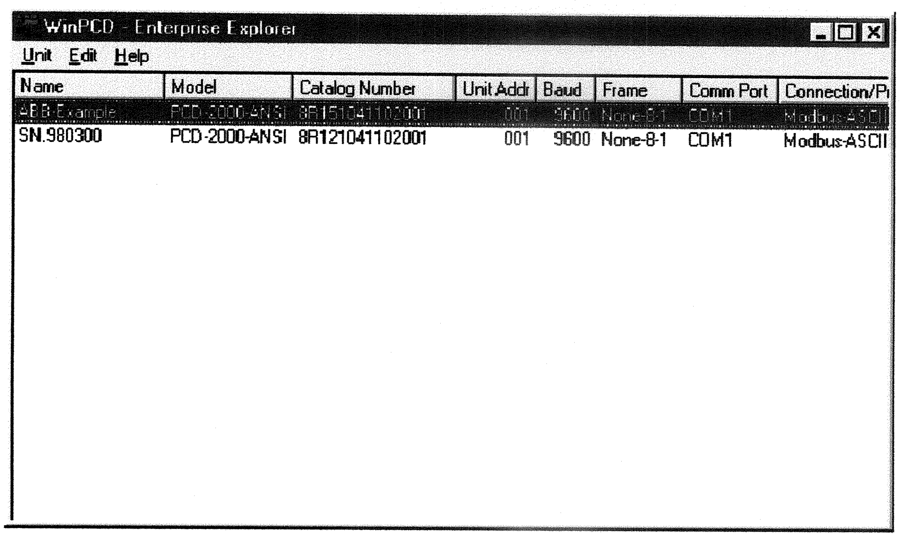
To print WinPCD screens with a laser jet printer by using the Print Screen key, you must change the character set mode of the printer from an ASCII character set to a line character set. Each printer has its own specific code to accomplish this. What code to use and how to program the code into the printer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

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 WinPCD, contact ABB Power Distribution.

4.1 WinPCD – Enterprise Explorer

The WinPCD -Enterprise Explorer window is used to create and manage information about one or more PCD2000 units. It is the first window to appear when you start WinPCD.

Figure 4-1. WinPCD Enterprise Explorer



The WinPCD -Enterprise Explorer contains a list of all PCD2000's currently in the database on the computer. You can select a PCD2000 unit already in the database, or add a new unit.

4.1.1 Add a PCD2000 Unit

To add a unit to your list of PCD2000's select Add from the Unit menu. You will be prompted to enter information about the unit (a name, the model number, and the catalog number). If the PCD2000 and the computer are already connected, press the Autodetect button to have WinPCD search for the unit and download the required information from it.

Figure 4-2. Add Unit Window

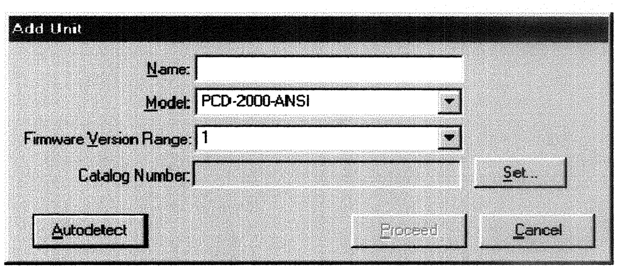
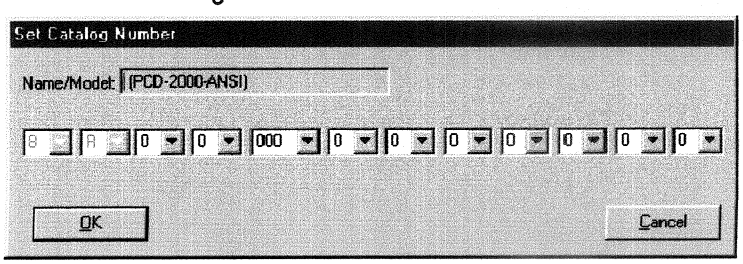


Figure 4-3. Set Catalog Number Window

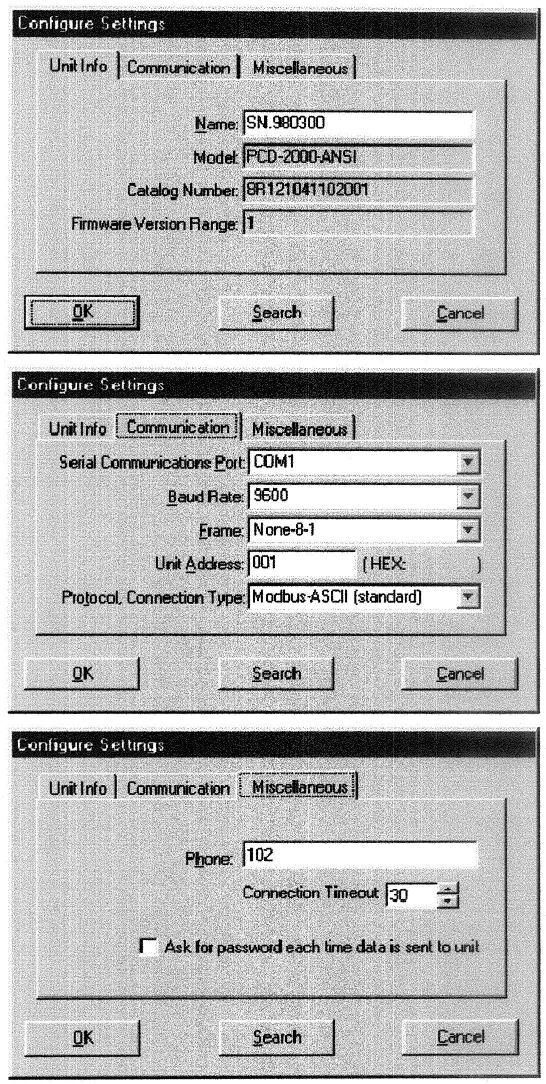


4.1.2 Local Setup for Data Communication

Before communicating with an actual PCD2000 unit, WinPCD must know how the data communications channel is configured. (Of course, this is not necessary to work "off line" with unit data stored in the WinPCD database.). These settings can be different for each PCD2000 in the WinPCD database. (Configuring the PCD2000's data communication settings are described in Section 9).

To configure the computer's data communications for a PCD2000 unit, select the unit in the Enterprise Explorer window, then select Configure from the Edit menu. A dialog window with three tabs will appear. If the PCD2000 is connected to the computer, you can click the Search button to search for the device. Otherwise, enter the appropriate information, then click the OK button.

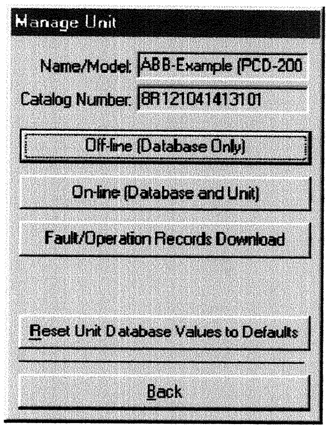
Figure 4-4. Configure Data Communications Settings Window



4.1.3 Start Communicating

To start communicating with a PCD2000 unit (either an actual unit or information about the unit in the WinPCD database), double-click on the name of the unit in the Enterprise Explorer window (or select it and choose Manage from the Unit menu). A dialog box will appear asking you whether you want to communicate with the database-representation of the unit, both the database and the actual unit (if connected), immediately download fault and operations records (this is a shortcut that bypasses the Main Menu),or reset the unit's information to the defaults.

Figure 4-5. Manage Unit Window



If you click "Off-line" or "On-line", the Main Menu will open. It is described beginning on page 4-5.

4.1.4 Enterprise Explorer Utilities

4.1.4.1 Clone a Unit

To clone (make a new copy) of a PCD2000 already in the WinPCD database, choose Clone from the Edit menu.

4.1.4.2 Copy One Unit's Information to Another Unit

To copy the information about one PCD2000 in the database to another PCD2000 already in the database (over-writing the existing information), choose Copy from the Edit menu. In the dialog box that appears, select a source PCD2000 and a destination PCD2000.

4.1.4.3 Import and Export Database Data

You can export data from a WinPCD database into a file that can then be imported into another WinPCD database. To do so, choose Import/Export from the Unit menu and specify a file name and location.

4.1.4.4 Delete a PCD2000 Unit

To delete information about a PCD2000 from the WinPCD database, select the unit in the Enterprise Explorer window, then choose Delete from the Unit menu.

4.1.4.5 Print Information about a PCD2000 Unit

To print information about a PCD2000 from the WinPCD database, select the unit in the Enterprise Explorer window, then choose Delete from the Unit menu.

4.1.5 Exit WinPCD

To exit the WinPCD application, choose Exit from the Unit menu.

4.2 WinPCD Main Menu

From the Main Menu (accessed through the Explorer window) you interact with a particular PCD2000 unit (or information about the unit stored in the database). The sub-menus accessed through the Main Menu are similar to the menus accessed through the front panel HMI, with some additional capabilities.

4.2.1 Metering Menu

Choices in the Metering menu enable you to view metering data stored in the database and/or data being communicated from a connected PCD2000 unit. See Section 7 for details.

4.2.2 Settings Menu

Choices in the Setting menu enable you to view and/or change the settings of the PCD2000. See the appropriate section of this manual for the type of setting you wish to view or change.

From any of the settings menus you will have three basic options:

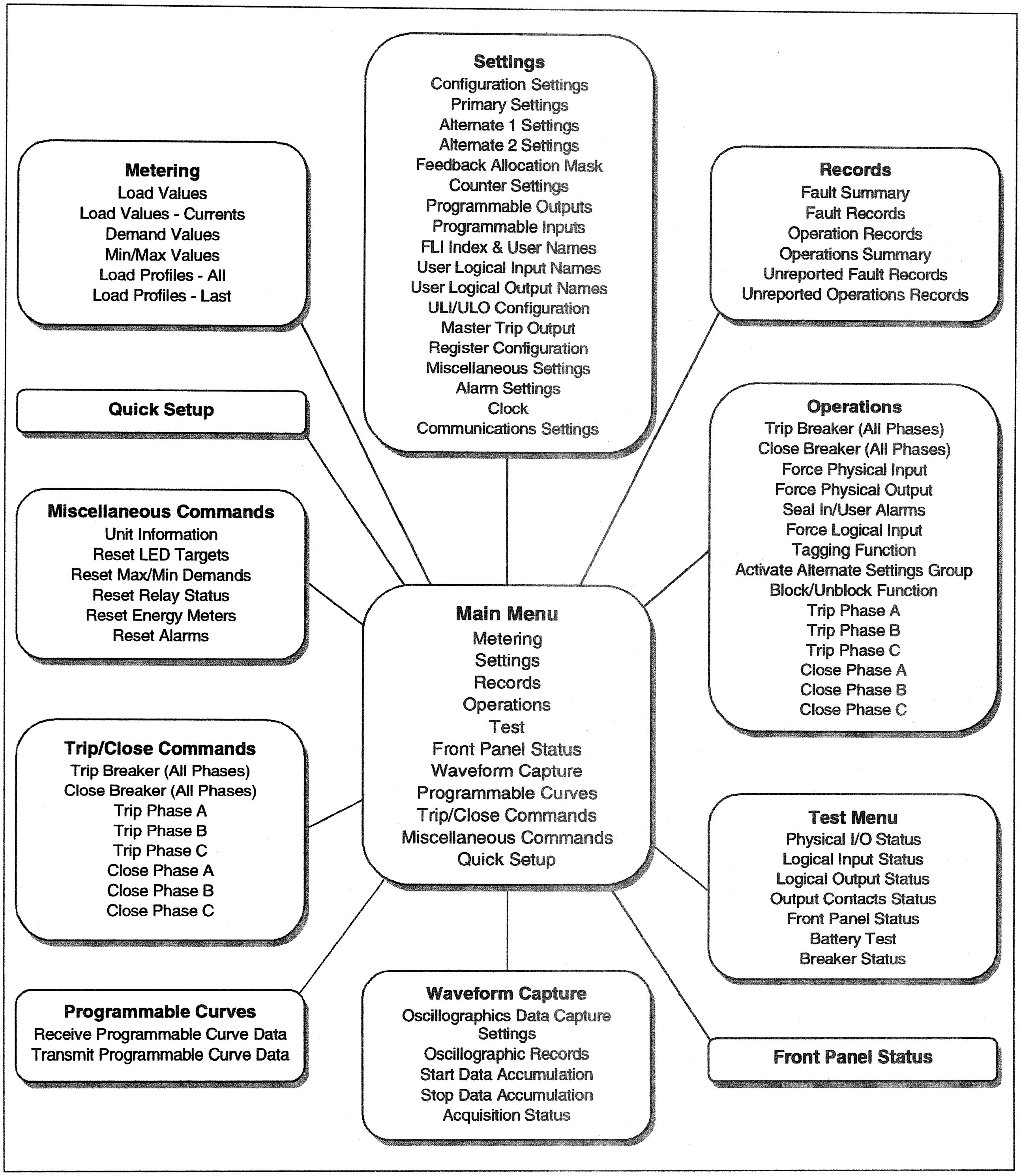
- Receive Data from Unit.
- Send Database Data to Unit.
- Send Unit Data to Database.

Receive Data will display unit data on the screen only. Send Data will send data from the database to the unit or vice-versa. Please be aware that choosing a send data option will replace data at the destination with data from the source.

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

1. From the WinPCD -Enterprise Explorer highlight the unit you wish to program and choose [Manage].
2. From the Manage Unit menu, choose [Database &Unit Values] for online programming or [Database Values] for offline programming.
3. From the Unit Information menu, choose [Proceed]. If you do not successfully reach this menu, check your communications link with the PCD2000 and try again.
4. From the Main Menu, highlight "Settings "and choose [Detail].
5. From the Settings menu highlight the settings group you wish to change and choose [Detail].
6. A settings menu will appear showing the settings group you have chosen.
7. At this point, you will see three columns:
   a. Setting -lists the setting name
   b. Database Value -this column shows the value for the setting stored in the database on your local PC.
   c. Actual Unit Value -this column shows the actual value stored in the PCD2000.

Figure 4-6. WinPCD Main Menu Outline



8. You now have several options to choose from:

   a. [Receive Data from Unit]-this option will download the unit settings values for display only.

b. If you have chosen the above option you will now have the option to [Send Unit Data to Database]- this option will send the unit data to the database and write over the existing data.

Note: If this is your first time accessing this particular PCD2000,it is highly recommended that you choose [Send Unit Data to Database] to ensure that the data-base and the PCD2000 start with the same settings. However, please be aware that this option replaces your existing database values.

c. [end Database Data to Unit]-this option will down-load the database values to the unit.

9. To change a setting value:

   a. Highlight the setting you wish to change.

   b. Choose [Database Value Detail].

   c. A window will appear allowing you to select the setting value from a list or to scroll the value up or down.

   d. Make your selection and choose [OK].

10. To Save Changes:

    a. Changes are automatically saved to the database.

    b. Choose [Send Database to Unit] to download the settings to the unit.

11. Choose [Back] to exit the menu for the current setting group.

When editing some settings in off line mode, you will be prompted for the phase and neutral tap range. This value is determined by jumpers on the PT/CT Module (see page 1-16).

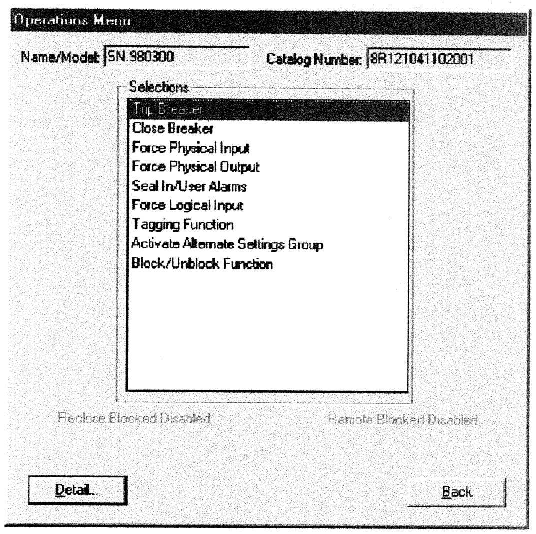
4.2.3 Records Menu

Choices in the Records menu enable you to view records data stored in the database and/or retrieve and view records from a connected PCD2000 unit. See Section 8 for details.

4.2.4 Operations Menu

When connected to a PCD2000 unit, choices in the Operations Menu enable you to operate the PCD2000 through WinPCD. (See also the Trip/Close Commands menu.)

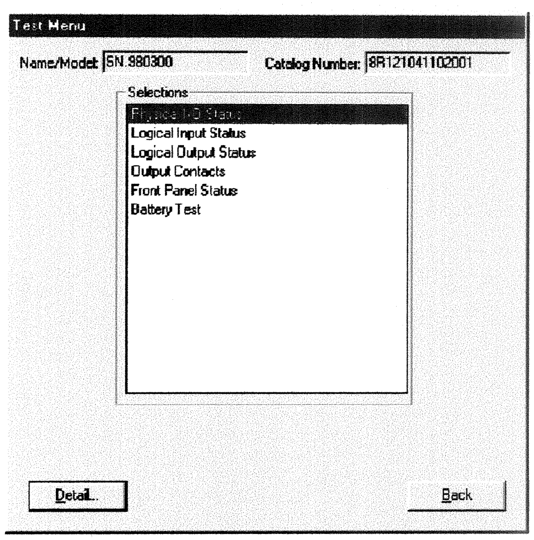
Figure 4-7. Operations Menu



4.2.5 Test Menu

When connected to a PCD2000 unit, choices in the Test Menu enable you to initiate tests of the PCD200 and view the results through WinPCD.

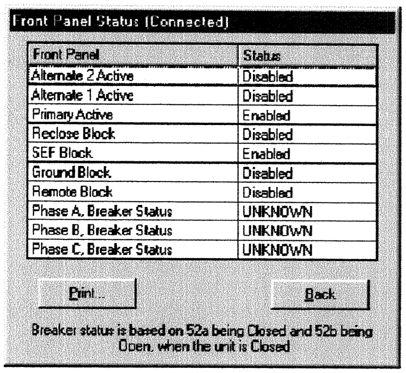
Figure 4-8. Test Menu



4.2.6 Front Panel Status Display

When connected to a PCD2000 unit, choosing Front Panel Status from the Main Menu will retrieve and display information describing the present status of the PCD2000.

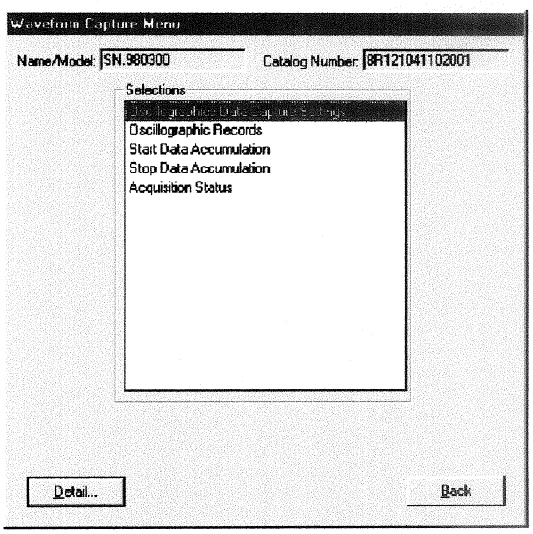
Figure 4-9. Front Panel Status



4.2.7 Waveform Capture Menu

Choices in the Waveform Capture Menu enable you to specify when and how the PCD2000 should capture waveform data. When connected to a PCD2000 unit, you can send a commands to collect waveform data. Wave form data is viewed with a separate application, POWERview (see page 4-12).

Figure 4-10. Waveform Capture Menu



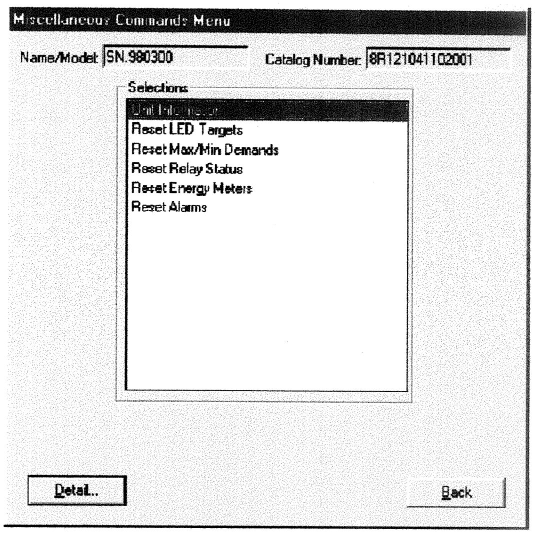
4.2.8 Programmable Curves Menu

Choices in the Programmable Curves Menu enable you to download and upload user-defined time-overcurrent curves created with the CurveGen application (see page 5-80).

4.2.9 Miscellaneous Commands Menu

When connected to a PCD2000 unit, choices in the Miscellaneous Commands Menu enable you to send additional types of commands to the PCD2000 through WinPCD. (See also the Operations Menu and Trip/Close Commands Menu.)

Figure 4-11. Miscellaneous Commands Menu



4.3 Quick Setup

For applications that mostly use the default settings of the PCD2000, you can choose Quick Setup from the Main Menu to see and set only those settings for which the appropriate value is usually application-specific (i.e., not the default). These are NOT a separate set of settings. The Quick Setup windows are just a faster way of getting to some of the settings.

Figure 4-12. Phase Overcurrent Tab of the Quick Setup Window

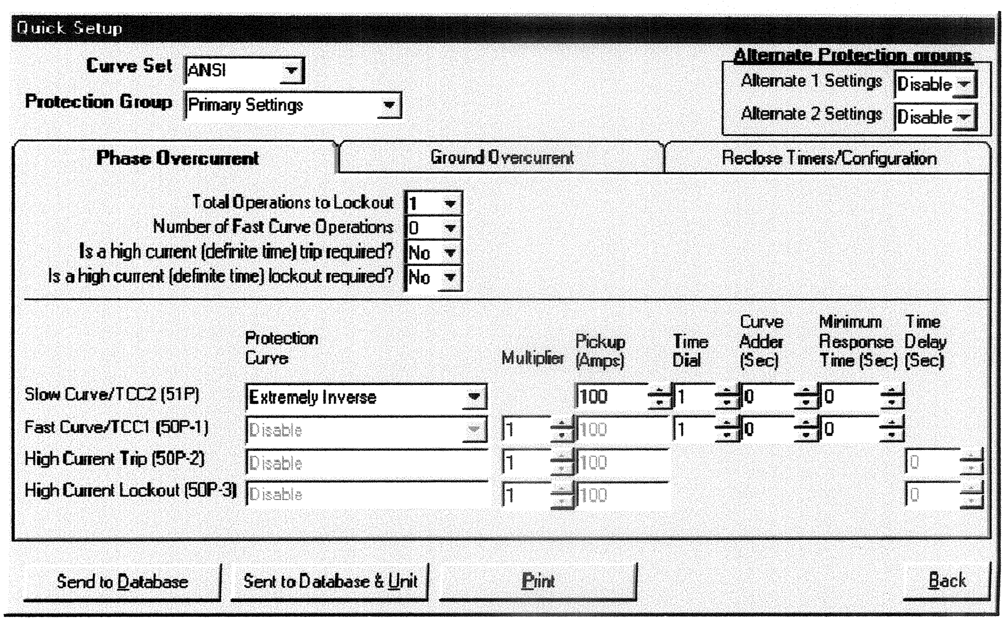


Figure 4-13. Ground Overcurrent Tab of the Quick Setup Window

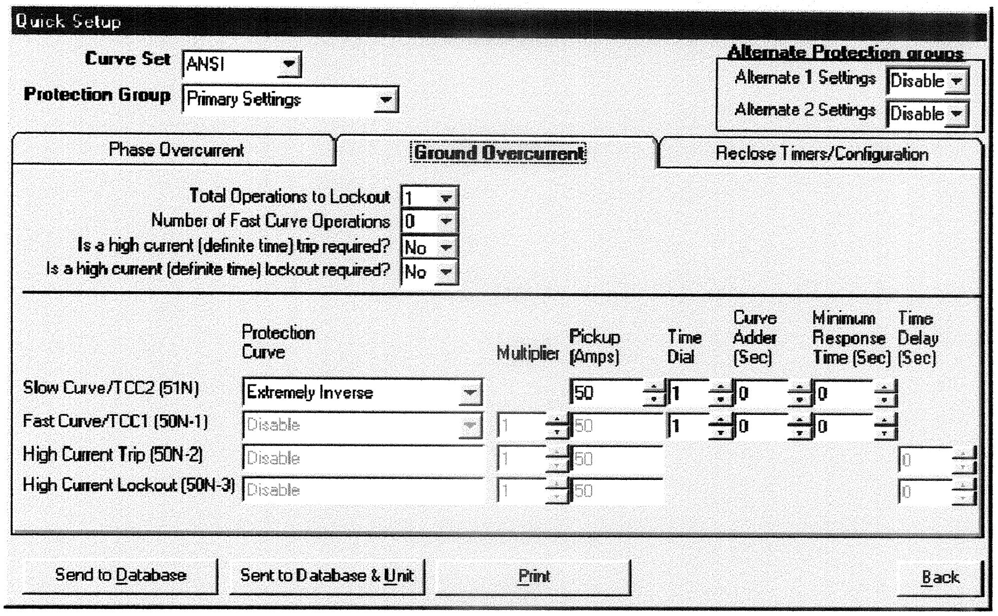
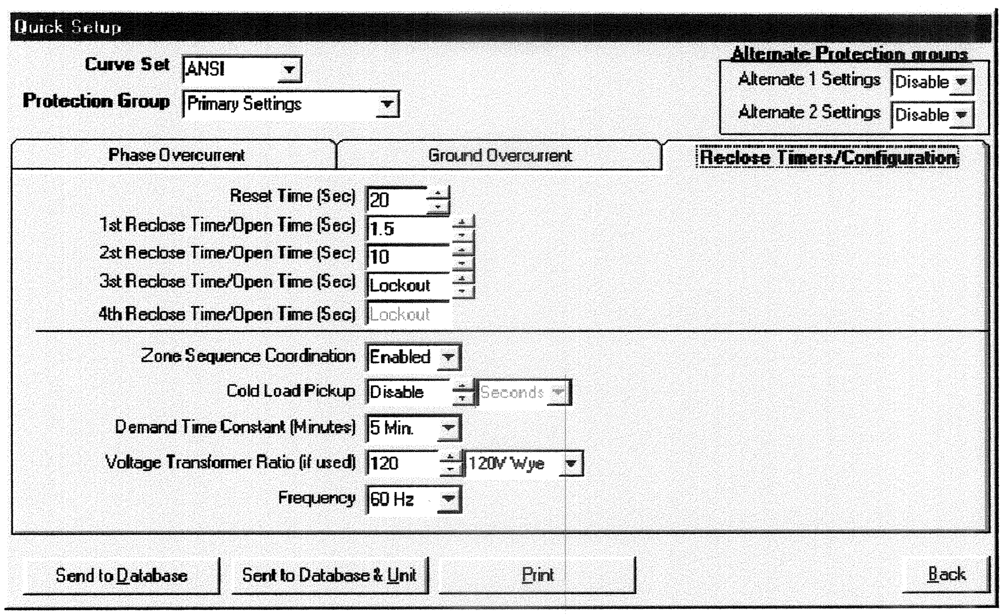


Figure 4-14. Recloser Timers/Configuration Tab of the Quick Setup Window



4.4 Waveform Analysis

Waveform analysis is performed by a separate ABB software application. ABB's POWERview Oscillographic Analysis Tool software program enhances the fault analysis capabilities of the ABB controls. The POWERview Oscillographic Analysis Tool displays the waveform data captured by these units. Besides all analog wave forms, this program shows digital input/output, pickup, and fault information.

The analog wave forms 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 wave form. 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 control; the unit ID number; and the catalog number.

You can overlay an individual analog wave form onto any other analog wave form. For example, you can overlay Va onto Ia to examine the phase relationship.

You can scale all current wave forms 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 wave forms with respect to the largest amplitude encountered for that wave form only; that is called the Normalized Scale. The Normalized Scale accentuates noise and other characteristics of the wave form.

A zoom feature allows you to position the left and right cursors within the wave form and then "zoom in" to closely examine that section of the wave form.

4.4.1 System Requirements and Installation

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

To install the POWERview Oscillographic 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 name 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.
4. Set up the executable application 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:ourdir/pwrview.exe), and click on "OK." The icon should appear in the Applications window of the Program Manager.

4.4.2 Using the POWERview Oscillographic Analysis Tool

The POWERview Oscillographic Analysis Tool is a menu-driven program. A parent window contains windows for the analog wave forms and for digital information.

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 Oscillographic 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.

4.4.3 Analog Display Windows

The analog waveform windows appear within the Main Display window. The Main Display window appears to the right of the analog wave forms and lists the file name, date and time the data was captured at the control, 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.

4.4.4 Menu Commands

Each menu on the POWERview Oscillographic Analysis Tool parent window has specific features.

4.4.4.1 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.

4.4.4.2 Assign Colors Menu

Use this menu to assign colors to the analog waveforms. This is especially helpful when you overlay two wave forms.

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

4.4.4.3 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.

4.4.4.4 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 wave form 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.

4.4.4.5 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. Double click on the parameters you want. As you double 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.

4.4.4.6 Zoom Menu

Zooming in allows you to enlarge a selected portion of the analog wave form. 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.

4.4.5 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 wave forms.

4.4.6 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 "Wave Form" 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 wave form.)
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 fundamentals (to 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.

5 Protection

5.1 Introduction

Distribution systems are designed to operate safely with protective devices to sense and isolate faults limiting the time and magnitude of power system interruptions. Protective relaying elements utilized within the PCD2000 are important toward accomplishing safe and reliable power to customers by preventing large losses of power due to unnecessary equipment outages or equipment damage as a result of a fault or overload.

Applying protective relaying elements on a power system is gained from knowledge and experience since there is a philosophy involved toward making the appropriate selections. Reading and understanding how the protective relaying elements within PCD2000 operate together will create a through understanding of the PCD2000. Ensuring maximum protection, minimum equipment cost, high sensitivity to faults, insensitivity to normal load currents and selectivity in isolating a small section in the system is the goal of a well-coordinated distribution system.

For more detailed information on setting up protective elements, refer to the Application Notes in the last section of this instruction book.

Table 5-1. Configuration Settings for Protection Elements

Setting	Description
Protection Mode	Protection behavior can be based on either fundamental (default) or RMS (root mean square) values.
Alternate 1 Settings	If you wish to use the first alternate-settings group, this setting must be enabled (the default is disabled).
Alternate 2 Settings	If you wish to use the second alternate-settings group, this setting must be enabled (the default is disabled).

Figure 5-1. PCD2000 Protective Elements - ANSI Designations

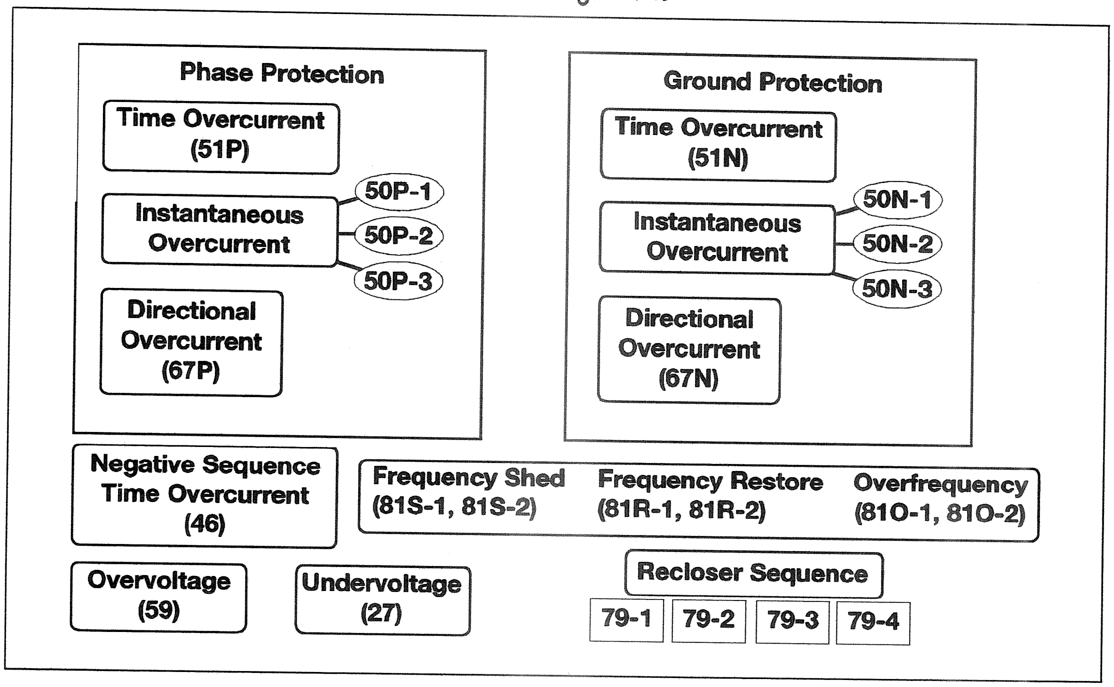


Figure 5-2. PCD2000 Protective Elements - IEC Designations

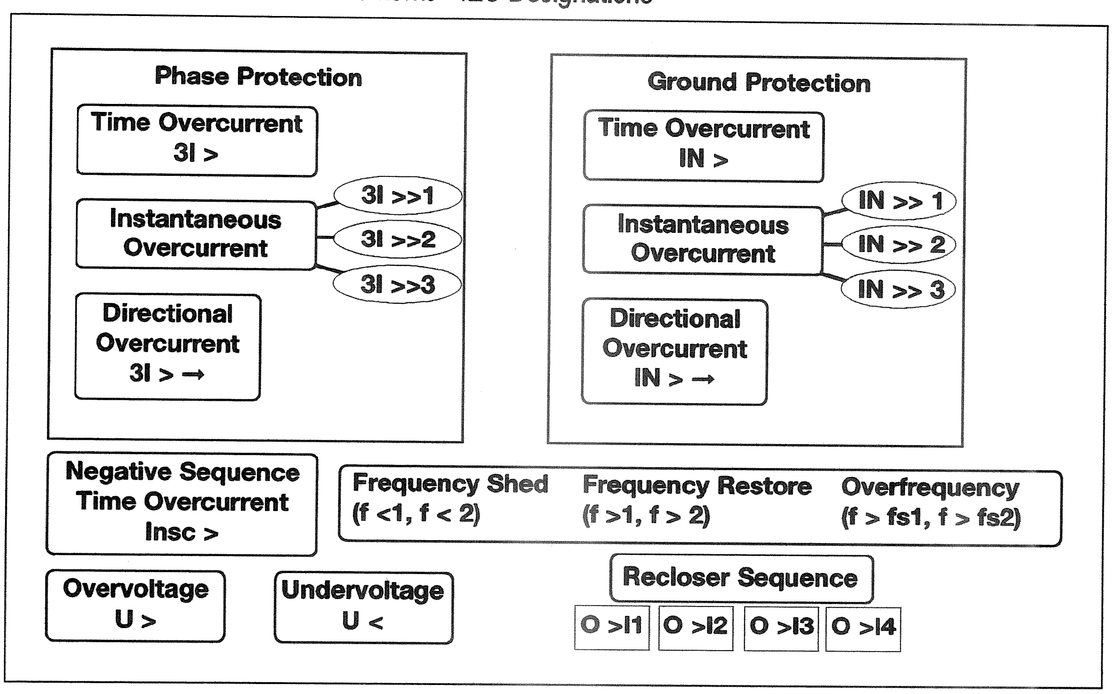


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Table 5-2. List of PCD2000 Device Element Numbers

Element Device Number	Function
27 I U <	Undervoltage
32 I	Directional Power
46 I Insc >	Negative Sequence Current
50 I 3I >>	Instantaneous Overcurrent
51 I 3I >	Inverse Time Overcurrent
59 I U >	Overvoltage
67 I 3I > →	Directional Overcurrent
79 I O	Recloser
81 I f	Frequency

Table 5-3. List of PCD2000 Suffix Letters

Element Suffix Letter	Function
P	Phase Protection
N	Ground-Fault Protection or Residual CT Circuit
O I >	Over
R	Restore
S	Shed
1	Recloser Sequence Number 1
2	Recloser Sequence Number 2
3	Recloser Sequence Number 3
4	Recloser Sequence Number 4
<	Under
V	Voltage

5.2 Phase Time-Overcurrent Element 51P (3I>)

The phase time overcurrent element 51P contained in the PCD2000 is set based on CT secondary current as connected to the phase current inputs: I_A, I_B, I_C. For PCD2000 in VR-3S or Cooper™ Retrofit applications, the 51P setting is expressed in primary amperes. Time overcurrent protection element is the most commonly used protective element for distribution systems and is used in both primary and back-up protection. The time overcurrent element provides a time delay characteristic versus current for tripping using an inverse time curve characteristic is based upon four factors, pickup value, curve type, time dial setting and reset mode. This inverse characteristic means that the 51P element operates slowly on small values of current above the pickup value and faster when current increases significantly above the pickup value. The 51P element is always Enabled in the Primary, Alternate 1 and Alternate 2 setting groups.

Multiple time curves and time dials are available for the 51P element to closely coordinate with other protection elements within the PCD2000 and other external devices on the distribution system. ANSI, IEC and Recloser (hydraulic) time current curves are included in the PCD2000. A User Programmable curve option is also available allowing the user to create custom time current curves for more enhanced coordination than the standard curve types provide.

There is another global setting that is also required to be selected, the Reset mode. The Reset mode can be either instantaneous or time delay. The time delay reset mode applies to the ANSI/IEEE curves. The instantaneous mode is used to coordinate with other instantaneous reset devices such as a recloser or other protective equipment on the distribution system. In the instantaneous mode the 51P element will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 51P element is set by factory default to operate the Trip contact. The 51P element will always initiate reclosing unless the recloser is disabled.

PCD2000 units ordered with the single-phase option have a separate 51P element for each phase: 51P-A, 51P-B, and 51P-C. All three elements share the same settings. For information about how they control logical outputs for tripping, see Section 11.

Table 5-4. 51P (3I>) Element Settings

51P (3I>) Setting	Description
51P Curve Select 3I> Curve	Selection of the time-overcurrent curve function used to calculate the time delay between pickup and trip. See Table 5-5 below for choices and details.
51P Pickup Amps 3I> Amps	The 51P element will pickup when the measured CT **secondary** current rises above the specified value. The setting range and increment depend on the configuration of the PT/CT module (see page 1-16).
51P Time Dial/Delay 3I> Time Multiplier	Value that is a variable in the time-overcurrent curve function. See Table 5-5 below for details.
51P Time-Curve Adder	An additional fixed time delay added to the time delay resulting from the time-overcurrent curve function. This setting is not available when using an IEC curve. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
51P Minimum Response	The minimum time delay that will occur between pickup and trip, even if the time delay would otherwise be shorter. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.

Table 5-5. 51P (3I>) Curve-Settings Details

Curve Set *	Curve	Time Dial/Delay Setting Range	Increment	See Page
ANSI	Extremely Inverse	1.0 to 10.0	0.1	5-47
	Very Inverse	1.0 to 10.0	0.1	5-48
	Inverse	1.0 to 10.0	0.1	5-49
	Short Time Inverse	1.0 to 10.0	0.1	5-50
	Short Time Extremely Inverse	1.0 to 10.0	0.1	5-51
	Definite Time	1.0 to 10.0	0.1	5-52
	Long Time Extremely Inverse	1.0 to 10.0	0.1	5-53
	Long Time Very Inverse	1.0 to 10.0	0.1	5-54
	Long Time Inverse	1.0 to 10.0	0.1	5-55
	Recloser Curve #8	1.0 to 10.0	0.1	5-56
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
IEC	Extremely Inverse	0.05 to 1.00	0.05	5-59
	Very Inverse	0.05 to 1.00	0.05	5-60
	Inverse	0.05 to 1.00	0.05	5-61
	Long Time Inverse	0.05 to 1.00	0.05	5-62
	Definite Time	0.0 to 10.0	0.1	5-63
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
Recloser	Curve A (101)	0.10 to 2.00	0.01	5-64
	Curve B (117)	0.10 to 2.00	0.01	5-65
	Curve C (133)	0.10 to 2.00	0.01	5-66
	Curve D (116)	0.10 to 2.00	0.01	5-67
	Curve E (132)	0.10 to 2.00	0.01	5-68
	Curve K (162)	0.10 to 2.00	0.01	5-69
	Curve N (104)	0.10 to 2.00	0.01	5-70
	Curve R (105)	0.10 to 2.00	0.01	5-71
	Curve W (138)	0.10 to 2.00	0.01	5-72
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80

* Choice of Curve Set is a Configuration Setting that applies to all protection elements.
** See page 5-80 for information on how to specify a custom time-overcurrent curve.

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5.3 Ground Time-Overcurrent Element 51N (IN>)

The ground or residual time overcurrent element 51N contained in the PCD2000 is set based on CT secondary current as connected to the phase current inputs: I_N. For PCD2000 in VR-3S or Cooper™ Retrofit applications, the 51N setting is expressed in primary amperes. A ground or residual time overcurrent protection element similar to the 51P is the most commonly used protective element for distribution systems and are used in both primary and back-up protection. The time overcurrent element provides a time delay characteristic versus current for tripping using an inverse time curve characteristic is based upon four factors, pickup value, curve type, time dial setting and reset mode. This inverse characteristic means that the element operates slowly on small values of current above the pickup value and faster when current increases significantly above the pickup value. The 51N element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

Multiple time curves and time dials are available for the 51N element to closely coordinate with other protection elements within the PCD2000 and other external devices on the distribution system. ANSI, IEC and Recloser (hydraulic) time current curves are included in the PCD2000. A User Programmable curve option is also available in the PCD2000 allowing the user to create custom time current curves for more enhanced coordination than the standard curve types.

There is another global setting that is also required to be selected, the Reset mode. The Reset mode can be either instantaneous or time delay. The time delay reset mode applies to the ANSI/IEEE curves. The instantaneous mode is used to coordinate with other instantaneous reset devices such as a recloser or other protective equipment on the distribution system. In the instantaneous mode the 51N element will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 51N element is set by factory default to operate the Trip contact. The 51N element will always initiate reclosing unless the recloser is disabled. Refer to the Reclosing section for more details.

PCD2000 units ordered with the single-phase option have a separate 51N element for each phase: 51N-A, 51N-B, and 51N-C. All three elements share the same settings. For information about how they control logical outputs for tripping, see Section 11.

Table 5-6. 51N (IN>) Element Settings

51N (IN>) Setting	Description
51N Curve Select IN> Curve	Selection of the time overcurrent function used to calculate the time delay between pickup and trip. See Table 5-7 below for details. Note that the Reset Mode may also affect the time delay (see page 5-44).
51N Pickup Amps IN> Amp	The 51P element will pickup when the measured CT **secondary** current rises above the specified value. The setting range and increment depend on the configuration of the PT/CT module (see page 1-16).
51N Time Dial/Delay IN> Time Multiplier	A specified value that is a variable in the time-overcurrent curve function. See Table 5-7 below for details.
51N Time-Curve Adder	An additional fixed time delay added to the time delay resulting from the 51N Curve Select and 51N Time Dial settings. This setting is not available when using an IEC curve. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
51N Minimum Response	The minimum time delay that will occur between pickup and trip, even if the time delay based on the time-overcurrent curve would be shorter.

Table 5-7. 51N Curve-Settings Details

Curve Set *	Curve	Time Dial/Delay Setting Range	Increment	See Page
ANSI	Extremely Inverse	1.0 to 10.0	0.1	5-47
	Very Inverse	1.0 to 10.0	0.1	5-48
	Inverse	1.0 to 10.0	0.1	5-49
	Short Time Inverse	1.0 to 10.0	0.1	5-50
	Short Time Extremely Inverse	1.0 to 10.0	0.1	5-51
	Definite Time	1.0 to 10.0	0.1	5-52
	Long Time Extremely Inverse	1.0 to 10.0	0.1	5-53
	Long Time Very Inverse	1.0 to 10.0	0.1	5-54
	Long Time Inverse	1.0 to 10.0	0.1	5-55
	Recloser Curve #8	1.0 to 10.0	0.1	5-56
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
IEC	Extremely Inverse	0.05 to 1.00	0.05	5-59
	Very Inverse	0.05 to 1.00	0.05	5-60
	Inverse	0.05 to 1.00	0.05	5-61
	Long Time Inverse	0.05 to 1.00	0.05	5-62
	Definite Time	0.0 to 10.0	0.1	5-63
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
Recloser	Curve 2 (135)	0.10 to 2.00	0.01	5-73
	Curve 3 (140)	0.10 to 2.00	0.01	5-74
	Curve 8 (113)	0.10 to 2.00	0.01	5-75
	Curve 8*	0.10 to 2.00	0.01	5-76
	Curve 8+ (111)	0.10 to 2.00	0.01	5-77
	Curve 9 (131)	0.10 to 2.00	0.01	5-78
	Curve 11 (141)	0.10 to 2.00	0.01	5-79
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80

* Choice of Curve Set is a Configuration Setting that applies to all protection elements.
** See page 5-80 for information on how to specify a custom time-overcurrent curve.

The 51N element can be disabled by pressing the Ground Blocked button on the front panel HMI, or supervised (torque controlled) by mapping the GRD logical input to a physical input for external supervision or logical output for internal supervision.

5.4 Phase Instantaneous Overcurrent Elements 50P-1

The 50P-1 is a phase instantaneous, Level 1, overcurrent element that is a multiple of the 51P element for accurate coordination. It should be enabled when instantaneous phase tripping is desired. The operating time the 50P-1 should be set to operate equal to or faster than the 51P element. The 50P-1 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The phase instantaneous overcurrent element 50P-1 contained in the PCD2000 is set based on CT secondary current as connected to the phase current inputs: I_A, I_B, I_C.

Multiple time curves and time dials are available for the 50P-1 element to closely coordinate with other protection elements within the PCD2000 and other external devices on the distribution system. User Programmable curve option is also available in the PCD2000 allowing the user to create custom time current curves for more enhanced coordination than the standard curve types.

There is another global setting that is also required to be selected, the Reset mode. The Reset mode can be either instantaneous or time delay. The time delay reset mode applies to the ANSI/IEEE curves. The instantaneous mode is used to coordinate with other instantaneous reset devices such as a recloser or other protective equipment on the distribution system. In the instantaneous mode the 50P-1 element will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 50P-1 element is set by factory default to operate the Trip contact. The 50P-1 element will always initiate reclosing unless the recloser is disabled. Refer to the Reclosing section for more details.

The 50P-1 element can be supervised (torque controlled) by mapping the PH3 logical input to a physical input for external supervision or logical output for internal supervision.

Table 5-8. 50P-1 (3I>>1) Elements Settings

50P (3I>>) Setting	Description
50P-1 Curve Select 3I>>1 Curve	Selection of the time overcurrent curve used to calculate the time delay between pickup and trip (see Table 5-9 below for details). Note that the Reset Mode may also affect the time delay (see page 5-44).
50P-1 Pickup 3I>>1 / 31>	The 50P-1 element will pickup when the measured CT **secondary** current rises above the specified value. The value is specified as a multiple of the 51P pickup setting. The setting range 0.5 to 20.0 multiples with an increment of 0.1.
50P-1 Time Dial/Delay t>>1 Time Multiplier	A specified value that is a variable in the time-overcurrent curve function. See Table 5-9 below for details.
50P-1 Time-Curve Adder	An additional fixed time delay added to the time delay resulting from the 50P-1 Curve Select and 50P-1 Time Dial settings. This setting is not available when using an IEC curve. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
50P-1 Minimum Response 3I>>1 Minimum Response	The minimum time delay that will occur between pickup and trip, even if the time delay based on the time-overcurrent curve would be shorter. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
50P-1 Curve Block Pickup	The 50P-1 element will not pickup if the current is higher than this setting. Use this setting to allow another protection element to handle higher-current faults. The setting range is 1 to 20, or disabled (the default).

Table 5-9. 50P-1 Curve-Settings Details

Curve Set *	Curve	Time Dial/Delay Setting Range	Increment	See Page
ANSI	Standard Instantaneous	1.0 to 10.0	0.1	5-57
	Inverse Instantaneous	1.0 to 10.0	0.1	5-58
	Short Time Inverse	1.0 to 10.0	0.1	5-50
	Short Time Extremely Inverse	1.0 to 10.0	0.1	5-51
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
IEC	Standard (Instantaneous)	-	-	-
	Definite Time	0.0 to 9.99	0.01	5-63
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
Recloser	Curve A (101)	0.10 to 2.00	0.01	5-64
	Curve B (117)	0.10 to 2.00	0.01	5-65
	Curve C (133)	0.10 to 2.00	0.01	5-66
	Curve D (116)	0.10 to 2.00	0.01	5-67
	Curve E (132)	0.10 to 2.00	0.01	5-68
	Curve K (162)	0.10 to 2.00	0.01	5-69
	Curve N (104)	0.10 to 2.00	0.01	5-70
	Curve R (105)	0.10 to 2.00	0.01	5-71
	Curve W (138)	0.10 to 2.00	0.01	5-72
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80

* Choice of Curve Set is a Configuration Setting that applies to all protection elements.
** See page 5-80 for information on how to specify a custom time-overcurrent curve.

PCD2000 units ordered with the single-phase option have a separate 50P element for each phase for each level: 50P-1 becomes 50P-1A, 50P-1B, 50P-1C; 50P-2 becomes 50P-2A, 50P-2B, 50P-2C; and 50P-3 becomes 50P-3A, 50P-3B, 50P-3C. All three elements for each level share the same settings. For information about how they control logical outputs for tripping, see Section 11.

For PCD2000 units ordered without the single-phase option, with the default settings the 50P-1 element will trip only when two or three phases exceed the pickup setting and does not operate for single-phase faults. This is applicable where instantaneous tripping for single-phase-to-ground faults are not desired. See two-phase 50P tripping on page 5-17.

When the circuit breaker is closed using the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 50P-1 can be disabled from tripping for a cold load pickup.

5.5 Ground Instantaneous Overcurrent Element 50N-1

The 50N-1 is a ground or residual instantaneous, Level 1, overcurrent element that is a multiple of the 51N element for accurate coordination. It should be enabled when ground or residual instantaneous phase tripping is desired. The operating time of the 50N-1 element should be set to operate equal to or faster than the 51N element. The 50N-1 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The ground or residual instantaneous overcurrent element 50N-1 contained in the PCD2000 is set based on CT secondary current as connected to the phase current inputs: I_N. For applications using a PCD2000 with a VR-3S or Cooper recloser, see Figure 1-13 for typical connections.

Multiple time curves and time dials are available for the 50N-1 element to closely coordinate with other protection elements within the PCD2000 and other external devices on the distribution system. A User Programmable curve option is also available allowing the user to create custom time current curves for more enhanced coordination than the standard curve types.

There is another global setting that is also required to be selected, the Reset mode. The Reset mode can be either instantaneous or time delay. The time delay reset mode applies to the ANSI/IEEE curves. The instantaneous mode is used to coordinate with other instantaneous reset devices such as a recloser or other protective equipment on the distribution system. In the instantaneous mode the 50N-1 element will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 50N-1 element is set by factory default to operate the Trip contact. The 50N-1 element will always initiate reclosing unless the recloser is disabled.

PCD2000 units ordered with the single-phase option have a separate 50N element for each phase for each level: 50N-1 becomes 50N-1A, 50N-1B, 50N-1C; 50N-2 becomes 50N-2A, 50N-2B, 50N-2C; and 50N-3 becomes 50N-3A, 50N-3B, 50N-3C. All three elements for each level share the same settings. For information about how they control logical outputs for tripping, see Section 11.

Table 5-10. 50N-1 (IN>>1) Element Settings

50N (IN>>) Settings	Description
50N-1 Curve Select IN>>1 Curve	Selection of the time overcurrent function used to calculate the time delay between pickup and trip. See Table 5-11 below for details. Note that the Reset Mode may also affect the time delay (see page 5-44).
50N-1 Pickup IN>>1 / IN>	The 50N-1 element will pickup when the measured CT **secondary** current rises above the specified value. The value is specified as a multiple of the 51N pickup setting (range 0.5 to 20.0 multiples, increment 0.1).
50N-1 Time Dial/Delay IN>>1 Time Multiplier	A specified value that is a variable in the time-overcurrent curve function. See Table 5-11 below for details.
50N-1 Time-Curve Adder	An additional fixed time delay added to the time delay resulting from the 50N-1 Curve Select and 50N-1 Time Dial settings. This setting is not available when using an IEC curve. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
50N-1 Minimum Response	The minimum time delay that will occur between pickup and trip, even if the time delay based on the time-overcurrent curve would be shorter. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
50N-1 Curve Block Pickup	The 50N-1 element will not pickup if the current is higher than this setting. Use this setting to allow another protection element to handle higher-current faults. The setting range is 1 to 20, or disabled (the default).

Table 5-11. 50N-1 Curve-Settings Details

Curve Set *	Curve	Time Dial/Delay Setting Range	Increment	See Page
ANSI	Standard Instantaneous	1.0 to 10.0	0.1	5-57
	Inverse Instantaneous	1.0 to 10.0	0.1	5-58
	Definite Time	1.0 to 10.0	0.1	5-52
	Short Time Inverse	1.0 to 10.0	0.1	5-50
	Short Time Extremely Inverse	1.0 to 10.0	0.1	5-51
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
IEC	Standard (Instantaneous)	-	-	-
	Definite Time	0.0 to 9.99	0.01	5-63
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
Recloser	Curve 2 (135)	0.10 to 2.00	0.01	5-73
	Curve 3 (140)	0.10 to 2.00	0.01	5-74
	Curve 8 (113)	0.10 to 2.00	0.01	5-75
	Curve 8*	0.10 to 2.00	0.01	5-76
	Curve 8+ (111)	0.10 to 2.00	0.01	5-77
	Curve 9 (131)	0.10 to 2.00	0.01	5-78
	Curve 11 (141)	0.10 to 2.00	0.01	5-79
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80

* Choice of Curve Set is a Configuration Setting that applies to all protection elements.
** See page 5-80 for information on how to specify a custom time-overcurrent curve.

The 50N-1 element can be disabled by pressing the Ground Blocked button on the front panel, or supervised (torque controlled) by mapping the GRD logical input to a physical input for external supervision or logical output for internal supervision.

When the circuit breaker is closed using the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 50N-1 can be disabled from tripping for a cold load pickup.

5.6 Phase Instantaneous Overcurrent Element 50P-2

The 50P-2 is a phase instantaneous, Level 2, overcurrent element that is set as a multiple of the 51P element for accurate coordination. It should be enabled when a second level of high-speed instantaneous phase tripping is desired. The 50P-2 element has a user-defined definite time characteristic. The operating time the 50P-2 should be set to operate equal to or faster than the 51P-1 element. The phase instantaneous time overcurrent element 50P-2 contained in the PCD2000 is set based on CT secondary current as connected to the phase current inputs: I_A, I_B, I_C. The 50P-2 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The instantaneous mode is used to coordinate with other instantaneous reset devices such as a recloser or other protective equipment on the distribution system. In the instantaneous mode the 50P-2 and all other instantaneous overcurrent elements will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 50P-2 element is set by factory default to operate the Trip contact. The 50P-2 element will always initiate reclosing unless the recloser is disabled.

The 50P-2 element can be supervised (torque controlled) by mapping the PH3 logical input to a physical input for external supervision or logical output for internal supervision.

PCD2000 units ordered with the single-phase option have a separate 50P element for each phase for each level: 50P-1 becomes 50P-1A, 50P-1B, 50P-1C; 50P-2 becomes 50P-2A, 50P-2B, 50P-2C; and 50P-3 becomes 50P-3A, 50P-3B, 50P-3C. All three elements for each level share the same settings. For information about how they control logical outputs for tripping, see Section 11.

For PCD2000 units ordered without the single-phase option, with the default settings the 50P-2 element will trip only when two or three phases exceed the pickup setting and does not operate for single-phase faults. This is applicable where instantaneous tripping for single-phase-to-ground faults are not desired. See two-phase 50P tripping on page 5-17.

If the circuit breaker is closed by pressing the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 50P-2 element is disabled from tripping for a period specified by the Cold Load Time setting (see page 5-33).

Table 5-12. 50P-2 (3I>>2) Elements Settings

50P-2 (3I>>2) Setting	Description
50P-2 Select 3I>>2 Curve	Choice of whether the 50P-2 element is usually enabled or disabled. The choice can be temporarily changed by the logical input PH3.
50P-2 Pickup 3I>>2 / 3I>	The 50P-2 element will pickup when the measured CT **secondary** current rises above the setting value, which is specified as a multiple of the 51P pickup setting. The range 0.5 to 20.0 multiples with an increment of 0.1.
50P-2 Time Delay t>>2	The definite time delay between a 50P-2 pickup and a 50P-2 trip output. The range is 0.00 to 9.99 seconds with an increment of 0.01.
50P-2 Curve Block Pickup	The 50P-2 element will not pickup if the current is higher than this setting. Use this setting to allow another protection element to handle higher-current faults. The setting range is 1 to 20, or disabled (the default).

5.7 Ground Instantaneous Overcurrent Element 50N-2

The 50N-2 is a ground or residual instantaneous, Level 2, overcurrent element that is set as a multiple of the 51N element for accurate coordination. It should be enabled when a second level of high-speed instantaneous ground or residual tripping is desired. The 50N-2 element has a user defined definite-time characteristic. The operating time the 50N-2 should be set to operate equal to or faster than the 51N-1 element. The ground or residual instantaneous time overcurrent element 50N-2 contained in the PCD2000 is set based on CT secondary current as connected to the phase current inputs: I_N. The 50N-2 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The instantaneous mode is used to coordinate with other instantaneous reset devices such as a Recloser or other protective equipment on the distribution system. In the instantaneous mode the 50N-2 element will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 50N-2 element is set by factory default to operate the Trip contact. The 50N-2 element will always initiate reclosing unless the recloser is disabled.

The 50N-2 element can be disabled by pressing the Ground Blocked button on the front panel, or supervised (torque controlled) by mapping the GRD logical input to a physical input for external supervision or logical output for internal supervision. To operate an external lockout relay with the 50N-2 a programmable output contact must be mapped to operate on the 50N-2 element.

PCD2000 units ordered with the single-phase option have a separate 50N element for each phase for each level: 50N-1 becomes 50N-1A, 50N-1B, 50N-1C; 50N-2 becomes 50N-2A, 50N-2B, 50N-2C; and 50N-3 becomes 50N-3A, 50N-3B, 50N-3C. All three elements for each level share the same settings. For information about how they control logical outputs for tripping, see Section 11.

If the circuit breaker is closed by pressing the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 50N-2 element is disabled from tripping for a period specified by the Cold Load Time setting (see page 5-33).

Table 5-13. 50N-2 (IN>>2) Element Settings

50N-2 (IN>>2) Settings	Description
50N-2 Select IN>>2 Curve	Choice of whether the 50N-2 element is usually enabled or disabled. Stage 2 is not available on units ordered with the SEF option. The choice can be temporarily changed by the logical input PH3.
50N-2 Pickup IN>>2 / IN>	The 50N-2 element will pickup when the measured CT **secondary** current rises above the setting value, which is specified as a multiple of the 51N pickup setting. The range 0.5 to 20.0 multiples with an increment of 0.1.
50N-2 Time Delay tN>>2	The definite time delay between a 50N-2 pickup and a 50N-2 trip output. The range is 0.00 to 9.99 seconds with an increment of 0.01.
50N-2 Curve Block Pickup	The 50N-2 element will not pickup if the current is higher than this setting. Use this setting to allow another protection element to handle higher-current faults. The setting range is 1 to 20, or disabled (the default).

5.8 Sensitive Earth Fault (SEF) Option

The sensitive earth fault (SEF) is applicable only to systems where all loads are connected line-to-line and there is no neutral or earth current flow unless an earth fault occurs. This option is not recommended for use on 4-wire multi-grounded systems. The SEF element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups. The default is disabled.

The SEF element is available as an option with PCD2000 and replaces the standard 50N-2 element. If the PCD2000 was ordered without the SEF option, the SEF Blocked target LED on the front panel will be lit at all times.

All SEF models have a separate SEF current input provided as I0 SEF. This input can be connected residually in series with the provided phase CT's (standard) or connected to a separate window type CT that encloses all three-phase conductors. See Table 5-14 below for applicable SEF settings. The SEF element has a user-defined definite time characteristic.

Table 5-14. Sensitive Earth Fault (SEF) Settings

SEF Setting	Description
SEF Torque Angle SEF Torque Angle	Specification of the torque angle. The setting range is 0° to 355° in 5° steps with a sector width of 180°.
SEF Pickup Amps SEF Pickup Amps	SEF pickup threshold setting in amperes. The setting range is 0.005 to 0.200, increment 0.0005.
SEF Cold Load Time SEF Cold Load Time	This setting is a separate Cold Load Timer that applies only to the SEF element.

The analog and digital filtering provide a rejection ratio of third harmonic greater than 50:1 to prevent incorrect operation due to the effects of distribution transformer excitation currents.

For loop schemes or ungrounded systems a directional SEF model is available. The directional unit is polarized by a separate zero sequence voltage input (V_0). The potential transformers should be connected Wye-grounded. The minimum polarization voltage is 2 volts and the torque angle can be set from 0 to 355° in 5° steps with a sector width of 180°.

The SEF tripping can be enabled or disabled in each step of the reclose sequence. It can also be supervised torque controlled by mapping the SEF logical input to a physical input for external supervision or logical output for internal supervision.

5.9 Phase Instantaneous Overcurrent Element 50P-3

The 50P-3 is a phase instantaneous, level 3, overcurrent element that is set as a multiple of the 51P element for accurate coordination. It should be enabled when a third level of high-speed instantaneous phase tripping is desired. The 50P-3 element has a user-defined definite time characteristic. The operating time the 50P-3 should be set to operate equal to or faster than the 51P-2 element. The 50P-3 element is set based on CT secondary current as connected to the phase current inputs: I_A, I_B, I_C. The 50P-3 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The instantaneous mode is used to coordinate with other instantaneous reset devices such as a recloser or other protective equipment on the distribution system. In the instantaneous mode the 50P-3 and all other instantaneous overcurrent elements will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 50P-3 element is set by factory default to operate the Trip contact. The 50P-3 element will always initiate reclosing unless the recloser is disabled.

The 50P-3 element can be disabled by pressing the Ground Blocked button on the front panel, or supervised (torque controlled) by mapping the PH3 logical input to a physical input for external supervision or logical output for internal supervision.

PCD2000 units ordered with the single-phase option have a separate 50P element for each phase for each level: 50P-1 becomes 50P-1A, 50P-1B, 50P-1C; 50P-2 becomes 50P-2A, 50P-2B, 50P-2C; and 50P-3 becomes 50P-3A, 50P-3B, 50P-3C. All three elements for each level share the same settings. For information about how they control logical outputs for tripping, see Section 11.

If the circuit breaker is closed by pressing the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 50P-3 element is disabled from tripping for a period specified by the Cold Load Time setting (see page 5-33).

Table 5-15. 50P-3 (3I>>3) Elements Settings

50P-3 (3I>>3) Setting	Description
50P-3 Select 3I>>3 Curve	Choice of whether the 50P-3 element is usually enabled or disabled. The choice can be temporarily changed by the logical input PH3.
50P-3 Pickup 3I>>3 / 3I>	The 50P-3 element will pickup when the measured CT **secondary** current rises above the setting value, which is specified as a multiple of the 51P pickup setting. The range 0.5 to 20.0 multiples with an increment of 0.1.
50P-3 Time Delay 3I>>3 Time Delay	The definite time delay between a 50P-3 pickup and a 50P-3 trip output. The range is 0.00 to 9.99 seconds with an increment of 0.01.

5.10 Ground Instantaneous Overcurrent Element 50N-3

The 50N-3 is a ground or residual instantaneous, Level 3, overcurrent element that is set as a multiple of the 51N element for accurate coordination. It should be enabled when a third level of high-speed instantaneous ground or residual tripping is desired. The 50N-3 element has a user defined definite time characteristic. The operating time the 50N-3 should be set to operate equal to or faster than the 50N-2 element. The 50N-3 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The instantaneous mode is used to coordinate with other instantaneous reset devices such as a Recloser or other protective equipment on the distribution system. In the instantaneous mode the 50N-3 elements will reset instantaneously when the current level measured by the PCD2000 drops below the pickup setting for one-half cycle.

The 50N-3 element is set by factory default to operate the Trip contact. The 50N-3 element will always initiate reclosing unless the recloser is disabled.

The 50N-3 element can be disabled by pressing the Ground Blocked button on the front panel, or supervised (torque controlled) by mapping the GRD logical input to a physical input for external supervision or logical output for internal supervision. To operate an external lockout relay with the 50N-3 a programmable output contact must be mapped to operate on the 50N-3 element.

PCD2000 units ordered with the single-phase option have a separate 50N element for each phase for each level: 50N-1 becomes 50N-1A, 50N-1B, 50N-1C; 50N-2 becomes 50N-2A, 50N-2B, 50N-2C; and 50N-3 becomes 50N-3A, 50N-3B, 50N-3C. All three elements for each level share the same settings. For information about how they control logical outputs for tripping, see Section 11.

If the circuit breaker is closed by pressing the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 50N-3 element is disabled from tripping for a period specified by the Cold Load Time setting (see page 5-33).

Table 5-16. 50N-3 (IN>>3) Element Settings

50N-3 (IN>>3) Settings	Description
50N-3 Select IN>>3 Curve	Choice of whether the 50N-3 element is usually enabled or disabled. The choice can be temporarily changed by the logical input PH3.
50N-3 Pickup IN>>3 / IN>	The 50N-3 element will pickup when the measured CT **secondary** current rises above the setting value, which is specified as a multiple of the 51N pickup setting. The range 0.5 to 20.0 multiples with an increment of 0.1.
50N-3 Time Delay IN>>3 Time Delay	The definite time delay between a 50N-3 pickup and a 50N-3 trip output. The range is 0.00 to 9.99 seconds with an increment of 0.01.

5.11 Two-Phase 50P Tripping

If two-phase-50P tripping is enabled, the 50P-1, 50P-2, and 50P-3 elements will trip only if two or three phases exceed the trip setting for phase-to-ground faults. Note that the residual current must exceed the instantaneous 50N-1, 50N-2, or 50N-3 pickup settings. **Note that if two-phase 50P tripping is enabled, the 50P elements will not respond to single-phase-to-ground faults.**

On distribution lines, the phase and ground instantaneous overcurrent elements are often set very high in order to coordinate with large downstream fuses. By enabling two-phase-50P tripping, the 50N-1 element can be set to coordinate with the large downstream fuses, while the 50P-1 element can be set below the 50N-1 pickup setting to increase sensitivity and improve clearing time for three-phase, phase-to-phase, and two-phases-to-ground faults on the main section of radial distribution lines.

For example, a 100A downstream fuse may require the upstream 50N-1 pickup setting to be 4000A or more. By enabling two-phase-50P tripping, the 50P-1 element can be set at 2000A. For three-phase, phase-to-phase, and two-phase-to-ground faults greater than 2000A, a 50P-1 instantaneous trip will occur. No 50P-1 trip occurs for single-phase-to-ground faults when the fault current is between 2000 and 4000A. For single-phase-to-ground faults where the current is greater than 4000A, a 50N-1 instantaneous trip will occur.

Table 5-17. Two-Phase 50P Tripping Setting

2-Phase 50P Trip Setting	Description
2 Phase Voting 2I>> Trip	Selection of whether the two-phase 50P tripping is enabled or disabled (default).

5 PROTECTION

5.12 Negative Sequence Time Overcurrent Element 46 (Insc>)

The negative sequence overcurrent element (46, Insc>) measures the amount of unbalanced current on the distribution line. Since the negative sequence element measures the amount of negative sequence current in the system, it can be set to pickup just above the maximum negative sequence current level produced by a single phase load unbalance. This makes the PCD2000 much more sensitive to phase to phase faults. The 46 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The negative sequence overcurrent element can also be used to detect phase to ground and phase to phase to ground faults, but whenever an unbalance condition occurs in association with ground, then zero sequence quantities are predominately present and the neutral elements of the PCD2000 can detect these faults. The negative sequence element can be used for backup to these type faults.

Multiple time curves and time dials are available. See Table 5-19 to closely coordinate with other devices in the system. User programmable curves are also available. The 46 pickup, curve type and time dial is all set in the Primary, Alternate 1 and Alternate 2 settings groups. For the 46 element to operate the trip contact, it must be selected in the master trip output mapping as defined in the programmable master trip contact (see page 6-17). The 46 element is set by factory default to operate the trip contact. The 46 element is set to initiate reclosing unless the recloser is disabled.

There are two selectable reset modes available for the 46 element. The instantaneous mode is used to coordinate with other instantaneous reset devices such as microprocessor based relays. In the instantaneous mode the 46 will reset when the current drops below the pickup setting for one-half cycle. The delayed mode simulates the action of an electromechanical induction disk relay. In this mode the 46 reset follows a slow reset characteristic that depends upon the duration of the overcurrent condition and the amount of load current flowing after the event (see page 5-44).

If the circuit breaker is closed by pressing the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 46 element is disabled from tripping for a period specified by the Cold Load Time setting (see page 5-33).

Table 5-18. 46 (Insc>) Element Settings

46 (Insc>) Setting	Description
46 Curve Select Insc> Curve	Selection of the time overcurrent function used to calculate the time delay between pickup and trip. See Table 5-19 below for details. Note that the Reset Mode may also affect the time delay (see page 5-44).
46 Pickup Amps Insc> Amp	The 46 element will pickup when the measured CT **secondary** current rises above the specified value. The setting range and increment depend on the configuration of the PT/CT module (see page 1-16).
46 Time Dial/Delay Insc> Time Multiplier	A specified value that is a variable in the time-overcurrent curve function. See Table 5-19 below for details.
46 Time-Curve Adder	An additional fixed time delay added to the time delay resulting from the 46 Curve Select and 46 Time Dial settings. This setting is not available when using an IEC curve. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
46 Minimum Response	The minimum time delay that will occur between pickup and trip, even if the time delay based on the time-overcurrent curve would be shorter. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.

Table 5-19. 46 Curve-Settings Details

Curve Set *	Curve	Time Dial/Delay Setting Range	Increment	See Page
ANSI	Extremely Inverse	1.0 to 10.0	0.1	5-47
	Very Inverse	1.0 to 10.0	0.1	5-48
	Inverse	1.0 to 10.0	0.1	5-49
	Short Time Inverse	1.0 to 10.0	0.1	5-50
	Definite Time	1.0 to 10.0	0.1	5-52
	Long Time Extremely Inverse	1.0 to 10.0	0.1	5-53
	Long Time Very Inverse	1.0 to 10.0	0.1	5-54
	Long Time Inverse	1.0 to 10.0	0.1	5-55
	Recloser Curve #8	1.0 to 10.0	0.1	5-56
IEC	Extremely Inverse	0.05 to 1.00	0.05	5-59
	Very Inverse	0.05 to 1.00	0.05	5-60
	Inverse	0.05 to 1.00	0.05	5-61
	Long Time Inverse	0.05 to 1.00	0.05	5-62
	Definite Time	0.0 to 10.0	0.1	5-63
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
Recloser	Curve A (101)	0.10 to 2.00	0.01	5-64
	Curve B (117)	0.10 to 2.00	0.01	5-65
	Curve C (133)	0.10 to 2.00	0.01	5-66
	Curve D (116)	0.10 to 2.00	0.01	5-67
	Curve E (132)	0.10 to 2.00	0.01	5-68
	Curve K (162)	0.10 to 2.00	0.01	5-69
	Curve N (104)	0.10 to 2.00	0.01	5-70
	Curve R (105)	0.10 to 2.00	0.01	5-71
	Curve W (138)	0.10 to 2.00	0.01	5-72
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80

* Choice of Curve Set is a Configuration Setting that applies to all protection elements.
** See page 5-80 for information on how to specify a custom time-overcurrent curve.

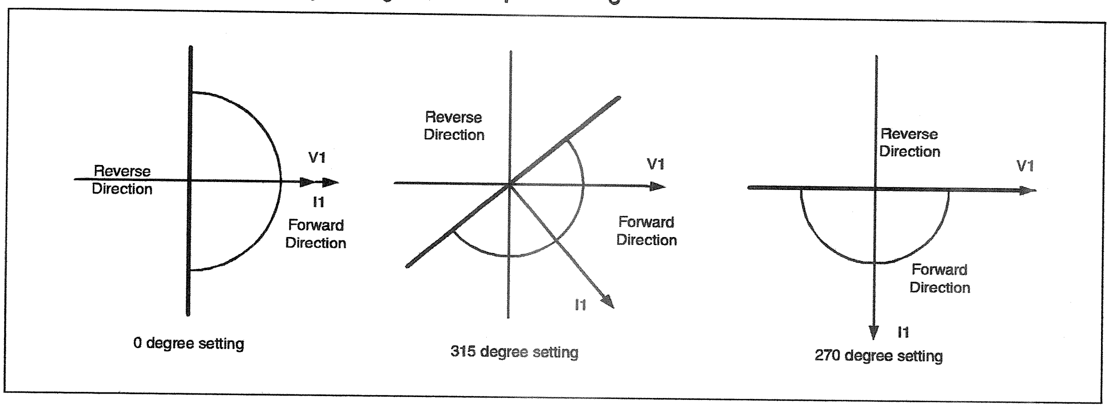
5.13 Directional Phase Time Overcurrent Element 67P (3I>-->)

The directional phase time overcurrent element (ANSI 67P, IEC 3I>-->) provides time overcurrent protection in one direction of power flow. The user defines which direction that the 67P element should sense (i.e., source or load direction). The 67P element is essentially a logical AND combination of a 32P element enabling a 51P element.

The 67P element has seven settings (see Table 5-20 below). The 67P settings can be different in the Primary, Alternate 1 and Alternate 2 setting groups.

The positive sequence voltage V_1 provides polarizing of the 67P in the power system. It is sensitive down to 1 volt AC line to line. If the polarizing voltage drops below this level the 67P will lose direction and will not trip. Then any tripping on the distribution line may be backed-up by the 51P element which is non-directional. The 67P element works by comparing the positive sequence voltage V_1 to the direction of the positive sequence current I_1. The torque angle is set between 0° to 355° in 5° steps (I_1 leading V_1) with a sector width of 180°. See Figure 5-3 for examples of the different positive sequence torque angle settings. It should be noted that when the voltage seen by the PCD2000 is at or near the minimum sensitivity point of 1-volt AC line to line the set angle may shift between 10°.

Figure 5-3. 67P Maximum Torque Angles, Example Settings.



There are two selectable reset modes available for the 67P element. The "instantaneous mode" is used to coordinate with other instantaneous reset devices such as microprocessor based relays. In the instantaneous mode the 67P will reset when the current drops below the pickup setting for one-half cycle. The "delayed mode" simulates the action of an electromechanical induction disk relay. In this mode the 67P reset follows a slow reset characteristic that depends upon the duration of the overcurrent condition and the amount of load current flowing after the event. The reset mode setting applies to all time overcurrent elements in the PCD2000.

If the circuit breaker is closed by pressing the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 67P is disabled from tripping for a period specified by the Cold Load Time setting (see page 5-33).

PCD2000 units ordered with the single-phase option have a separate 67P element for each phase for each level: 67P becomes 67P-A, 67P-B, and 67P-C. All three elements share the same settings. A minimum trip time delay of 50 milliseconds is imposed on the single-phase 67P-X units in order to guarantee directionality is established before the PCD2000 can initiate a trip signal. For information about how they control logical outputs for tripping, see Section 11.

Table 5-20. 67P (3I>-->) Element Settings

67P (3I>-->) Setting	Description
67P Select 3I>--> Select	Selection of whether the 67P element is enabled or disabled (default).
67P Curve Select 3I>--> Curve	Selection of the time overcurrent function used to calculate the time delay between pickup and trip. See Table 5-21 below for details. Note that the Reset Mode may also affect the time delay (see page 5-44).
67P Pickup Amps 3I>--> Amp	The element will pickup when the measured CT **secondary** current rises above the specified value. The setting range and increment depend on the configuration of the PT/CT module (see page 1-16).
67P Time Dial/Delay 3I>-->Time Multiplier	A specified value that is a variable in the time-overcurrent curve function. See Table 5-21 below for details.
67P Torque Angle 3I>--> Torque Angle	Specification of the torque angle. The setting range is 0° to 355° in 5° steps with a sector width of 180°.
67P Time-Curve Adder	An additional fixed time delay added to the time delay resulting from the 67P Curve Select and 67P Time Dial settings. This setting is not available when using an IEC curve. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
67P Minimum Response	The minimum time delay that will occur between pickup and trip, even if the time delay based on the time-overcurrent curve would be shorter. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.

Table 5-21. 67P Curve-Settings Details

Curve Set *	Curve	Time Dial/Delay Setting Range	Increment	See Page
ANSI	Extremely Inverse	1.0 to 10.0	0.1	5-47
	Very Inverse	1.0 to 10.0	0.1	5-48
	Inverse	1.0 to 10.0	0.1	5-49
	Short Time Inverse	1.0 to 10.0	0.1	5-50
	Definite Time	1.0 to 10.0	0.1	5-52
	Long Time Extremely Inverse	1.0 to 10.0	0.1	5-53
	Long Time Very Inverse	1.0 to 10.0	0.1	5-54
	Long Time Inverse	1.0 to 10.0	0.1	5-55
	Recloser Curve #8	1.0 to 10.0	0.1	5-56
IEC	Extremely Inverse	0.05 to 1.00	0.05	5-59
	Very Inverse	0.05 to 1.00	0.05	5-60
	Inverse	0.05 to 1.00	0.05	5-61
	Long Time Inverse	0.05 to 1.00	0.05	5-62
	Definite Time	0.0 to 10.0	0.1	5-63
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
Recloser	Curve A (101)	0.10 to 2.00	0.01	5-64
	Curve B (117)	0.10 to 2.00	0.01	5-65
	Curve C (133)	0.10 to 2.00	0.01	5-66
	Curve D (116)	0.10 to 2.00	0.01	5-67
	Curve E (132)	0.10 to 2.00	0.01	5-68
	Curve K (162)	0.10 to 2.00	0.01	5-69
	Curve N (104)	0.10 to 2.00	0.01	5-70
	Curve R (105)	0.10 to 2.00	0.01	5-71
	Curve W (138)	0.10 to 2.00	0.01	5-72
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80

* Choice of Curve Set is a Configuration Setting that applies to all protection elements.
** See page 5-80 for information on how to specify a custom time-overcurrent curve.

5.14 Directional Ground Time Overcurrent Element 67N (IN>-->)

The directional phase time overcurrent element (ANSI 67N, IEC IN>-->) provides time overcurrent protection in one direction of power flow. The user defines which direction that the 67N element should sense (i.e., source or load direction). The 67N element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

Multiple time curves and time dials are available. See Table 5-23 below to closely coordinate with other devices in the system. User programmable curves are also available.

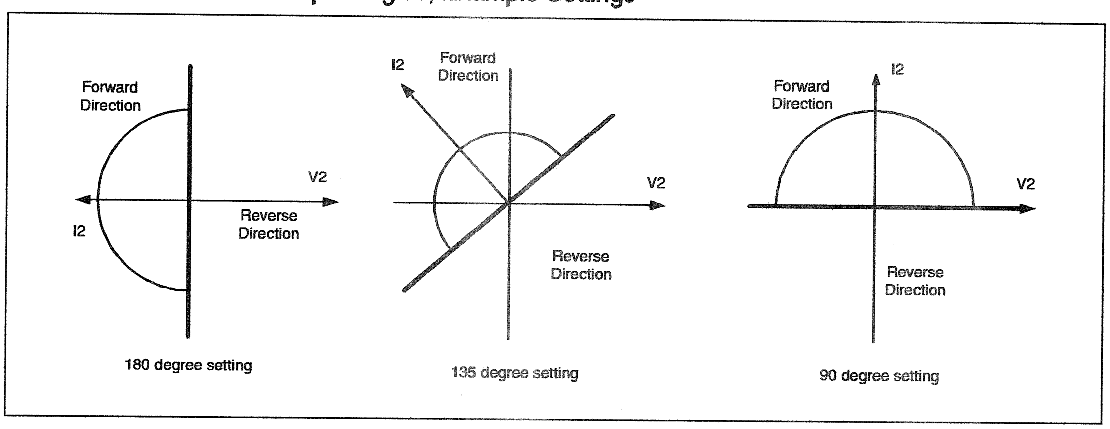
For the 67N element to operate the trip contact it must be selected in the master trip output mapping. The 67N element is set by factory default to operate the trip contact. The 67N element is set to initiate reclosing unless the recloser is disabled. However, The 67N element is disabled by factory default settings.

The negative sequence voltage V_2 provides polarizing of the 67N in the power system. It is sensitive down to 1 volt AC line to line. If the polarizing voltage drops below this level the 67N will lose direction and will not trip. Then any tripping on the distribution line may be backed-up by the 51N element which is non-directional.

Note: If the PCD2000 contains a directional sensitive earth unit the 67N element can be polarized with negative sequence voltage (V_2) or zero sequence voltage (V_0). The 67N element is achieved by comparing the negative sequence voltage V_2 to the direction of the negative sequence current I_2.

The torque angle is set between 0° to 355° in 5° steps (I_2 leading V_2) with a sector width of 180°. See Figure 5-4 for examples of the different negative sequence torque angle settings. It should be noted that when the voltage seen by the PCD2000 is at or near the minimum sensitivity point of 1-volt AC line-to-line the set angle may shift between ±10°.

Figure 5-4. 67N Maximum Torque Angles, Example Settings



There are two selectable reset modes available for the 67N element. The "instantaneous mode" is used to coordinate with other instantaneous reset devices such as microprocessor based relays. In the instantaneous mode the 67N will reset when the current drops below the pickup setting for one-half cycle. The "delayed mode" simulates the action of an electromechanical induction disk relay. In this mode the 67N reset follows a slow reset characteristic that depends upon the duration of the overcurrent condition and the amount of load current flowing after the event.

If the circuit breaker is closed by pressing the CLOSE button on the front panel, or by an external source such as a control switch or via SCADA, the 67N element is disabled from tripping for a period specified by the Cold Load Time setting (see page 5-33).

PCD2000 units ordered with the single-phase option have a separate 67N element for each phase and for each level: 67N becomes 67N-A, 67N-B, and 67N-C. All three elements share the same settings. A minimum trip time delay of 50 milliseconds is imposed on the single-phase 67N-X units in order to guarantee directionality is established before the PCD2000 can initiate a trip signal.

Table 5-22. 67N (IN>–>) Element Settings

67N (IN>–>) Setting	**Description**
67N Select IN>--> Select	Choice of whether the 67N element is enabled or disabled.
67N Curve Select IN>--> Curve	Selection of the time overcurrent function used to calculate the time delay between pickup and trip. See Table 5-23 below for details. Note that the Reset Mode may also affect the time delay (see XXX).
67N Pickup Amps IN>--> Amp	The 50P-1 element will pickup when the measured CT **secondary** current rises above the specified value. The setting range and increment depend on the configuration of the PT/CT module (see page 1-16).
67N Time Dial/Delay IN>--> Time Multiple	A specified value that is a variable in the time-overcurrent curve function. See Table 5-23 below for details.
67N Torque Angle IN>--> Torque Angle	Specification of the torque angle. The setting range is 0° to 355° in 5° steps with a sector width of 180°.
67N Time-Curve Adder	An additional fixed time delay added to the time delay resulting from the 67N Curve Select and 67N Time Dial settings. This setting is not available when using an IEC curve. The setting range is 0.00 to 2.00 seconds with an increment of 0.01 second.
67N Minimum Response	The minimum time delay that will occur between pickup and trip, even if the time delay based on the time-overcurrent curve would be shorter.

Table 5-23. 67N Curve-Settings Details

Curve Set *	Curve	Time Dial/Delay Setting Range	Increment	See Page
ANSI	Extremely Inverse	1.0 to 10.0	0.1	5-47
	Very Inverse	1.0 to 10.0	0.1	5-48
	Inverse	1.0 to 10.0	0.1	5-49
	Short Time Inverse	1.0 to 10.0	0.1	5-50
	Definite Time	1.0 to 10.0	0.1	5-52
	Long Time Extremely Inverse	1.0 to 10.0	0.1	5-53
	Long Time Very Inverse	1.0 to 10.0	0.1	5-54
	Long Time Inverse	1.0 to 10.0	0.1	5-55
	Recloser Curve #8	1.0 to 10.0	0.1	5-56
IEC	Extremely Inverse	0.05 to 1.00	0.05	5-59
	Very Inverse	0.05 to 1.00	0.05	5-60
	Inverse	0.05 to 1.00	0.05	5-61
	Long Time Inverse	0.05 to 1.00	0.05	5-62
	Definite Time	0.0 to 10.0	0.1	5-63
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80
Recloser	Curve 2 (135)	0.10 to 2.00	0.01	5-73
	Curve 3 (140)	0.10 to 2.00	0.01	5-74
	Curve 8 (113)	0.10 to 2.00	0.01	5-75
	Curve 8*	0.10 to 2.00	0.01	5-76
	Curve 8+ (111)	0.10 to 2.00	0.01	5-77
	Curve 9 (131)	0.10 to 2.00	0.01	5-78
	Curve 11 (141)	0.10 to 2.00	0.01	5-79
	User Curve 1 **	1.0 to 10.0	0.1	5-80
	User Curve 2 **	1.0 to 10.0	0.1	5-80
	User Curve 3 **	1.0 to 10.0	0.1	5-80

* Choice of Curve Set is a Configuration Setting that applies to all protection elements.
** See page 5-80 for information on how to specify a custom time-overcurrent curve.

5.15 Positive Directional Power Element 32P (I1-->)

The 32P positive directional power element can supervise (torque control) other protection elements of the PCD2000. The 32P element operates independently of the 67P element.

The 32P element compares the angle of the positive sequence current (I_1) to the angle of the positive sequence voltage (V_1). Using the voltage angle as the reference (0° degrees) the current angle is compared to a setting. If the angular difference is within ±90° degrees, the logical output "32P" goes HIGH. Although the 32P element is independent of the 67P element, the angle setting is defined in the same manner: I_1 leading V_1 (see Figure 5-3 on page 5-20).

The 32P element has two settings: (1) whether it is enabled or disabled, and (2) the torque angle. See Table 5-24 below. The 32P settings can be different in the Primary, Alternate 1 and Alternate 2 setting groups.

If the breaker is closed by an external source such as a control switch or via SCADA, the 32P element can be temporarily disabled by the Cold Load Timer function (see page 5-33).

The logical output 32P can be programmed to control a physical output contact, and so supervise external devices (see Section 6).

Note: If the 32P element is used to supervise the 50P element, a minimum of 50 milliseconds time delay on the 50P element is required for proper coordination. Also note that the set angle might shift 10° when the voltage seen by the PCD2000 is at or near the minimum sensitivity point of 1-volt AC line-to-line.

Table 5-24. 32P (I1-->) Element Settings

32P (I1-->) Setting	Description
32P Select I1--> Select	Selection of whether the 32P element is enabled or disabled (default).
32P Torque Angle I1--> Torque Angle	Specification of the 32P torque angle. The setting range is 0° to 355° in 5° steps with a sector width of 180°.

5.16 Negative Directional Power Element 32N (I2-->)

The 32N negative directional power element can supervise (torque control) other protection elements of the PCD2000. The 32N element operates independently of the 67N element.

The 32N element compares the angle of the negative sequence current (I_2) to the angle of the negative sequence voltage (V_2). Using the voltage angle as the reference (0° degrees) the current angle is compared to a setting. If the angular difference is within ±90° degrees, the logical output "32N" goes HIGH. Although the 32N element is independent of the 67N element, the angle setting is defined in the same manner: I_2 leading V_2 (see Figure 5-4 on page 5-23).

The 32N element has two settings: (1) whether it is enabled or disabled, and (2) the torque angle. See Table 5-25 below. The 32N settings can be different in the Primary, Alternate 1 and Alternate 2 setting groups.

If the breaker is closed by an external source such as a control switch or via SCADA, the 32N element can be temporarily disabled by the Cold Load Timer function (see page 5-33).

The logical output 32N can be programmed to control a physical output contact, and so supervise external devices (see Section 6).

Note: If the 32N element is used to supervise the 50N element, a minimum of 50 milliseconds time delay on the 50N element is required for proper coordination. Also note that the set angle might shift 10° when the voltage seen by the PCD2000 is at or near the minimum sensitivity point of 1-volt AC line-to-line.

Table 5-25. 32N (I2-->) Element Settings

32N (I2-->) Setting	Description
32N Select I2--> Select	Selection of whether the element is enabled or disabled (default).
32N Torque Angle I2--> Torque Angle	Specification of the torque angle. The setting range is 0° to 355° in 5° steps with a sector width of 180°.

5.17 Frequency Load Shed and Restoration Elements 81 (f)

The PCD2000 provides two independent logical modules contain elements for underfrequency load shedding (81S) and overfrequency load restoration (81R) alarming (81O). The 81S, 81R and 81O elements can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups. These elements use the frequency measured on phase C as their operating quantity.

The 81S is an underfrequency Load Shed unit; when the distribution system frequency drops below a threshold for a specified period of time an output is generated so that load can be shed. The inverse element is the 81R; it will restore load after a shed operation occurs when the system frequency goes above a programmable threshold for a given amount of time.

The logical outputs from these modules can be assigned to physical outputs for tripping and closing of a circuit breaker based on frequency. The 81 element in general is used to shed load on a recloser when the distribution system becomes unstable and the frequency begins to decrease. If the stability of the system is sacrificed due to overloading the frequency will generally drop off slowly. The time delay of the underfrequency load shed trip element can be set to a toleration point to allow time for the power system to recover.

The power system frequency is measured from the zero crossing on the V_{A-N} voltage input for Wye connected VTs and V_{A-B} for Delta connected VTs.

Two independent logical frequency elements are provided with separate logical outputs. The first element has 81S-1, 81R-1 and 81O-1 for its logical outputs, while the second module has 81S-2, 81R-2 and 81O-2 for its logical outputs. These outputs become active when the frequency pickup setting has been reached its limit. There is one exception to this which involves the 81V element where the system voltage is below the voltage block setting (see page 5-29)

When the circuit breaker is closed by an external source such as a control switch or via SCADA the 81S, 81R and 81O are disabled from tripping for Cold Load Time.

The frequency-shed outputs 81S-1 and 81S-2 can be assigned to the same trip output contact with each set a different frequency threshold and trip time setting. This provides fast tripping response for severe disturbances and slower trip times for more tolerable system disturbances.

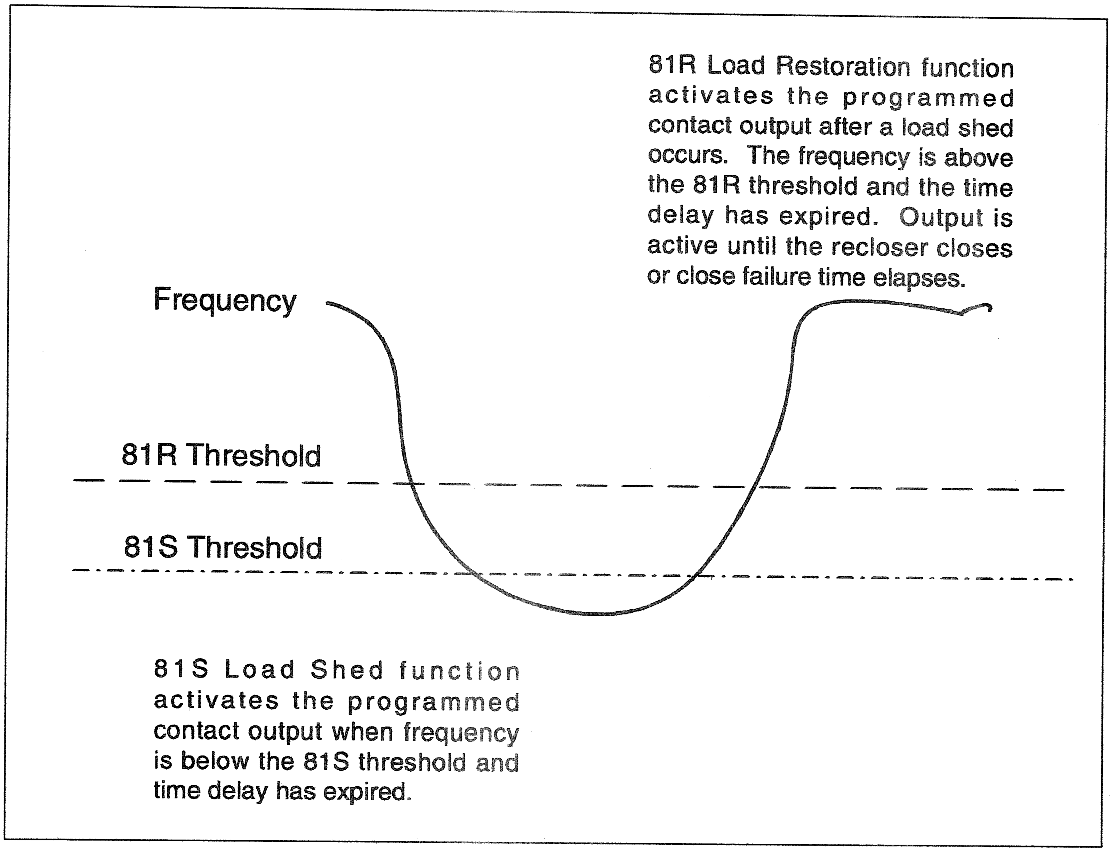
Example: Set 81S-1 to sense a slight underfrequency condition and assign a longer time period. Set 81S-2 to a lower frequency with a shorter time period. This will allow a longer trip time for slight underfrequency conditions and shorter trip time for more sever underfrequency conditions.

The restoration elements (81R-1 and 81R-2) can be used to automatically restore load after a frequency load shed trip of the 81S-1 or 81S-2 element trip the recloser. The PCD2000 senses a load-shed trip by the operation of 81S-1 or 81S-2 and by the change of the 52A and 52B contacts. During this condition the 81R-1 and 81R-2 logical outputs are allowed to operate. The 81R element will activate when the frequency rises above the frequency setting and the associated timer expires. If the power system frequency falls back below the 81 setting before expiration of the load restore timer, the timer will reset and begin again when the frequency returns to normal. The 81R logical outputs remain active until a successful recloser close or until the trip fail time expires see trip fail timer in the recloser section for more details. The 81R element is not armed again until the next load shed operation.

Two overfrequency elements are also included (81O-1 and 81O-2). Their logical outputs activate when the frequency rises above the 81R setting and the 81R time delay expires. They each can be used to trip the recloser but they do not initiate an automatic restoration.

The hysteresis or dropout point for the 81S and the 81R logical outputs are 0.02 Hz above the frequency setting. The hysteresis for the 81O element is 0.02 Hz below the frequency setting.

Figure 5-5. 81S and 81 R Elements



5.17.1 Voltage Block Element 81V

This element blocks operation of the logical outputs 81S-1 and 81S-2 when the power system voltage is below the 81V setting. The 81V element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups. Wye connected VTs use $V_{A\text{-}N}$ and Delta connected VTs use $V_{A\text{-}B}$ for their monitoring of the voltage. Operation of the logical outputs is resorted when the voltage returns to normal. The 81S-1 or 81S-2 elements will de-activate if they are active at the time when the power system voltage falls below the 81V setting. The range for this setting is from 40 to 200 VAC.

When the circuit breaker is closed by an external source such as a control switch or via SCADA the 81V is disabled from tripping for Cold Load Time.

Table 5-26. 81 (f) Element Settings

81 (f) Setting	Description
81 Select f Select	Choice of whether the 81 element is enabled or disabled.
81s-1 Pickup Frequency f<1 Hz	Specification of frequency at which the 81S-1 element will pickup. Setting range is 56 to 64 Hz for 60Hz models and 46 to 54 Hz for 50 Hz models, with an increment of 0.01 Hz.
81s-1 Time Delay tf<1	Time delay between 81S-1 pickup and load shed. Setting range is 0.08 to 9.98 seconds, with an increment of 0.02 second.
81r-1 Pickup Frequency f>1 Hz	Specification of frequency at which the 81R-1 element will pickup. Setting range is 56 to 64 Hz for 60Hz models and 46 to 54 Hz for 50 Hz models, with an increment of 0.01 Hz.
81r-1 Time Delay tf>1	Time delay between 81R-1 pickup and load restoration. Setting range is 0 to 999 seconds with an increment of 1 second.
81s-2 Pickup Frequency f<2 Hz	Specification of frequency at which the 81S-2 element will pickup. Setting range is 56 to 64 Hz for 60Hz models and 46 to 54 Hz for 50 Hz models, with an increment of 0.01 Hz.
81s-2 Time Delay tf<2	Time delay between 81S-2 pickup and load shed. Setting range is 0.08 to 9.98 seconds, with an increment of 0.02 second.
81r-2 Pickup Frequency f>2 Hz	Specification of frequency at which the 81R-2 element will pickup. Setting range is 56 to 64 Hz for 60Hz models and 46 to 54 Hz for 50 Hz models, with an increment of 0.01 Hz.
81r-2 Time Delay tf>2	Time delay between 81R-2 pickup and load restoration. Setting range is 0 to 999 seconds with an increment of 1 second.
81v Voltage Block fU< Block	If the voltage is below the specified value, the 81-S and 81S-2 elements will be blocked (so load restoration will not be attempted). Setting range is 40 to 200 volts AC with an increment of 1 volt. See Section 5.17.1.

5.18 Undervoltage Element 27 (U<)

The undervoltage element is provided for alarm and control purposes when the system voltage drops below a preset threshold. The 27 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups. Two logical outputs are provided with the 27 element: one for single-phase undervoltage 27P-1 and one for three-phase undervoltage 27-3P. The 27-1P element will operate when any single phase drops below the undervoltage setting. The 27-3P element will operate when all three phase drop below the undervoltage setting.

Neither element can operate the main trip contact. Their logical outputs must be mapped to physical outputs if alarming or tripping is desired. The 27 element can also be used to supervise torque control other protective elements such as the 51P. Mapping the 27 element to the PH3 logical input via the programmable logic provides a voltage controlled overcurrent protective element.

When the circuit breaker is closed by an external source such as a control switch or via SCADA the 27 is disabled from tripping for Cold Load Time.

The 27 element threshold and time delays are set in the Primary, Alternate 1 and Alternate 2 setting groups (see Table 5-27). The time delay range for each element is from 0 to 60 seconds. If trip times below one second are desired, set the time delay to zero and place the desired trip time in the physical output timers.

PCD2000 units ordered with the single-phase option have a separate 27 element for each phase for each level: 27 becomes 27-A, 27-B, and 27-C. All three elements for each level share the same settings. Two additional logical outputs are provided: 27-1P is the logical OR of the three separate phases, while 27-3P is the logical AND. For information about how they control logical outputs for tripping, see Section 11.

Table 5-27. 27 (U<) Element Settings

27 (U<) Setting	Description
27 Select U< Select	Choice of whether the 27 element is enabled (default) or disabled.
27 Pickup Voltage U< Volts	Pick will occur if the voltage drops below the specified value. The setting range is 10 to 200 volts with an increment of 1 volt.
27 Time Delay tU<	Time delay between pickup and trip. The setting range is 0 to 60 seconds with an increment of 1 second.

5.19 Overvoltage Element 59 (U>)

The overvoltage element 59 is provided for alarm and control purposes when the system voltage rises above a preset threshold. The 59 element can be Enabled or Disabled in the Primary, Alternate 1 and Alternate 2 setting groups.

The 59 element cannot operate the Main Trip contact. The logical output, for the 59 element must be connected to a physical output if alarming or tripping is desired.

When the circuit breaker is closed by an external source such as a control switch or via SCADA the 59 is disabled from tripping for Cold Load Time.

The 59 element threshold and time delays are set in the Primary, Alternate 1 and Alternate 2 setting groups. See Table 5-28. The time delay range for each element is from 0 to 60 seconds. If trip times below one second are desired set the time delay to zero and place the desired trip time in the physical output timers.

PCD2000 units ordered with the single-phase option have a separate 59 element for each phase for each level: 59 becomes 59-A, 59-B, and 59-C. All three elements for each level share the same settings. Two additional logical outputs are provided: 59-1P is the logical OR of the three separate phases, while 59-3P is the logical AND. For information about how they control logical outputs for tripping, see Section 11.

Table 5-28. 59 (U>) Element Settings

59 (U>) Setting	Description
59 Select U> Select	Choice of whether the 59 element is enabled (default) or disabled.
59 Pickup Voltage U> Pickup	Pick will occur if the voltage drops below the specified value. The setting range is 70 to 250 volts with an increment of 1 volt.
59 Time Delay tU>0	Time delay between pickup and trip. The setting range is 0 to 60 seconds with an increment of 1 second.

5.20 Cold Load Timer

The cold load timer is set in the Primary, Alternate 1 and Alternate 2 setting groups and is used to block unintentional tripping of protection elements due to inrush currents seen by the PCD2000 after the recloser circuit has been open for a specified period of time. The timer is set from 0 to 254 with a resolution of 1 in either seconds or minutes. During the cold load time delay period a logical output CLTA is asserted. This logical output can be mapped to a physical output for alarm and control purposes. The cold load timer is operational only after the recloser has been closed for the specified period of time. It does not operate during a normal PCD2000 reclose sequence. The cold load timer is disabled in the factory default settings.

Cold Load Time in the PCD2000 allows for this restoration current to be sensed as cold load current which may exceed the normal load current of the distribution circuit. Due in part to the amount of time the circuit has been de-energized along with to the DC resistance of the downstream circuit. Removal of the DC resistance from the circuit is directly related to the amount of time necessary for the circuit to normalize at load current. During this time the cold load current may exceed normal time overcurrent relay settings. Therefore, to restore the circuit cold load pickup settings allow for restoration of the load and simultaneously protect the circuit.

Cold load time is accomplished by extending both the time and pickup values of the phase and neutral time overcurrent elements. Whenever the cold load pickup is inactive the phase and neutral time overcurrent elements operate normally. When cold load time becomes active the protection elements associated with cold load time are extended while keeping the same time dial and time overcurrent curves to maintain coordination with other protection devices both upstream and downstream.

A separate neutral Cold Load Time element is supplied in PCD2000 units ordered with the sensitive earth fault (SEF) option.

Table 5-29. Cold Load Timer Settings

Cold Load Timer Setting	Description
Cold Load Timer Mode Cold Load Timer Mode	Choice of the time unit for the Cold Load Timer (seconds or minutes). This is a Configuration setting.
Cold Load Time Cold Load Time	Duration of Cold Load Timer. Setting is either "disable," or a value in the range 1 to 254. The unit of time is seconds of minutes (see above row).

5.21 Recloser Element 79 (O-->I)

After a fault has occurred, the 79 Reclosing Element closes the unit when the programmed open time interval expires. Zero to four reclosures may be selected, and each recloser has its own separate open interval timer. The multishot reclose sequence occurs only if the PCD2000 initiates an overcurrent trip or a programmable 79M input is initiated.

The reset time begins timing down from the Reset Time setting to zero after each reclosure, provided the phase and ground currents are below the lowest pickup setting of all the elements. At each step in the reclose sequence, you can enable or disable the 50P-1, 50P-2, 50P-3, 51N, 50N-1, 50N-2 or 50N-3 elements or set the element to lockout reclosing as a result of tripping on any one of these elements. Disable the reclosing element in the Primary, Alternate 1, and Alternate 2 Settings by selecting LOCKOUT for the first Reclose Open Interval Time or by opening the permanently programmed 43A contact input.

A lockout state occurs under any of the following conditions:

- A fault persists for the entire programmed reclosing sequence.
- The unit is manually closed and a fault occurs before the expiration of the reset time.
- A TRIP output occurs and the fault current is not removed or the breaker's 52a and 52b contacts do not indicate that the unit opened. Both the removal of the fault current and the opening of the unit must occur before the Trip Failure Time (5 to 60 cycles) expires, or the PCD2000 will proceed to lockout.
- The reclose element is programmed to lock out after 1 51P, 50P-1, 50P-2, 50P-3, 51N, 50N-1, 50N-2, 50N-3, 67P or 67N overcurrent trip.
- The 79V element is enabled, the bus voltage is below the voltage block setting, and the block time delay has expired.
- A Reclose Block is activated from the HMI or via SCADA and an overcurrent trip occurs.
- In addition to a front panel target (LED) indication that the unit is in the Lockout State, a programmable lockout alarm (79LOA) contact is available. The Lockout State is cleared when the 52a and 52b contact inputs indicate that the unit has been manually closed and the reset time has expired.

Figure 5-6. Recloser Sequence

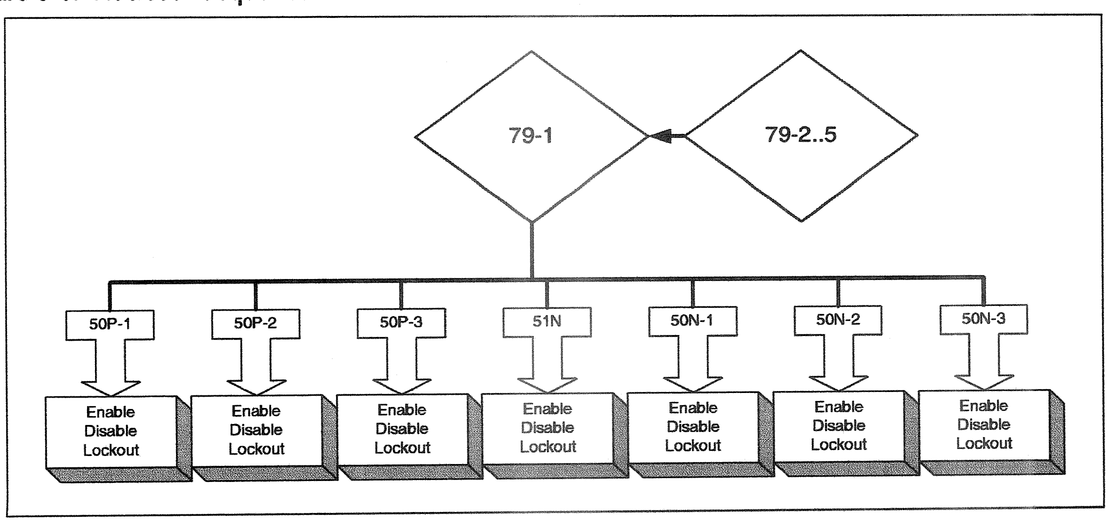


Table 5-30. 79 (O-->I) Element Settings

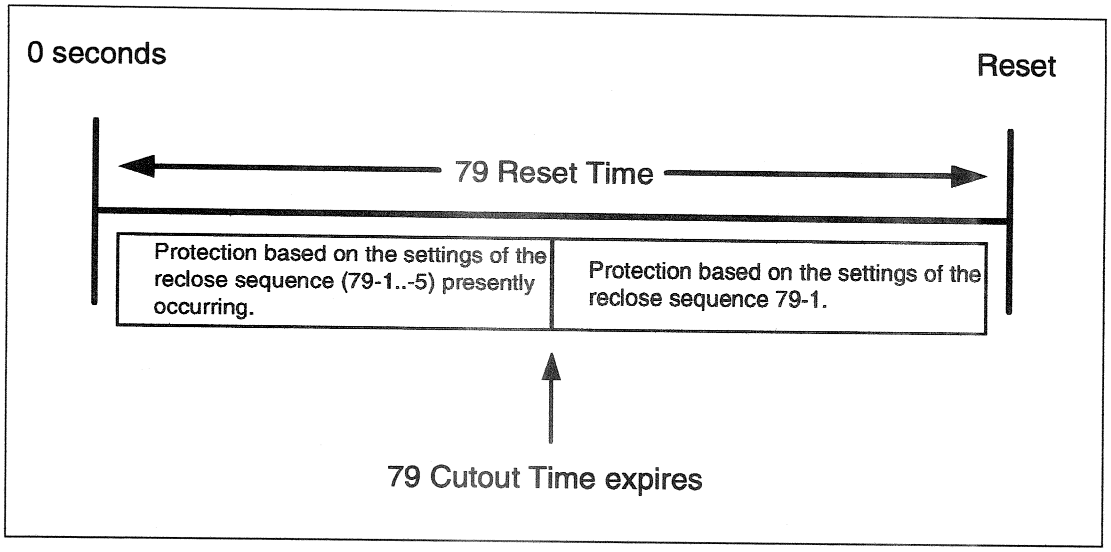
79 (O->I) Setting	Description
Reclose Mode	For units ordered with the single-phase tripping and reclosing option, this setting specifies the tripping mode (OPUP or OOAP). See Section 11. This is a configuration setting.
79 Reset Time	Specification of the recloser reset time. The setting range is 3 to 200 seconds, increment 1 second.
79-1 Mode Select: 51P 79-1 Mode Select: 50P-1 79-1 Mode Select: 50P-2 79-1 Mode Select: 50P-3 79-1 Mode Select: 51N 79-1 Mode Select: 50N-1 79-1 Mode Select: 50N-2 79-1 Mode Select: 50N-3 79-1 Mode Select: 46 79-1 Mode Select: 67P 79-1 Mode Select: 67N	Specification of whether each enabled protection element remains enabled is disabled, or can cause lockout during Stage 1 of the reclose sequence. For units ordered with the single-phase tripping option, the choices are: disable, enable with single-phase operation, enable with three-phase operation, lockout with single-phase operation, lockout with three-phase operation, or alarm (which has no effect on the reclose sequence, but allows alarm logical outputs to operate).
79-1 Open Interval Time	Specification of the Stage 1 open interval time. The setting range is 0.1 to 200.0 seconds, increment 0.1 second.
79-2 Select	Specification of whether Stage 2 reclosing is enabled or disabled.
79-2 Mode Select: 51P 79-2 Mode Select: 50P-1 79-2 Mode Select: 50P-2 79-2 Mode Select: 50P-3 79-2 Mode Select: 51N 79-2 Mode Select: 50N-1 79-2 Mode Select: 50N-2 79-2 Mode Select: 50N-3 79-2 Mode Select: 46 79-2 Mode Select: 67P 79-2 Mode Select: 67N	Specification of whether each enabled protection element remains enabled is disabled, or can cause lockout during Stage 2 of the reclose sequence. For units ordered with the single-phase tripping option, the choices are: disable, enable with single-phase operation, enable with three-phase operation, lockout with single-phase operation, lockout with three-phase operation, or alarm (which has no effect on the reclose sequence, but allows alarm logical outputs to operate).
79-2 Open Interval Time	Specification of the Stage 2 open interval time. The setting range is 0.1 to 200.0 seconds, increment 0.1 second.
79-3 Select	Specification of whether Stage 3 reclosing is enabled or disabled.
79-3 Mode Select: 51P 79-3 Mode Select: 50P-1 79-3 Mode Select: 50P-2 79-3 Mode Select: 50P-3 79-3 Mode Select: 51N 79-3 Mode Select: 50N-1 79-3 Mode Select: 50N-2 79-3 Mode Select: 50N-3 79-3 Mode Select: 46 79-3 Mode Select: 67P 79-3 Mode Select: 67N	Specification of whether each enabled protection element remains enabled is disabled, or can cause lockout during Stage 3 of the reclose sequence. For units ordered with the single-phase tripping option, the choices are: disable, enable with single-phase operation, enable with three-phase operation, lockout with single-phase operation, lockout with three-phase operation, or alarm (which has no effect on the reclose sequence, but allows alarm logical outputs to operate).
79-3 Open Interval Time	Specification of the Stage 3 open interval time. The setting range is 0.1 to 200.0 seconds, increment 0.1 second.
79-4 Select	Specification of whether Stage 4 reclosing is enabled or disabled.

79 (O–>I) Setting	Description
79-4 Mode Select: 51P 79-4 Mode Select: 50P-1 79-4 Mode Select: 50P-2 79-4 Mode Select: 50P-3 79-4 Mode Select: 51N 79-4 Mode Select: 50N-1 79-4 Mode Select: 50N-2 79-4 Mode Select: 50N-3 79-4 Mode Select: 46 79-4 Mode Select: 67P 79-4 Mode Select: 67N	Specification of whether each enabled protection element remains enabled is disabled, or can cause lockout during Stage 4 of the reclose sequence. For units ordered with the single-phase tripping option, the choices are: disable, enable with single-phase operation, enable with three-phase operation, lockout with single-phase operation, lockout with three-phase operation, or alarm (which has no effect on the reclose sequence, but allows alarm logical outputs to operate).
79-4 Open Interval Time	Specification of the Stage 4 open interval time. The setting range is 0.1 to 200.0 seconds, increment 0.1 second.
79-5 Select	Specification of whether Stage 5 reclosing is enabled or disabled.
79-5 Mode Select: 51P 79-5 Mode Select: 50P-1 79-5 Mode Select: 50P-2 79-5 Mode Select: 50P-3 79-5 Mode Select: 51N 79-5 Mode Select: 50N-1 79-5 Mode Select: 50N-2 79-5 Mode Select: 50N-3 79-5 Mode Select: 46 79-5 Mode Select: 67P 79-5 Mode Select: 67N	Specification of whether each enabled protection element remains enabled is disabled, or can cause lockout during Stage 5 of the reclose sequence. For units ordered with the single-phase tripping option, the choices are: disable, enable with single-phase operation, enable with three-phase operation, lockout with single-phase operation, lockout with three-phase operation, or alarm (which has no effect on the reclose sequence, but allows alarm logical outputs to operate).
79-5 Open Interval Time	Specification of the Stage 5 open interval time. The setting range is 0.1 to 200.0 seconds, increment 0.1 second.
79 Cutout Time	Specification of the recloser cutout time (see Section 5.21.1 below). The setting range is 1 to 200 seconds, increment 1 second.
79v Select	Specification of whether the 79V element is enabled or disabled.
79 Pickup Voltage	Specification of the 79V element's pickup voltage. The setting range is10 to 200 volts AC, increment 1 volt.
79v Time Delay	Specification of the 79V element's time delay voltage. The setting range is 4 to 200, increment 1. (See next setting concerning the units used.)
79v Timer Mode	Specification of whether the 79V time delay is in second or minutes.

5.21.1 79 Cutout Time Element

The 79 Cutout Time (79-CO) element allows for the detection of low-level or intermittent faults prior to the resetting of the reclose sequence. At the end of the selected cutout time period, all overcurrent elements are re-enabled based on the 79-1 settings. For example, if the 79-3 reclose sequence is set for ten seconds and the 79 Cutout Time is set for five seconds, the first five seconds of the reclose sequence follow the overcurrent element settings for the 79-3 reclose sequence. But the second five seconds (after the cutout time period) follow the 79-1 settings. The 79-CO setting is programmable from 1 to 200 seconds. When enabled, the 79-CO setting must be less than the 79 Reset Time.

Figure 5-7. 79 Cutout Time



5.21.2 79S Single-Shot Reclosure

The programmable 79S input element initiates a single-shot reclosure when the 52a and 52b contact inputs indicate that the breaker has been externally tripped. The close signal is initiated after the 79-1 open interval time expires. If the breaker remains closed for the Reset Time setting, the reclose sequence resets. If the breaker reopens within the Reset Time setting, no other reclosures are issued.

The front panel Reclose Block Control blocks this element, the 43a logical input and the SCADA reclose block point.

For PCD2000 units ordered with the single-phase option, when Single Phase Reclosing is enabled the Single Reclose Initiate function will not be available.

5.21.3 79M Multishot Reclosure

Based on an external device tripping the unit, the programmable 79M input element steps through the entire reclose sequence. When the 79M input is enabled, the multishot reclose sequence is initiated or continued when the 52a and 52b contact inputs indicate that the unit has been tripped by an external device.

The front panel Reclose Block Control blocks this element, the 43a logical input and the SCADA reclose block point.

For PCD2000 units ordered with the single-phase option, when Single Phase Reclosing is enabled the Multishot Reclose Initiate function will not be available.

5.21.4 Changing from Single-Phase to Three-Phase Operation

When the global mode control is changed from single-phase to three-phase and the breaker status is not consistent with a normal three-phase operation, the system will not be ready for normal three-phase operation. Certain events must occur to obtain pole consistency as detailed in the table below.

Breaker state when going into the three-phase mode.	**Actions required acquiring pole consistency and readiness for normal operation.**
All poles open and/or locked out.	None.
All poles closed.	None.
One or two poles open.	Manual or remote open operation. Manual or remote close operation. Fault and subsequent trip on closed pole(s).
One or two poles open & locked out.	Manual or remote open operation. Manual or remote close operation. Fault and subsequent trip on closed pole(s).

If a fault occurs when the poles are inconsistent all closed poles will be opened and driven to lockout. The trip criteria will be based on the 79-1 settings.

5.22 Breaker Failure Element

A Breaker Failure Alarm will occur if a PCD2000 sends a TRIP signal and one or more of the following occur:

- The fault current fails to drop below at least 5 percent of the lowest pickup setting.
- The unit's 52a and/or 52b contacts do not indicate that the recloser/breaker opened.
- The unit enters a special failure mode when a Recloser Control Module (DIO Type 2) is installed.

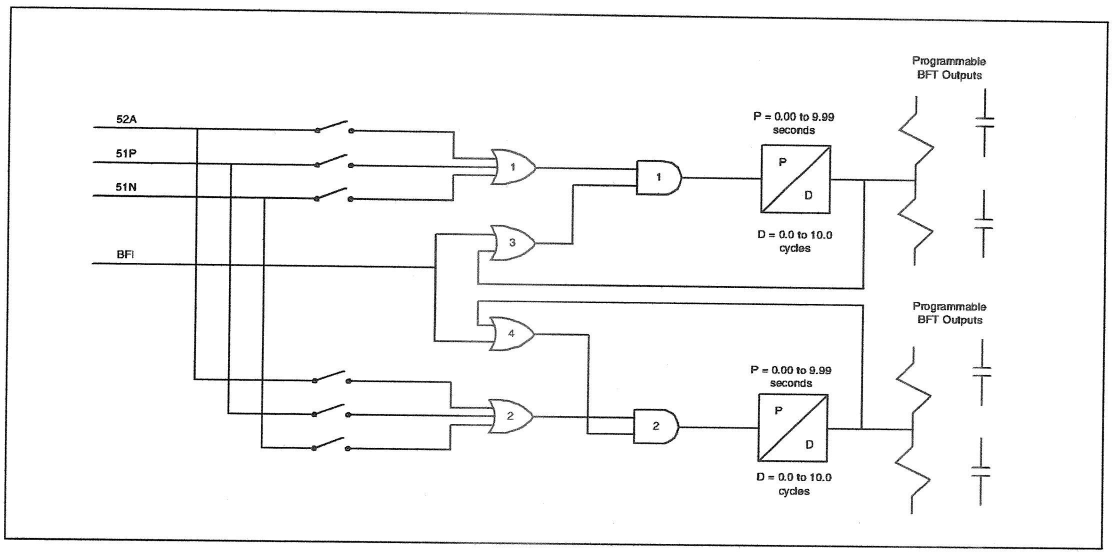
The drop in the fault current and the opening of the unit must occur before the Trip Failure Time expires or the Breaker Failure Alarm will activate. The status light for the unit will blink alternating red and green at this time.

During the Breaker Failure Alarm, the PCD2000 continues to send a TRIP signal until the unit opens, either through SCADA or manual tripping. When the unit is tripped, the PCD2000 goes into lockout and the Breaker Failure Alarm is removed.

The BFT and ReTrip logical outputs share the same logic and both require a Breaker Fail Initiate (BFI) input and a "starter "input. The starter input can be from an internal PCD2000 phase and ground level detector, 52a contact or a combination of both.

The BFT and Retrip logical outputs must be mapped to physical outputs and the BFI and starter inputs must be mapped to physical inputs for operation.

Figure 5-8. Breaker Fail Logic



5 PROTECTION

Table 5-31. Breaker Failure Settings

Setting	Description
Trip Failure Time	Specification of the time allowed after a trip output for the recloser to report that it has tripped (via the 52a and 52b contacts). This is a configuration setting with a range of 5 to 60 cycles with an increment of 1. The default is 18 cycles.
Close Failure Time	Specification of the time allowed after a reclose command output for the recloser to report that it has closed (via the 52a and 52b contacts). This is a configuration setting with a range of 5 to 60 cycles with an increment of 1. The default is 18 cycles.
Breaker Fail Mode	Choice of what the PCD2000 should attempt to do if a breaker failure is detected. It can either try to force all poles open, or it can try to force all poles to the original state.

5.22.1 Breaker Failure Modes of Operation (DIO Type 2 - Recloser Control Module only)

In PCD2000 units using a Recloser Control Module (DIO Type 2) to drive a VR-3S magnetic actuator, the breaker fail logic must account for the recloser's unique method of operation. The recloser is actually three independent single pole units that are driven in unison but operate independently. If one of the poles were to fail, there would be pole inconsistency. Also, the trip and close circuits are driven by short term current pulses to cause linear motion, not a continuous current flow as with a conventional breaker. Therefore, the trip circuit cannot "stand" on the trip, the trip output must be re-pulsed periodically to continue an attempt to open/close a malfunctioning pole.

There are two modes of breaker failure which can be programmed within the configuration settings group; they are the "Open" and "Original" selections. (Note: These will only show up in the configuration menu when a Recloser Control Module is installed.)

The Open Mode will attempt to drive a malfunctioning pole to the open state. This is normally used as the recloser open position is considered the "safe" state when failures occur.

A detail of the **Open Mode** of operation is given below for clarification:

Starting from the closed state:

1. Trip is issued: trip pulses applied to all three phases.
2. Breaker fail to trip timer is started.
3. If all three poles of the breaker clear before the breaker fail to trip timer expires, the PCD2000 shall go to the open state. This is normal operation.
4. If any pole remains closed after expiration of the fail to trip timer, a trip pulse is re-applied after a one-second interval and the fail to trip timer is restarted. The breaker fail alarm will be asserted and a failure logged.
5. This re-trip operation shall occur up to two times, after which the PCD2000 will give up and remain in the Failure State.

Starting from the open state:

1. Close pulses are issued on all three poles (ARC, external, manual).
2. Breaker fail to close timer is started.
3. If all poles close before the close timer expires, the PCD2000 shall go to the closed state. This is normal operation.
4. If any pole(s) remain open once the fail timer expires, a close pulse will be re-applied after one-second interval and the fail timer restarted.

5. This reclose operation shall occur up to two times. If any pole(s) remain open at this point an attempt to drive all the poles open shall be made. The breaker fail alarm shall pickup and a fail operation logged.
6. This operation, in itself, will make up to three attempts to open after which further operations will be halted and breaker failure shall be logged.
7. If one of the attempts is successful the breaker fail alarm will expire.

The **Original Mode** will attempt to drive a malfunctioning pole back to its original state before the current sequence of events started. In particular, if a failure occurs while trying to trip, but is not successful after several retries, the PCD2000 will attempt to close the recloser (the original state). This is useful if you want an upstream recloser to take the system offline due to the failure.

A detail of the Original Mode of operation is given below for clarification:

Starting from the closed state:

1. Trip is issued: trip pulses applied to all three phases.
2. Breaker fail to trip timer is started.
3. If all three poles of the breaker clear before the breaker fail to trip timer expires, the PCD2000 shall go to the open state. This is normal operation.
4. If any pole remains closed the after expiration of the fail to trip timer, a trip pulse is re-applied after a one second interval and the fail to trip timer is restarted.
5. This re-trip operation shall occur up to two times. If any pole(s) remain closed then at this point an attempt to drive all the poles closed shall be made. The breaker fail alarm shall pickup and an operation logged.
6. This operation, in itself, will make up to three attempts to close after which further operations will be halted. Upon every attempt to close an operation will be logged indicating close attempt.
7. If one of the attempts is successful the breaker fail alarm will expire.

Starting from the open state:

1. Close pulses are issued on all three poles (automatic reclose, external or manual).
2. Breaker fail to close timer is started.
3. If all poles close before the close timer expires, the PCD2000 shall go to the closed state. This is normal operation.
4. If any pole(s) remain open once the fail timer expires, a close pulse will be re-applied after one-second interval and the fail timer restarted.
5. This re-close operation shall occur up to two times. If any pole(s) remain open at this point an attempt to drive all the poles open shall be made. The breaker fail alarm shall pickup and a fail operation logged.
6. This operation, in itself, will make up to three attempts to open after which further operations will be halted and breaker failure shall be logged.
7. If one of the attempts is successful the breaker fail alarm will expire.

If a failure drives the recloser to the closed or indeterminate state all protection will be disabled.

Protection will be re-enabled if the breaker status changes to the open state (all poles), or the front panel Trip/Close buttons are actuated.

5.23 Counter and Alarm-Threshold Settings

The PCD2000 can issue alarms when internal event-counters reach a particular value, or when monitored system-information values reach a particular threshold. These alarms control logical outputs that can be programmed to control physical outputs, and so communicate with external devices.

Table 5-32. Alarm Settings

HMI Abbreviation	WinPCD Name and Description
KSI Sum	KSI Summation Alarm Threshold If and when any KSI Sum Counter reaches this setting value, the KSI logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 1 to 9999 kA, with an increment of 1.
OC Trip	Overcurrent Trip Counter Alarm If and when any Overcurrent Trip Counter reaches this setting value, the OCTC logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 1 to 9999, with an increment of 1.
79 Counter 1	Reclosure Counter Alarm 1 If and when any Recloser Counter 1 counter reaches this setting value, the 79CA1 logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 1 to 9999, with an increment of 1.
79 Counter 2	Reclosure Counter Alarm 2 If and when any Recloser Counter 2 counter reaches this setting value, the 79CA2 logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 1 to 9999, with an increment of 1.
Phase Demand	Phase Demand Alarm If the Phase Current Demand of any phase goes above this setting value for 60 seconds, the PDA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 1 to 9999 A, with an increment of 1.
Neutral Dmnd	Neutral Demand Alarm If the Neutral Current Demand goes above this setting value for 60 seconds, the NDA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 1 to 9999 A, with an increment of 1.
Dmnd 3P-kVAR	3 Phase kVAR Alarm If the 3-Phase kVAR Demand goes above this setting value for 60 seconds, the VarDA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 0 to 99,990 kVar, with an increment of 10.
Low PF	Low PF Alarm If the Power Factor drops below this setting value for 60 seconds, the LPFA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 0.5 to 1.0 (lagging), with an increment of 0.01.
High PF	High PF Alarm If the Power Factor goes above this setting value for 60 seconds, the HPFA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 0.5 to 1.0 (lagging), with an increment of 0.01.
Load Current	Load Current Alarm If the Load Current of any phase goes above this setting value for 60 seconds, the LOADA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 1 to 9999 A, with an increment of 1.

HMI Abbreviation	WinPCD Name and Description
Pos kVAR	Positive kVAR Alarm If the Positive 3-Phase kVAR Demand goes above this setting value for 60 seconds, the PVarA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 0 to 99,990 kVar, with an increment of 10.
Neg kVAR	Negative kVAR Alarm If the Negative 3-Phase kVAR Demand goes above this setting value for 60 seconds, the NVarA logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 0 to 99,990 kVar, with an increment of 10.
Pos kWatts 1	Pos Watt Alarm 1 If the Positive kWatts level goes above this setting value for 60 seconds, the PWatt1 logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 0 to 9999 kWatts, with an increment of 1.
Pos kWatts 2	Pos Watt Alarm 2 If the Positive kWatts level goes above this setting value for 60 seconds, the PWatt2 logical output will go HIGH. Can be set to "Disable" (default) or to a value in the range 0 to 9999 kWatts, with an increment of 1.

Table 5-33. Initial Values of Counters Settings

HMI Abbreviation	WinPCD Name and Description
KSI SumA KSI SumB KSI SumC	KSI Sum A Counter KSI Sum B Counter KSI Sum C Counter Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 kA with an increment of 1.
OC Trip OC Trip A OC Trip B OC Trip C OC Trip N	Over Current Trip Counter Overcurrent Trip A Counter Overcurrent Trip B Counter Overcurrent Trip C Counter Overcurrent Trip N Counter Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.
Bkr Oper Bkr Oper A Bkr Oper B Bkr Oper C	Breaker Operations Counter Phase A Pole Operations Counter Phase B Pole Operations Counter Phase C Pole Operations Counter Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.
79 Cntr 1 79 Cntr 1 A 79 Cntr 1 B 79 Cntr 1 C	Reclose Counter 1 Phase A Recloser Counter 1 Phase B Recloser Counter 1 Phase C Recloser Counter 1 Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.
79 Cntr 2 79 Cntr 2 A 79 Cntr 2 B 79 Cntr 2 C	Reclose Counter 2 Phase A Recloser Counter 2 Phase B Recloser Counter 2 Phase C Recloser Counter 2 Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.

HMI Abbreviation	WinPCD Name and Description
1st Recl 1st Recl A 1st Recl B 1st Recl C	1st Reclose Counter Phase A Stage 1 Reclose Counter Phase B Stage 1 Reclose Counter Phase C Stage 1 Reclose Counter Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.
2nd Recl 2nd Recl A 2nd Recl B 2nd Recl C	2nd Reclose Counter Phase A Stage 2 Reclose Counter Phase B Stage 2 Reclose Counter Phase C Stage 2 Reclose Counter Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.
3rd Recl 3rd Recl A 3rd Recl B 3rd Recl C	3rd Reclose Counter Phase A Stage 3 Reclose Counter Phase B Stage 3 Reclose Counter Phase C Stage 3 Reclose Counter Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.
4th Recl 4th Recl A 4th Recl B 4th Recl C	4th Reclose Counter Phase A Stage 4 Reclose Counter Phase B Stage 4 Reclose Counter Phase C Stage 4 Reclose Counter Each setting value will be the initial value of the corresponding counter after a reset of the counters. Setting range is 0 (default) to 9999 with an increment of 1.

5.24 Time Overcurrent Curves

The PCD2000 is equipped with a comprehensive selection of time overcurrent curves. Standard ANSI/IEEE curves, IEC curves, and Recloser curves are available. A Configuration setting determines whether elements set to use ANSI/IEEE curves reset instantaneously, or according to the corresponding reset curve. In addition, the PCD2000 can store up to three user-defined curves (see page 5-80)

Table 5-34. Curve Settings that Apply to All Time Overcurrent Elements

HMI Abbreviation	WinPCD Name and Description
Curve Set	Curve Set Choice of whether the curve-choice setting for the time-overcurrent elements will be from a list of ANSI, IEC, or recloser curves. (User-defined curves are available for any Curve Set setting). This is a Configuration Setting, and so affects all three settings sets (Primary, Alternate 1, and Alternate2.
Reset Mode	Reset Mode Choice of whether to have time-overcurrent elements reset instantaneously when they drop out, or reset in a delayed manner that simulates the behavior of an electromechanical protection element. This choice only applies when the time-overcurrent curve is an ANSI curve (IEC and Recloser curves always reset instantaneously). This is a Configuration Setting, and so affects all three settings sets (Primary, Alternate 1, and Alternate2).

5.24.1 ANSI Curves

The ANSI curves are defined by the following equations and table of coefficients. These curves are plotted beginning on page 5-47.

$$\text{Trip Time} = \left(\frac{A}{M^P - 1} + B \right) \times \left(\frac{14n - 5}{9} \right)$$

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

Table 5-35. ANSI Curves

ANSI Curve	Value of Constants						See Page
	A	B	C	P	D	E	
Extremely Inverse	6.407	0.025	1	2.0	3	0.998	5-47
Very Inverse	2.855	0.0712	1	2.0	1.346	0.998	5-48
Inverse	0.0086	0.0185	1	0.02	0.46	0.998	5-49
Short Time Inverse [1]	0.00172	0.0037	1	0.02	0.092	0.998	5-50
Short Time Extremely Inverse [2]	1.281	0.005	1	2.0	0.6	0.998	5-51
Definite Time	-	-	-	-	-	-	5-52
Long Time Extremely Inverse [3]	64.07	0.250	1	2.0	30	0.998	5-53
Long Time Very Inverse [4]	28.55	0.712	1	2.0	13.46	0.998	5-54
Long Time Inverse [5]	0.086	0.185	1	0.02	4.6	0.998	5-55
Recloser Curve #8	4.211	0.013	0.35	1.8	3.29	1.5	5-56
Standard Instantaneous	-	-	-	-	-	-	5-57
Inverse Instantaneous	-	-	-	-	-	-	5-58

[1] Time delay of Short Time Inverse curve is 1/5 that of the Inverse curve.
[2] Time delay of Short Time Extremely Inverse curve is 1/5 that of the Extremely Inverse curve.
[3] Time delay of Long Time Extremely Inverse curve is 10 times that of the Extremely Inverse curve.
[4] Time delay of Long Time Very Inverse curve is 10 times that of the Very Inverse curve.
[5] Time delay of Long Time Inverse curve is 10 times that of the Inverse curve.

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5.24.2 IEC Curves

The IEC curves are defined by the following equation and table of coefficients. The reset time of all IEC curves is instantaneous. These curves are plotted beginning on page 5-59.

$$\text{Trip Time} = \left(\frac{K}{(G/Gb)^{\partial}} - 1 \right) \times (\text{Time Dial})$$

Table 5-36. IEC Curves

IEC Curve	Value of Constants K	∂	See Page
Extremely Inverse	80.0	2.0	5-59
Very Inverse	13.5	1.0	5-60
Inverse	0.14	0.02	5-61
Long Time Inverse	120.0	1.0	5-62
Definite Time	-	-	5-63

5.24.3 Recloser Curves

The recloser curves are defined by the following equation and table of coefficients. The reset time of all recloser curves is instantaneous. These curves are plotted beginning on page 5-64.

$$\text{Trip Time} = \left(\frac{A}{M^{P} - C} + B \right) \times \text{time dial}$$

Table 5-37. Recloser Curves

Recloser Curve	Value of Constants A	B	C	P	See Page
A (101)	0.208242	-0.00237	-1.13281	2.30657	5-64
B (117)	4.22886	0.008933	0.319885	1.7822	5-65
C (133)	8.76047	0.029977	0.380004	1.80788	5-66
D (116)	5.23168	0.000462	0.17205	2.17125	5-67
E (132)	10.7656	0.004284	0.249969	2.18261	5-68
K (162)	11.9847	-0.000324	0.688477	2.01174	5-69
N (104)	0.285625	-0.071079	0.464202	0.911551	5-70
R (105)	0.001015	-0.13381	0.998848	0.00227	5-71
W (138)	15.4628	0.056438	0.345703	1.6209	5-72
2 (135)	11.4161	0.488986	0.239257	1.84911	5-73
3 (140)	13.5457	0.992904	0.379882	1.76391	5-74
8 (113)	1.68546	0.158114	0.436523	1.78873	5-75
8*	1.42302	-0.007846	0.442626	1.42529	5-76
8+ (111)	1.42732	-0.003704	0.366699	1.70112	5-77
9 (131)	2.75978	5.10647	0.614258	1.0353	5-78
11 (141)	21.6149	10.6768	-0.67185	2.69489	5-79

Figure 5-9. ANSI Extremely Inverse Curve

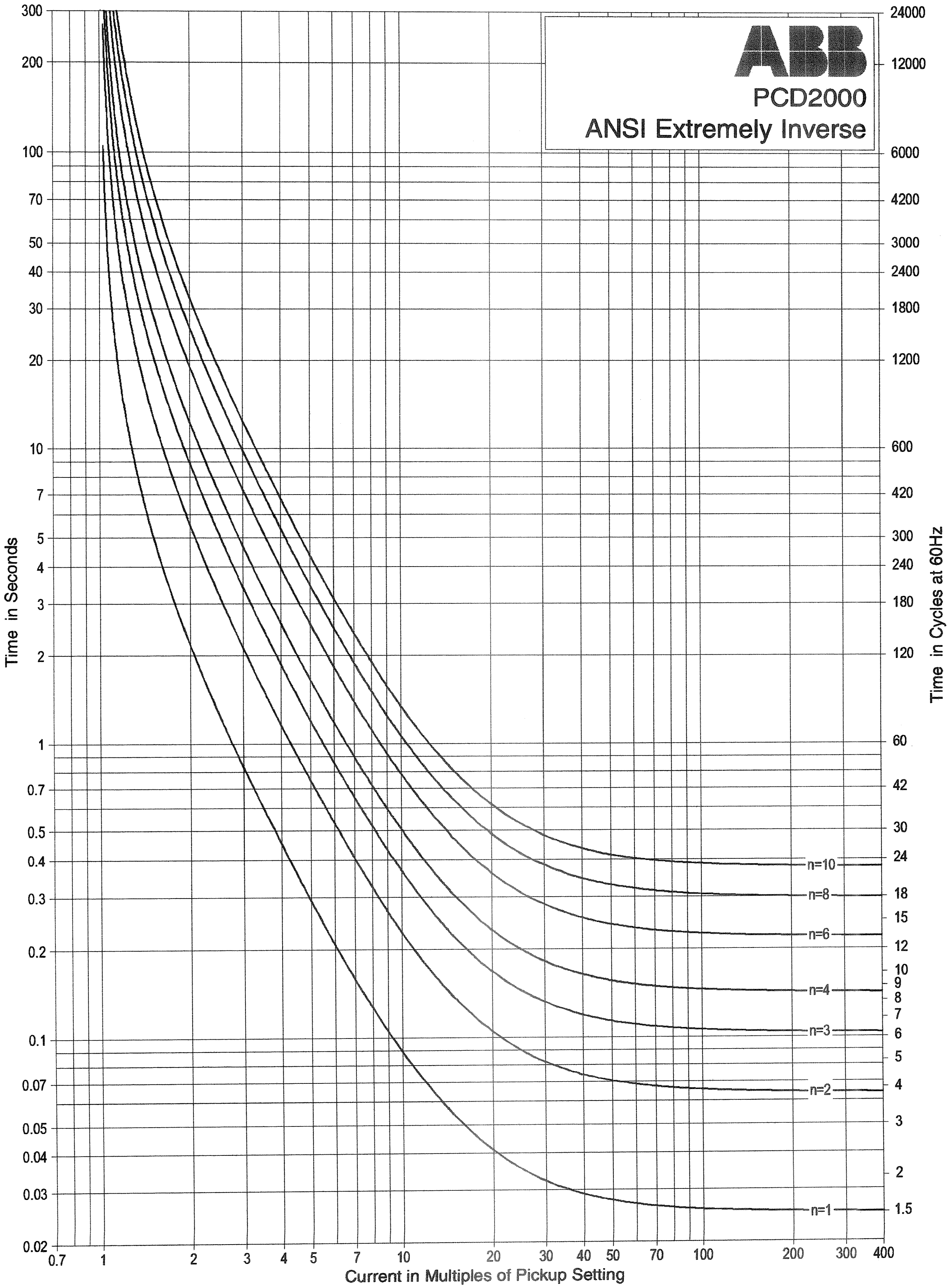

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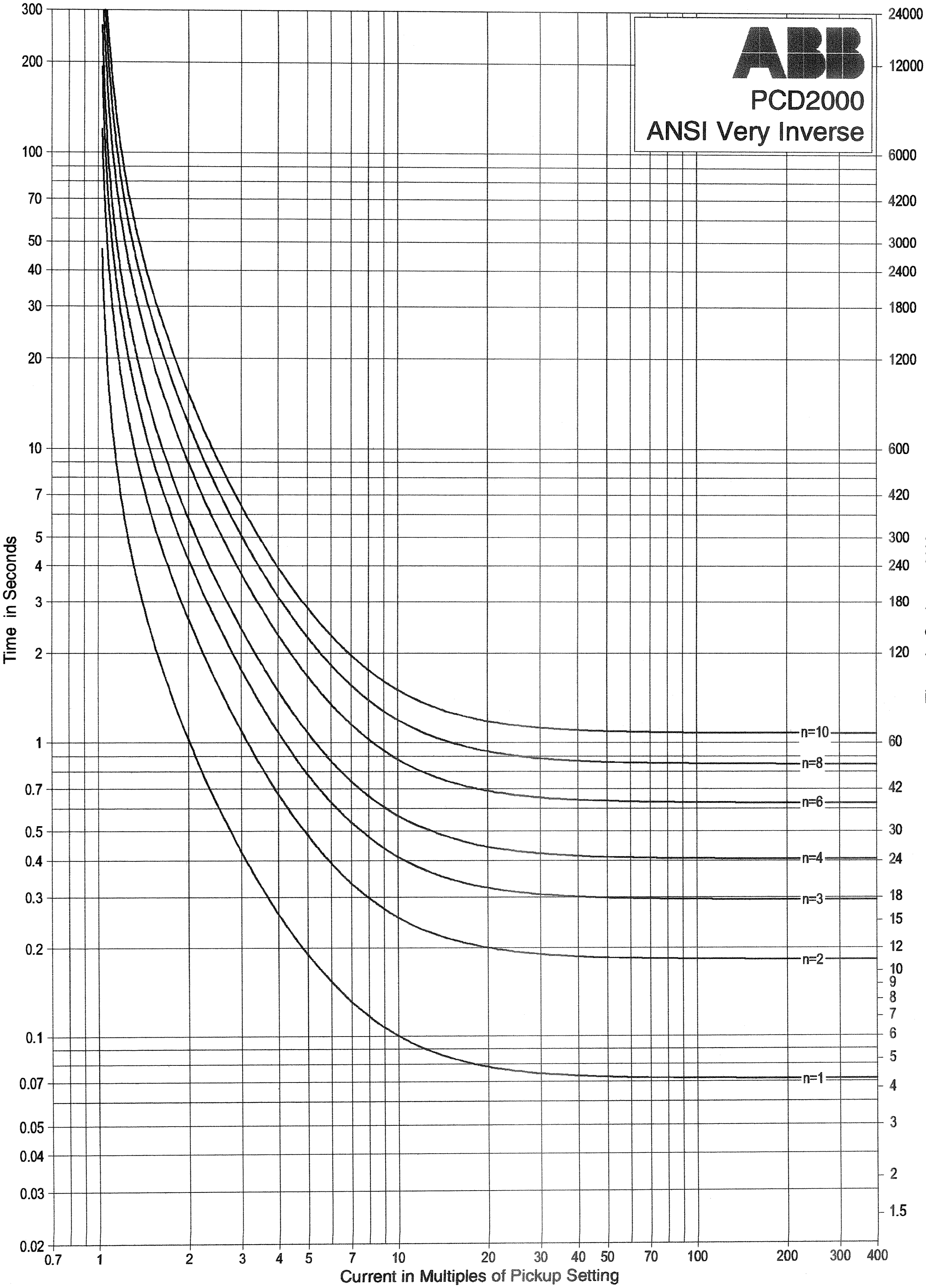
Figure 5-10. ANSI Very Inverse Curve



5 PROTECTION

Figure 5-11. ANSI Inverse Curve

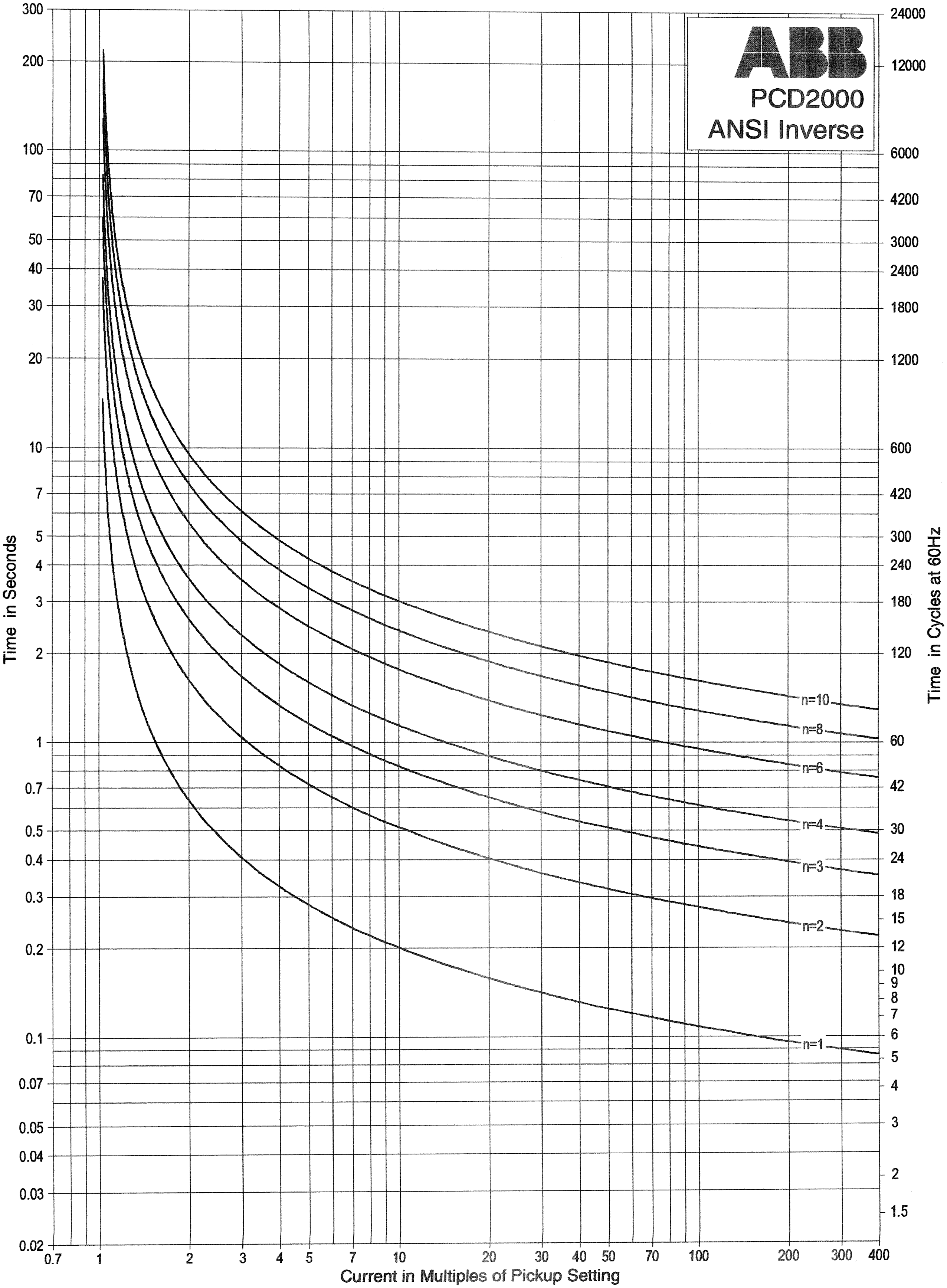


Figure 5-12. ANSI Short Time Inverse Curve

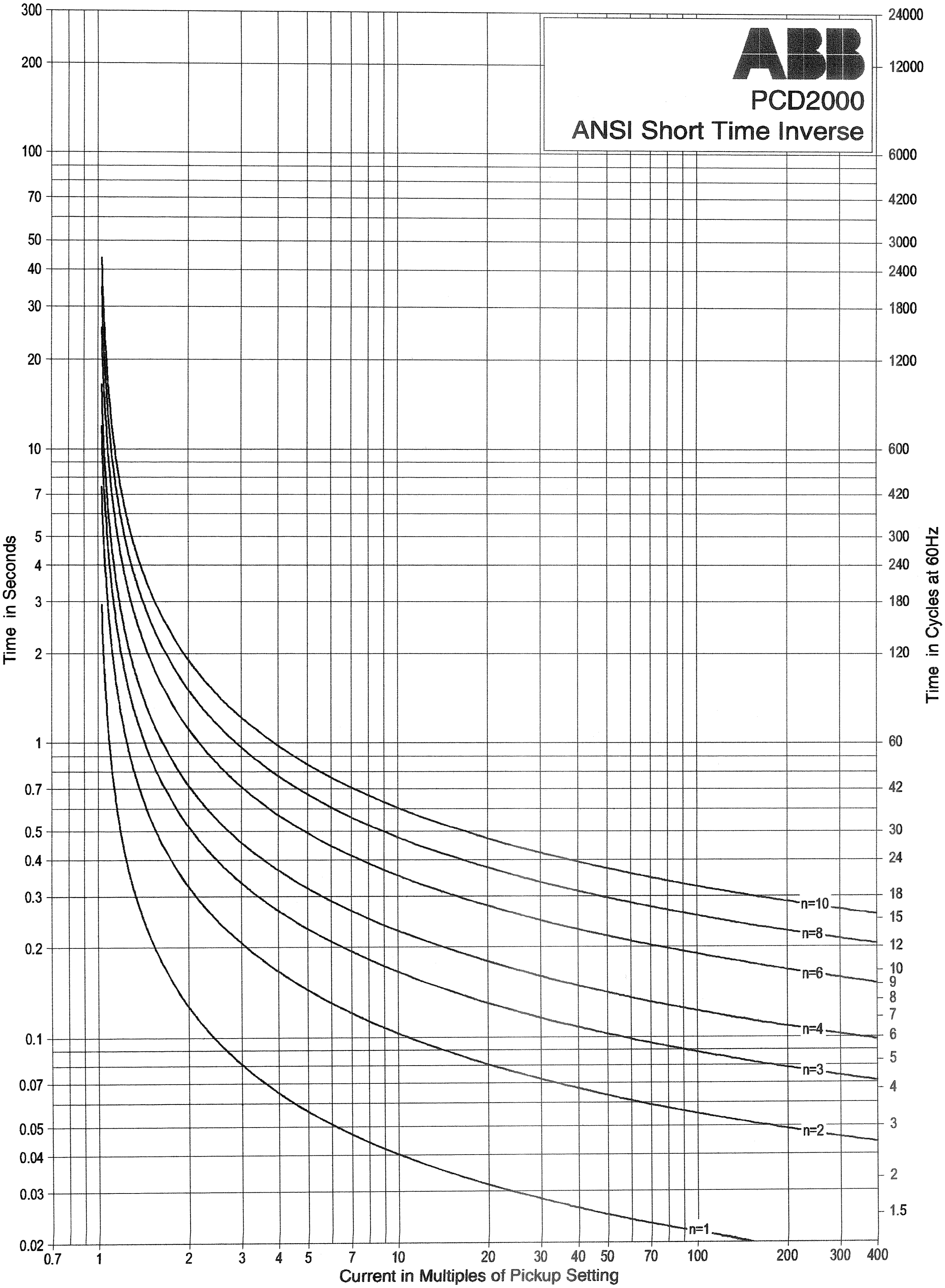


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Figure 5-13. ANSI Short Time Extremely Inverse Curve

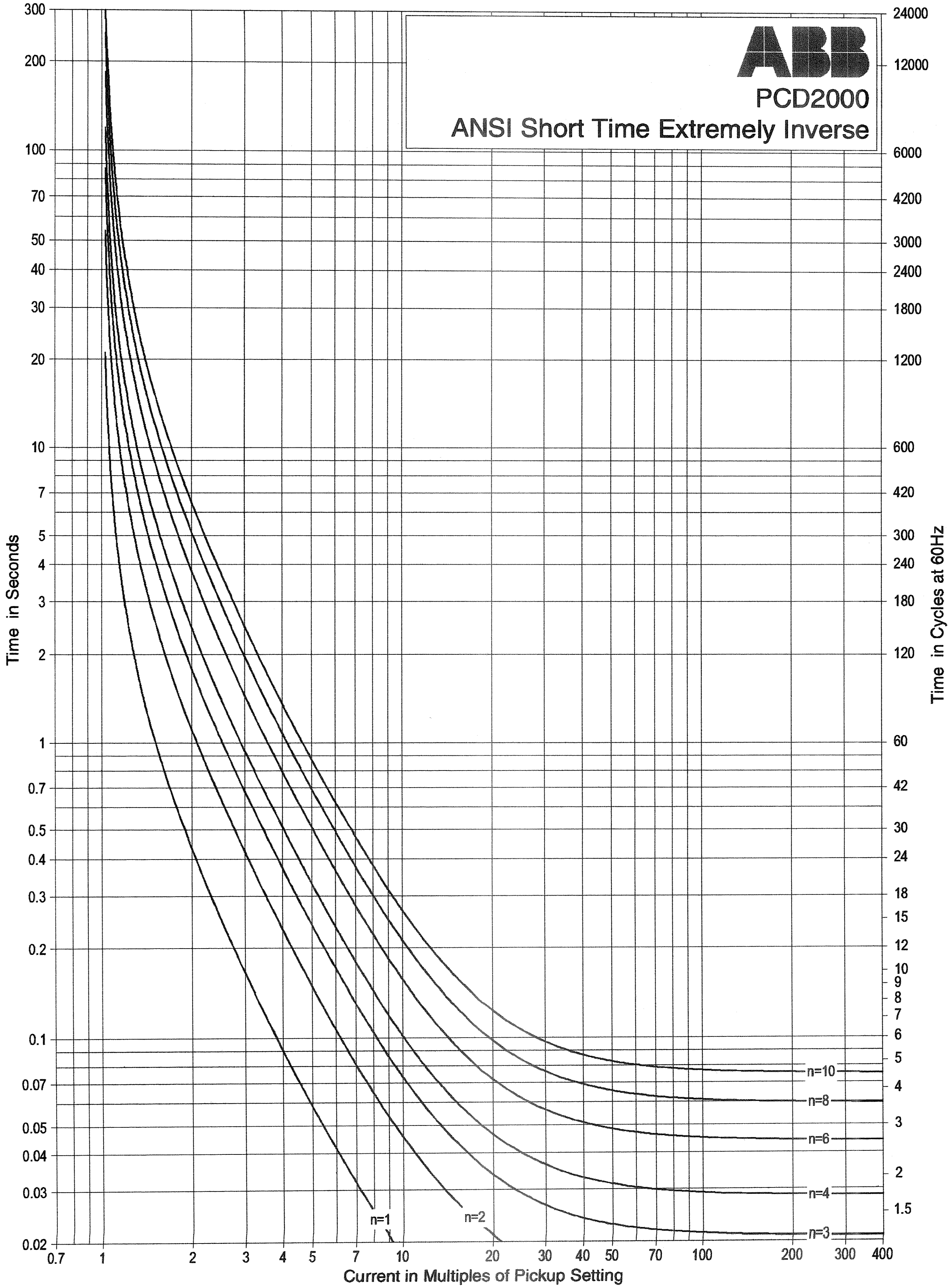

Figure 5-14. ANSI Definite Time Curve

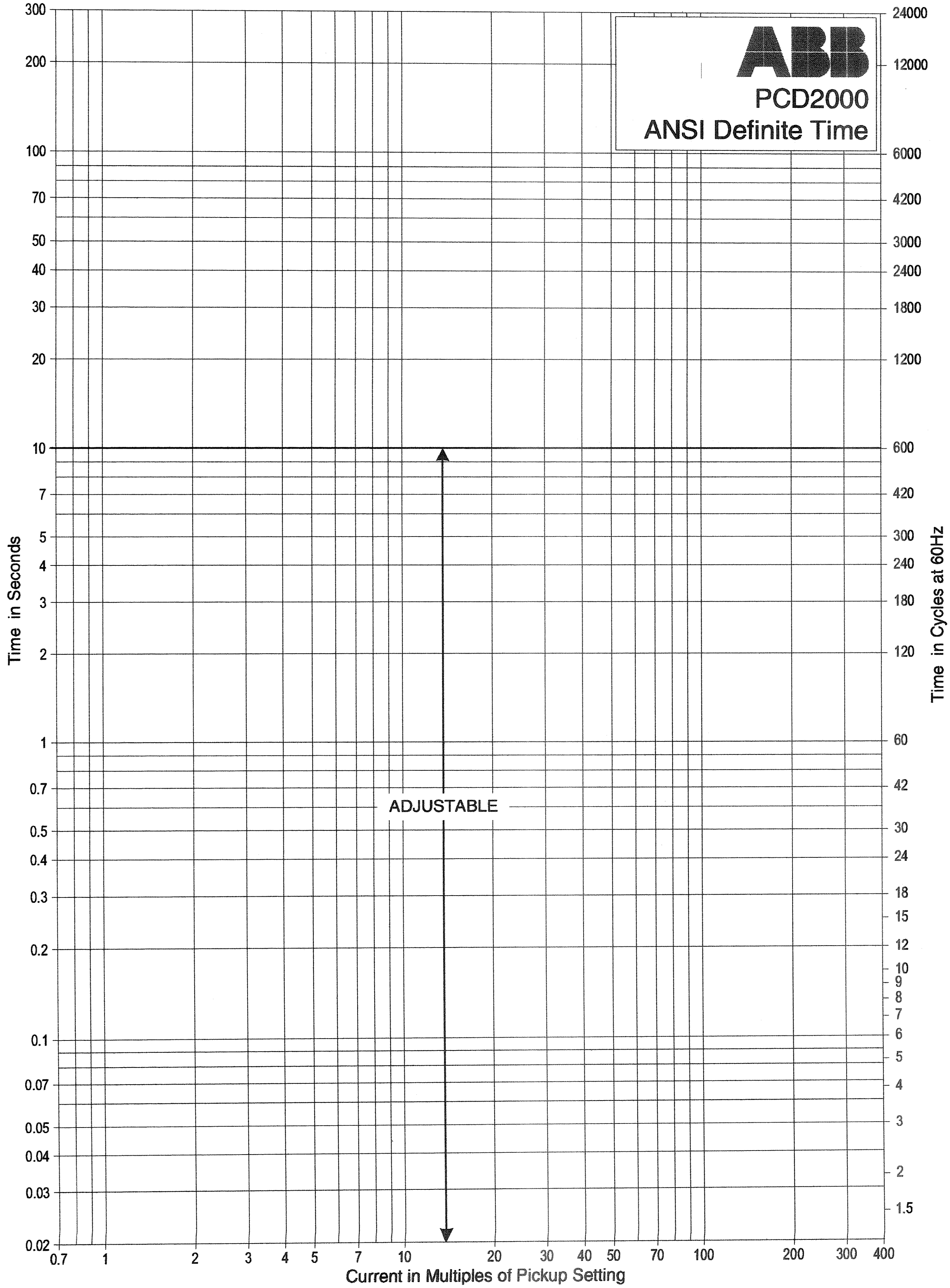

Figure 5-15. ANSI Long Time Extremely Inverse Curve

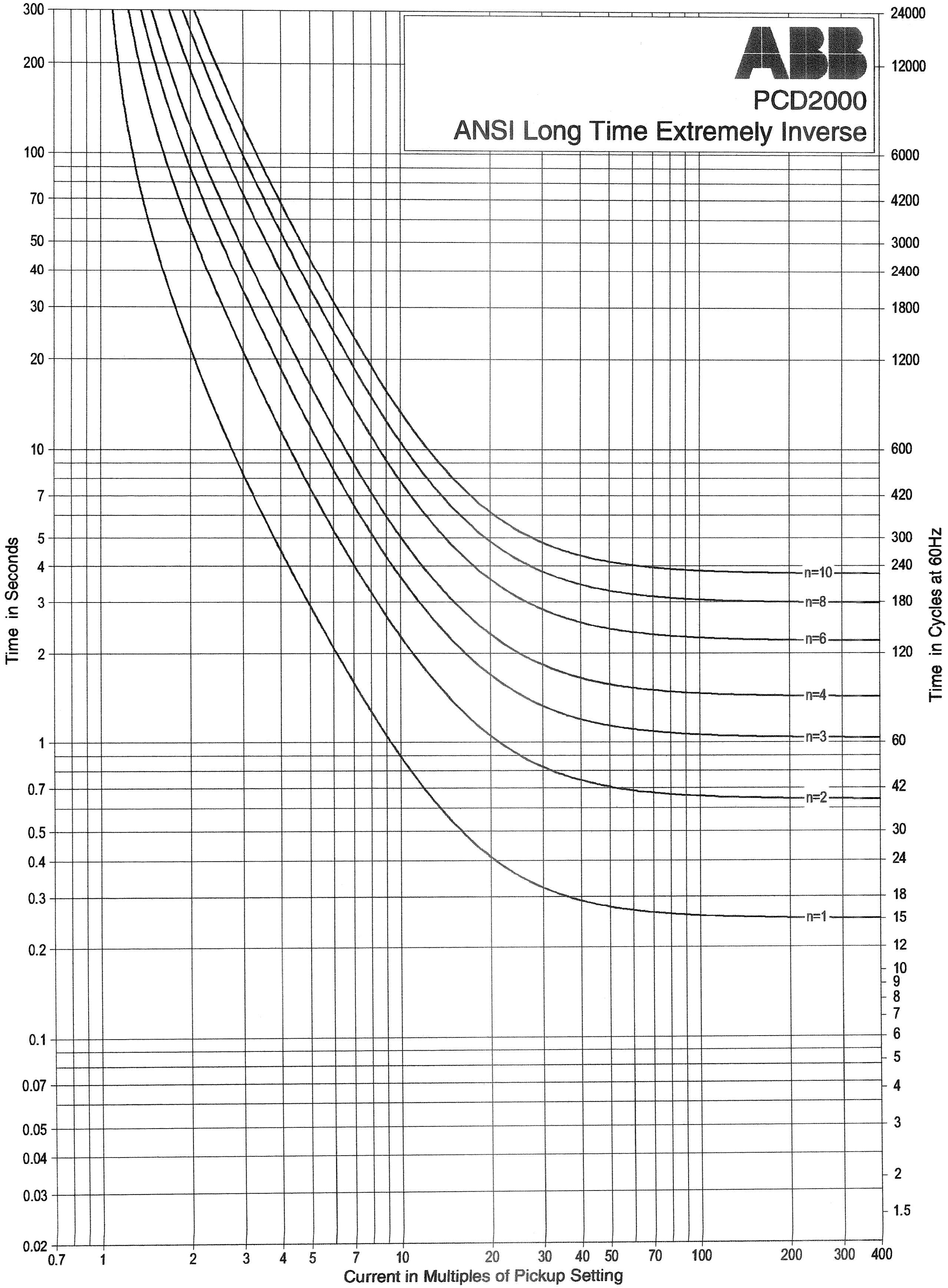

Figure 5-16. ANSI Long Time Very Inverse Curve

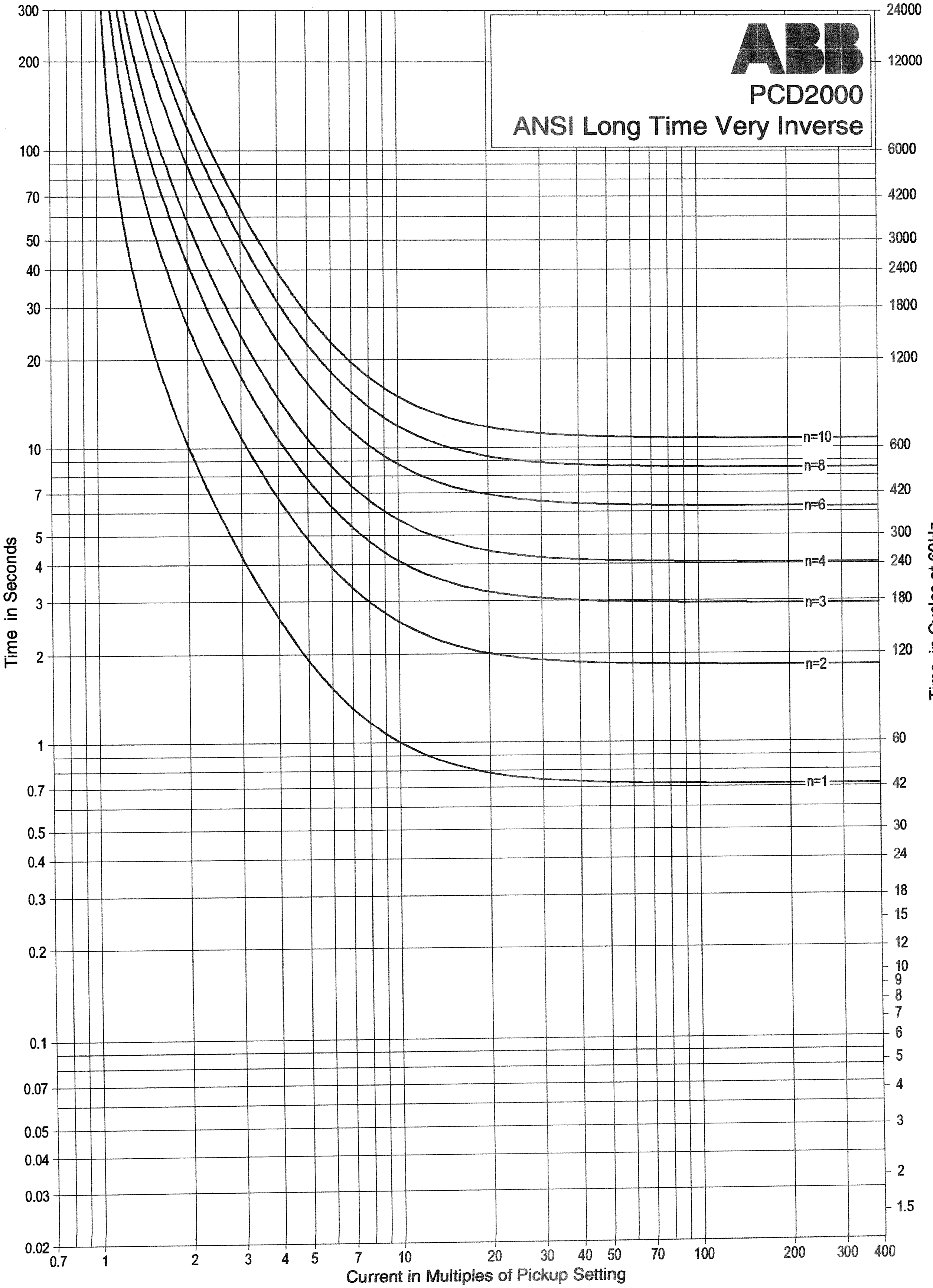

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Figure 5-17. ANSI Long Time Inverse Curve

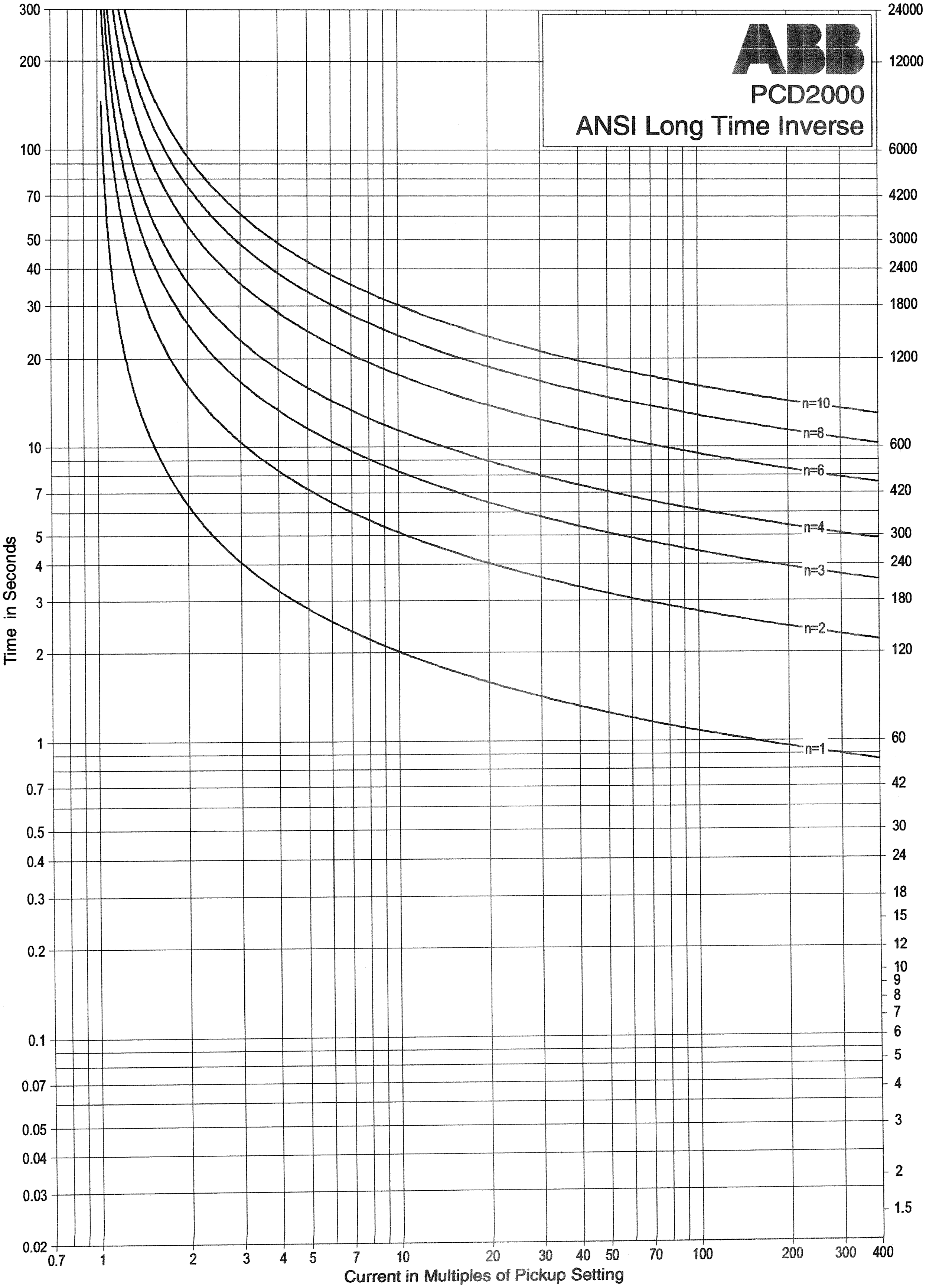

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Figure 5-18. ANSI Recloser Curve #8

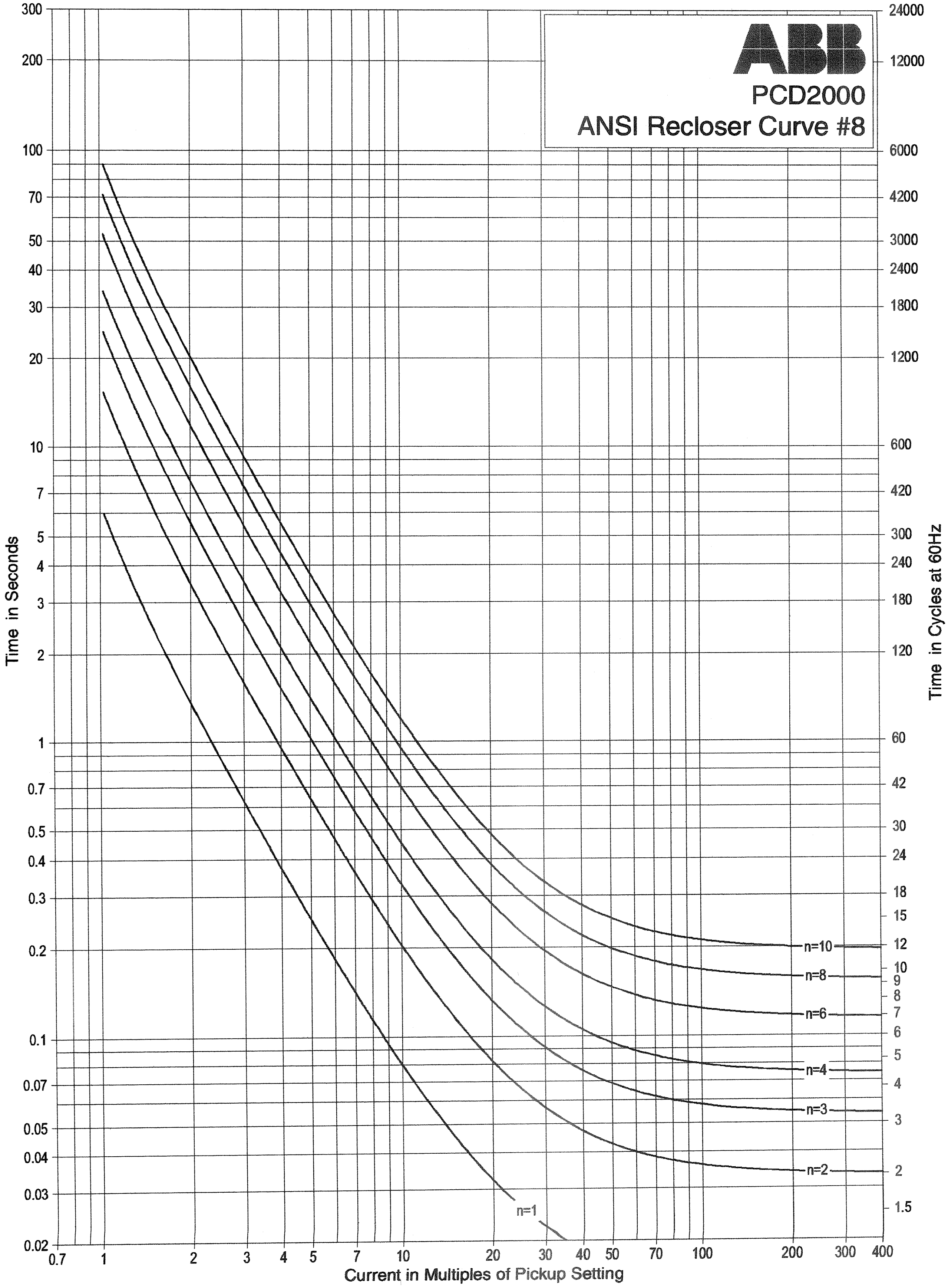

Figure 5-19. ANSI Standard Instantaneous Curve

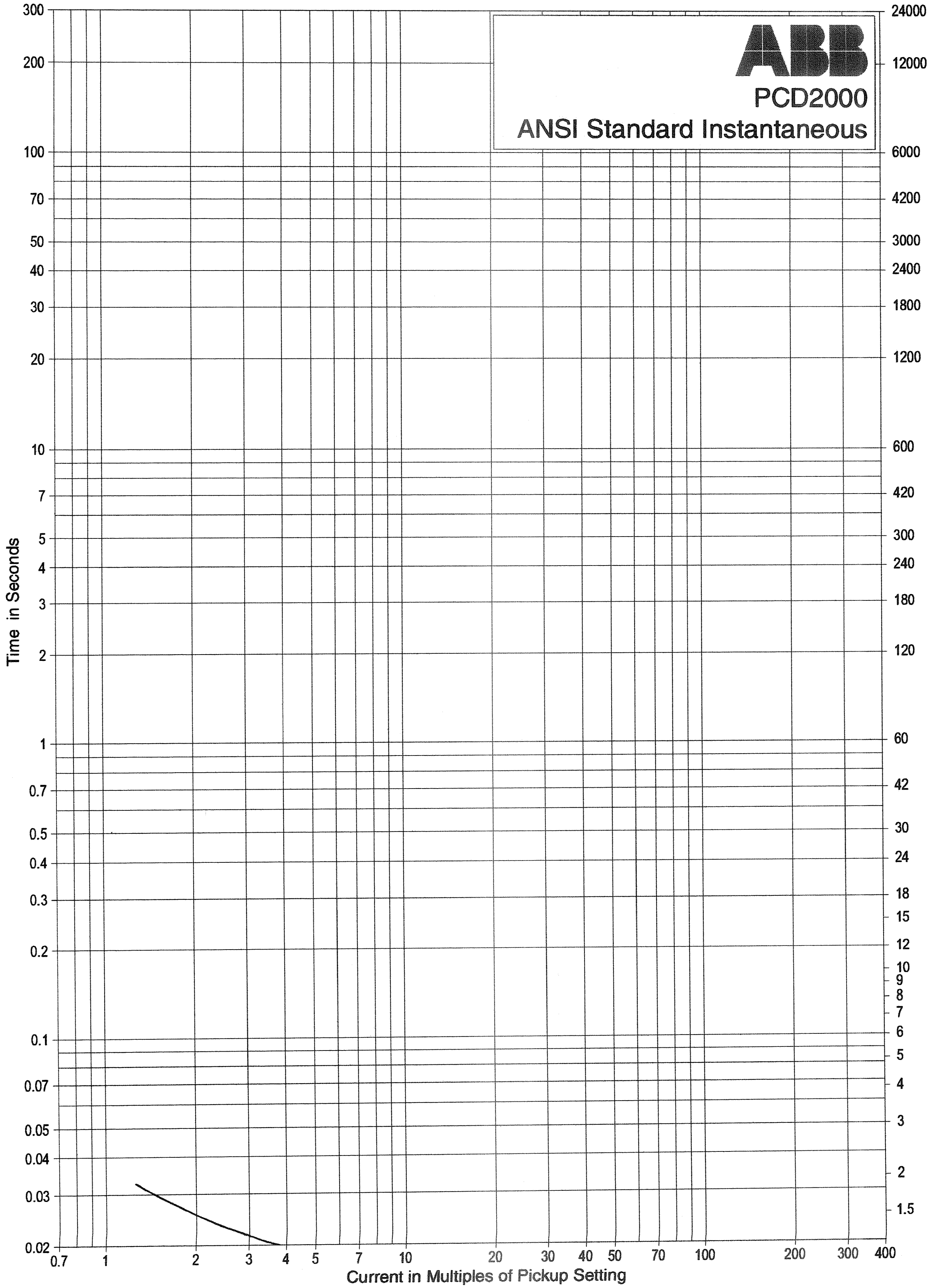

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Figure 5-20. ANSI Inverse Instantaneous Curve

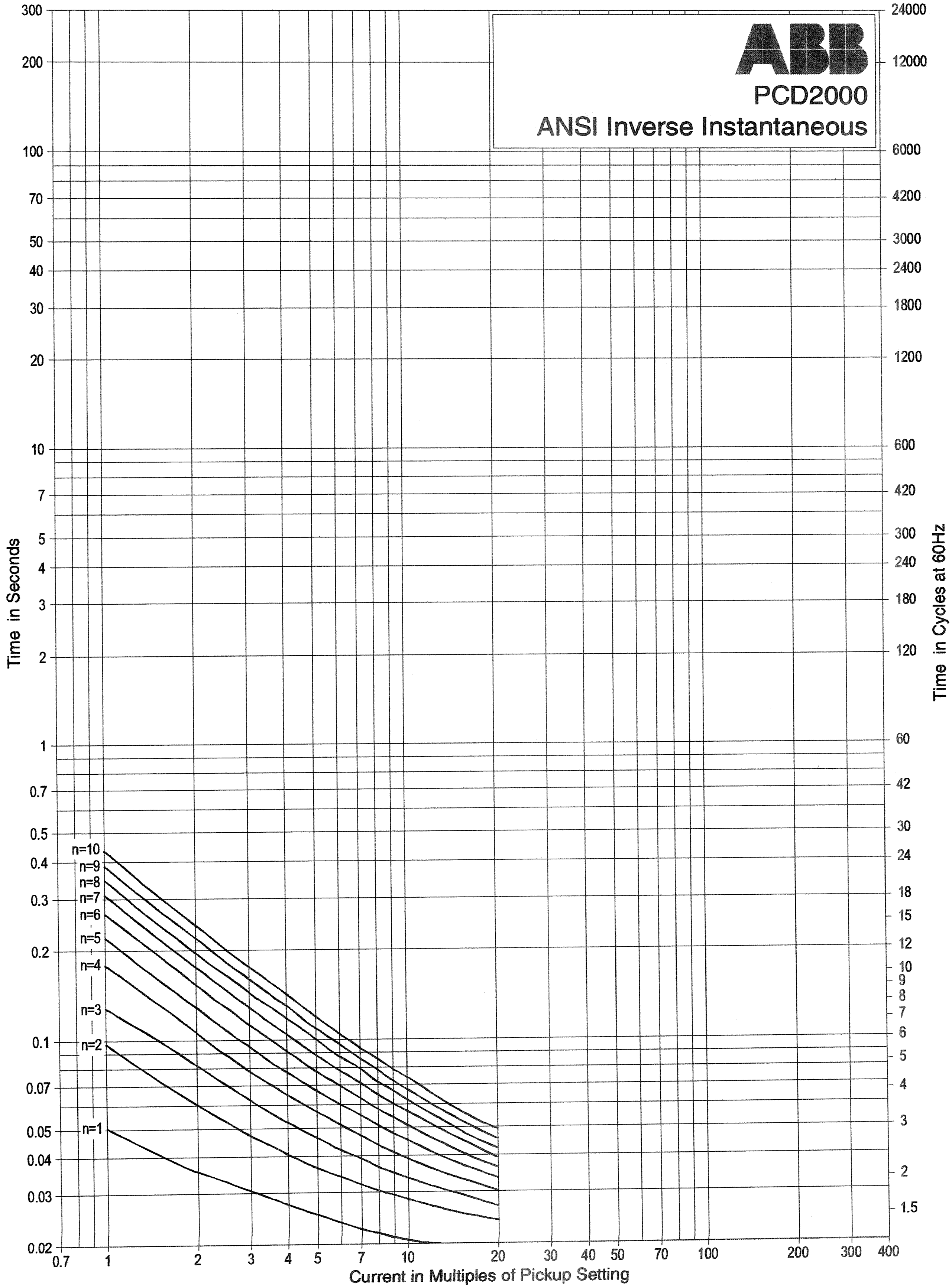

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Figure 5-21. IEC Extremely Inverse Curve

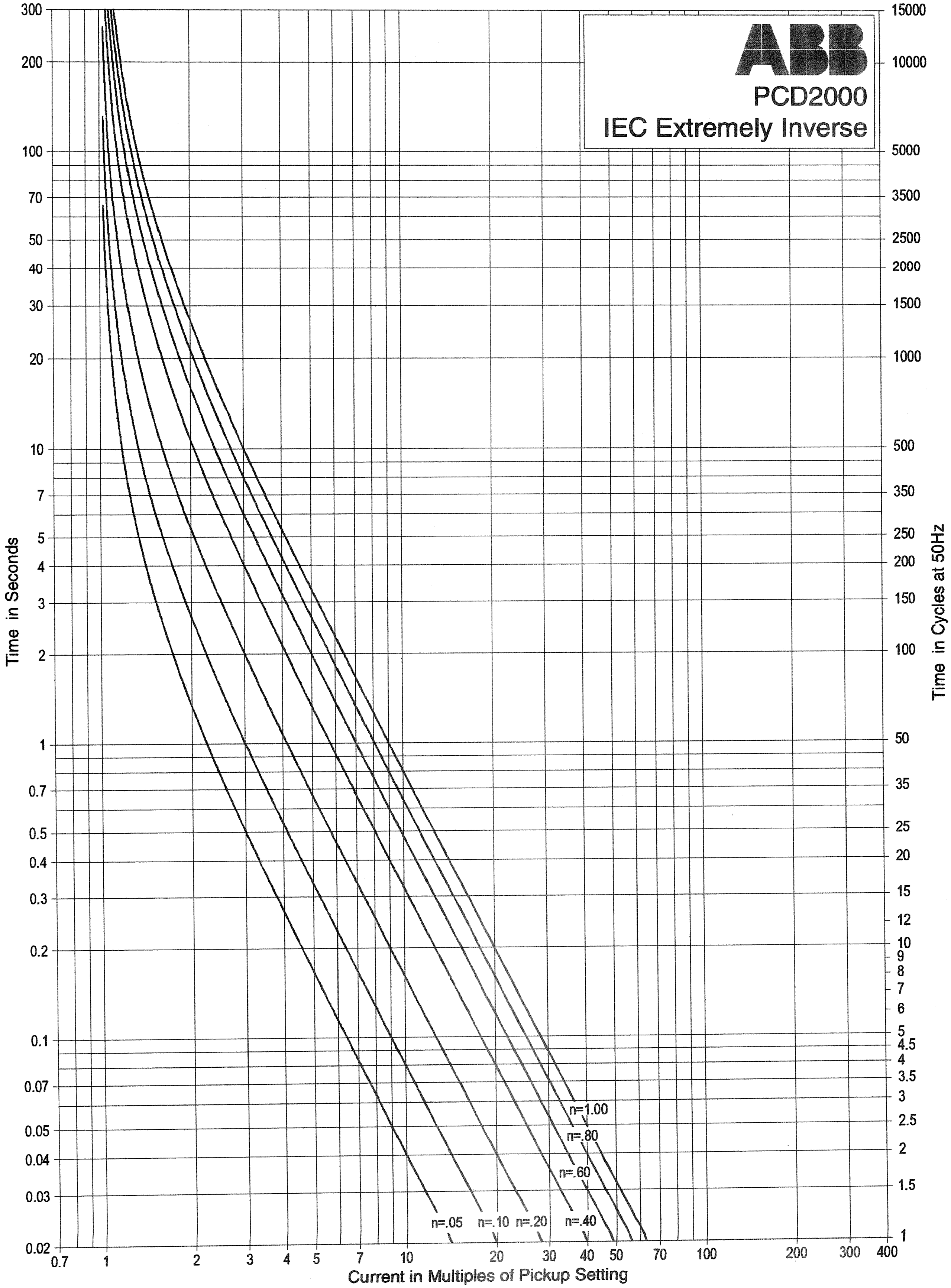

Figure 5-22. IEC Very Inverse Curve

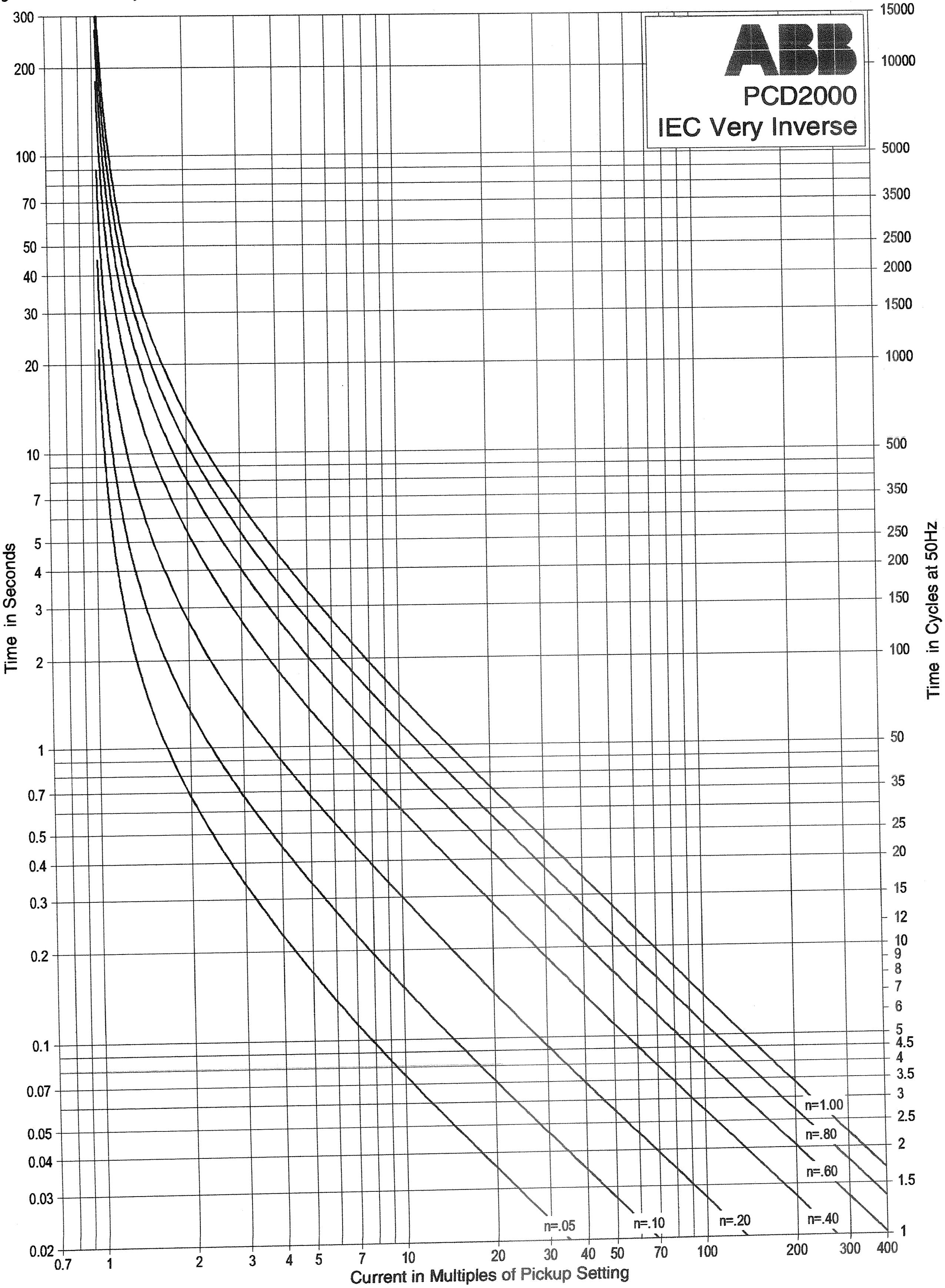

Figure 5-23. IEC Inverse Curve

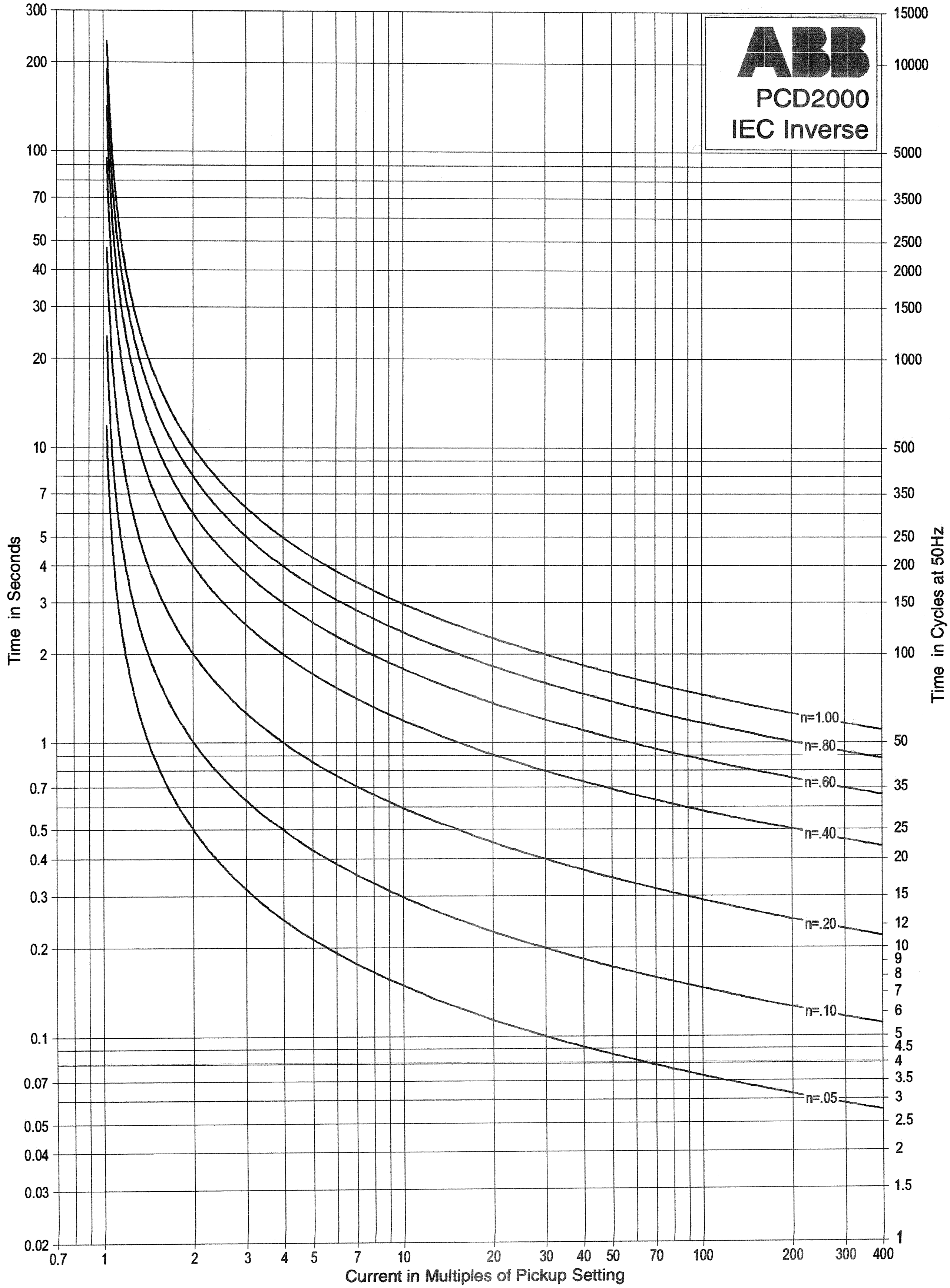

Figure 5-24. IEC Long Time Inverse Curve

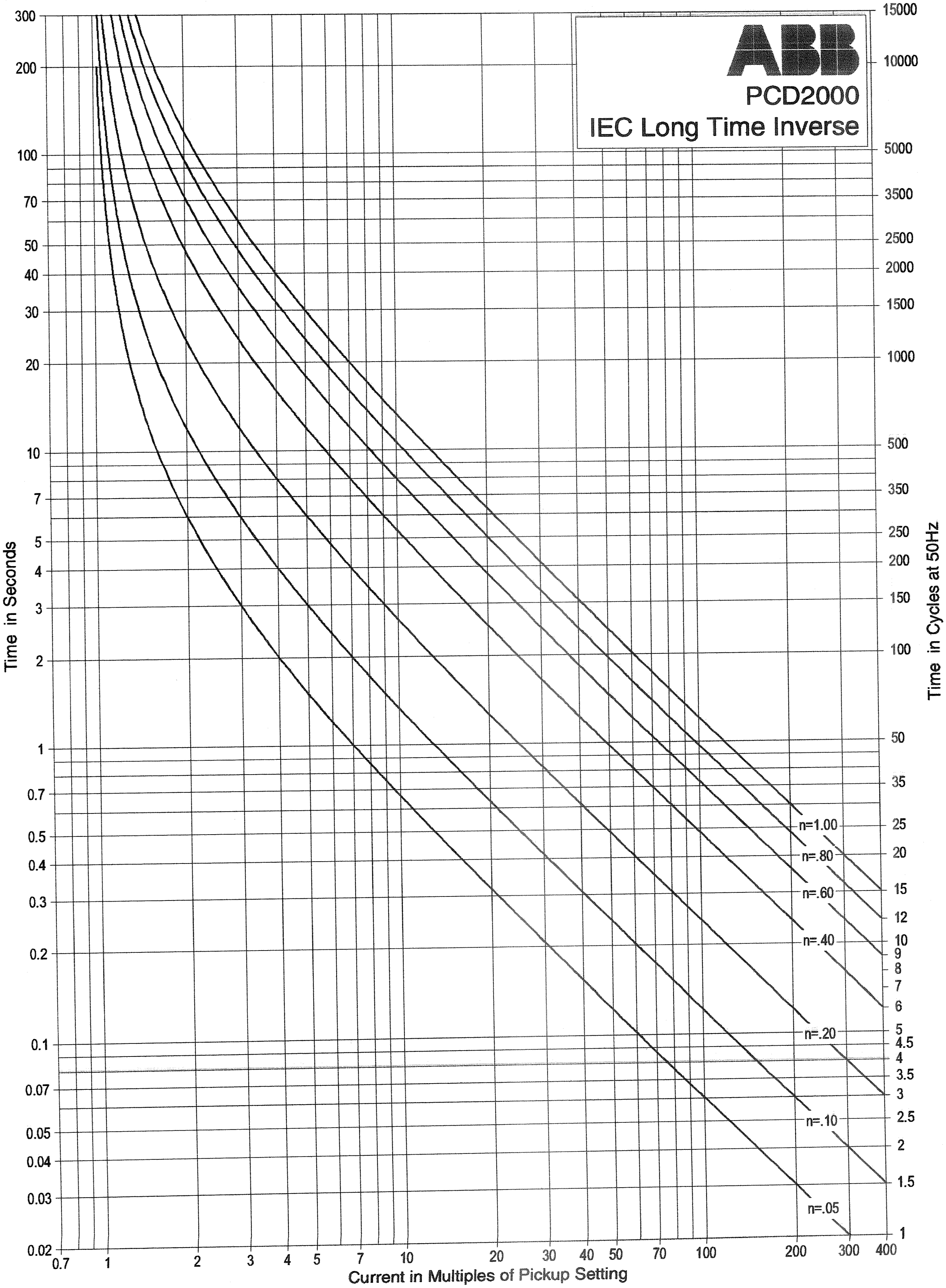

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Figure 5-25. IEC Definite Time Curve

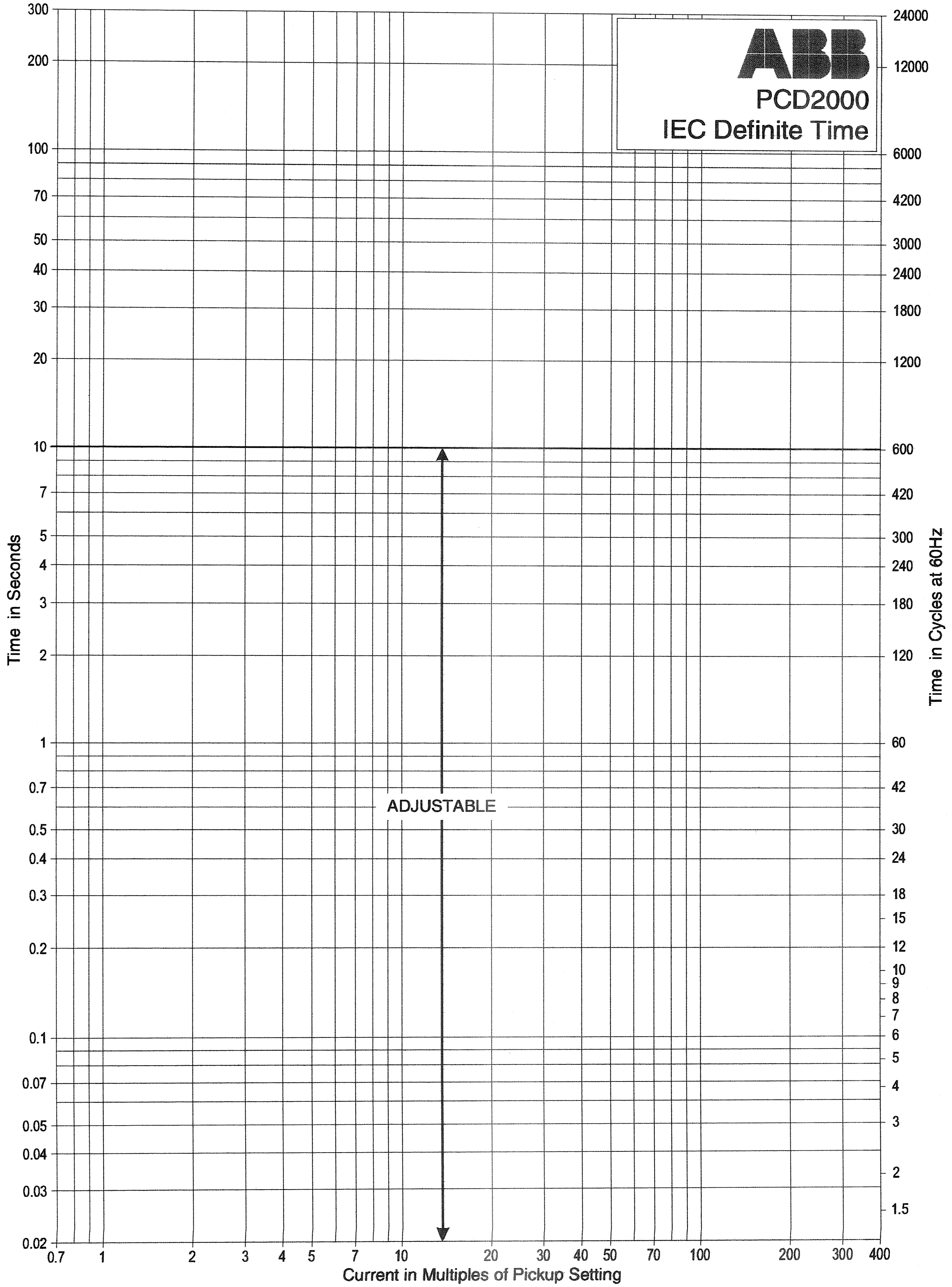

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Figure 5-26. Recloser Curve A (101)

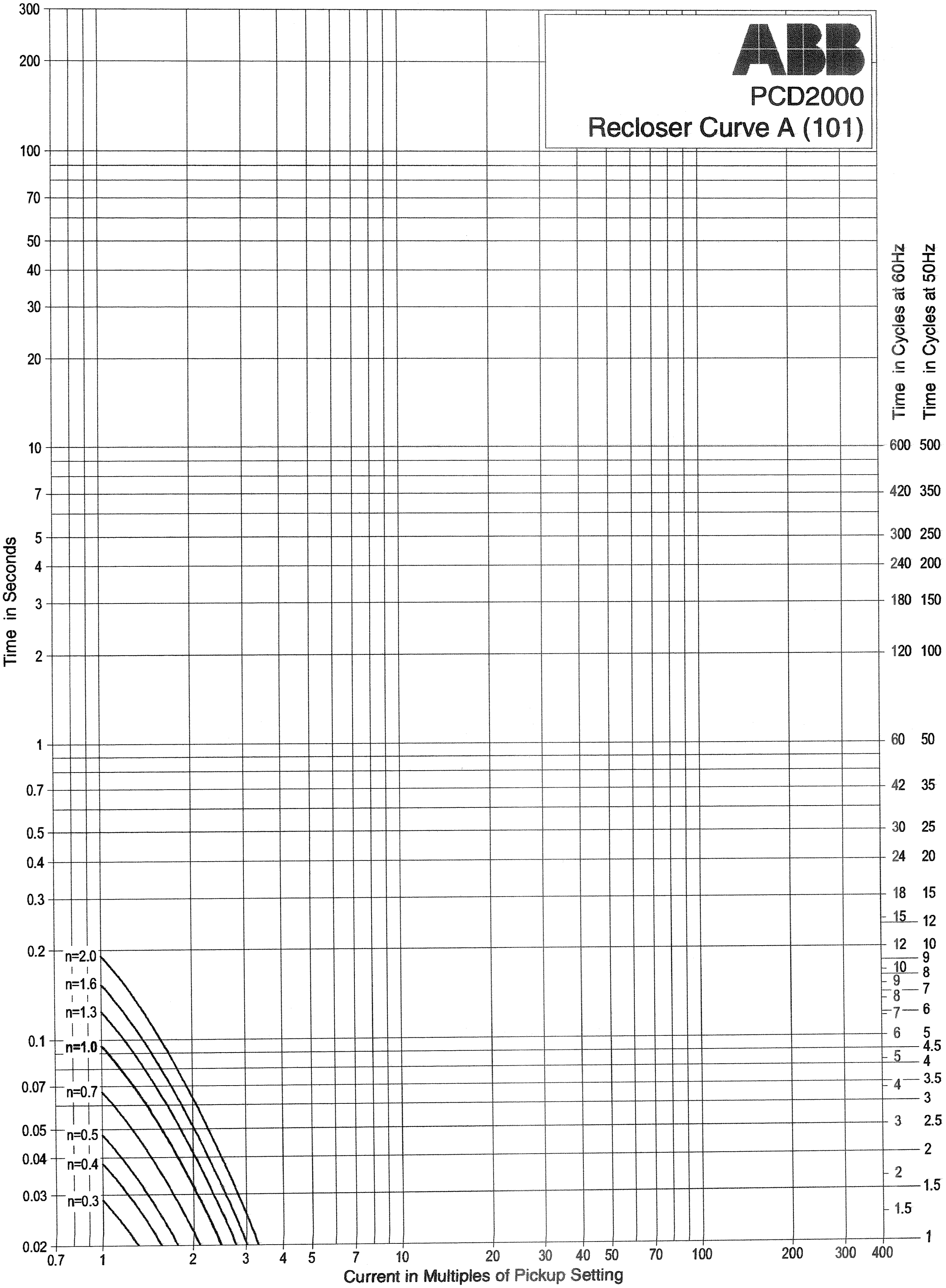


Figure 5-27. Recloser Curve B (117)

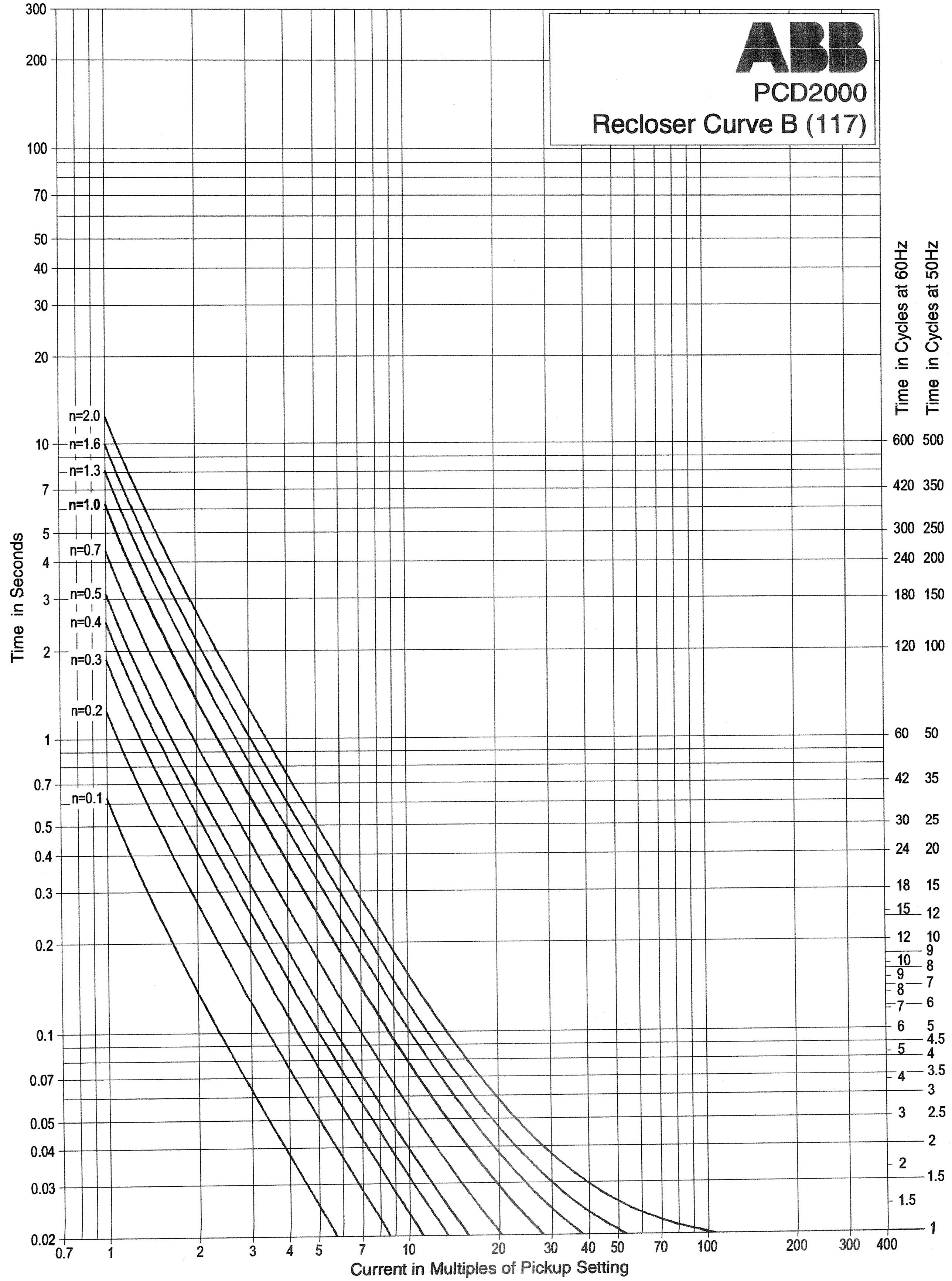


Figure 5-28. Recloser Curve C (133)

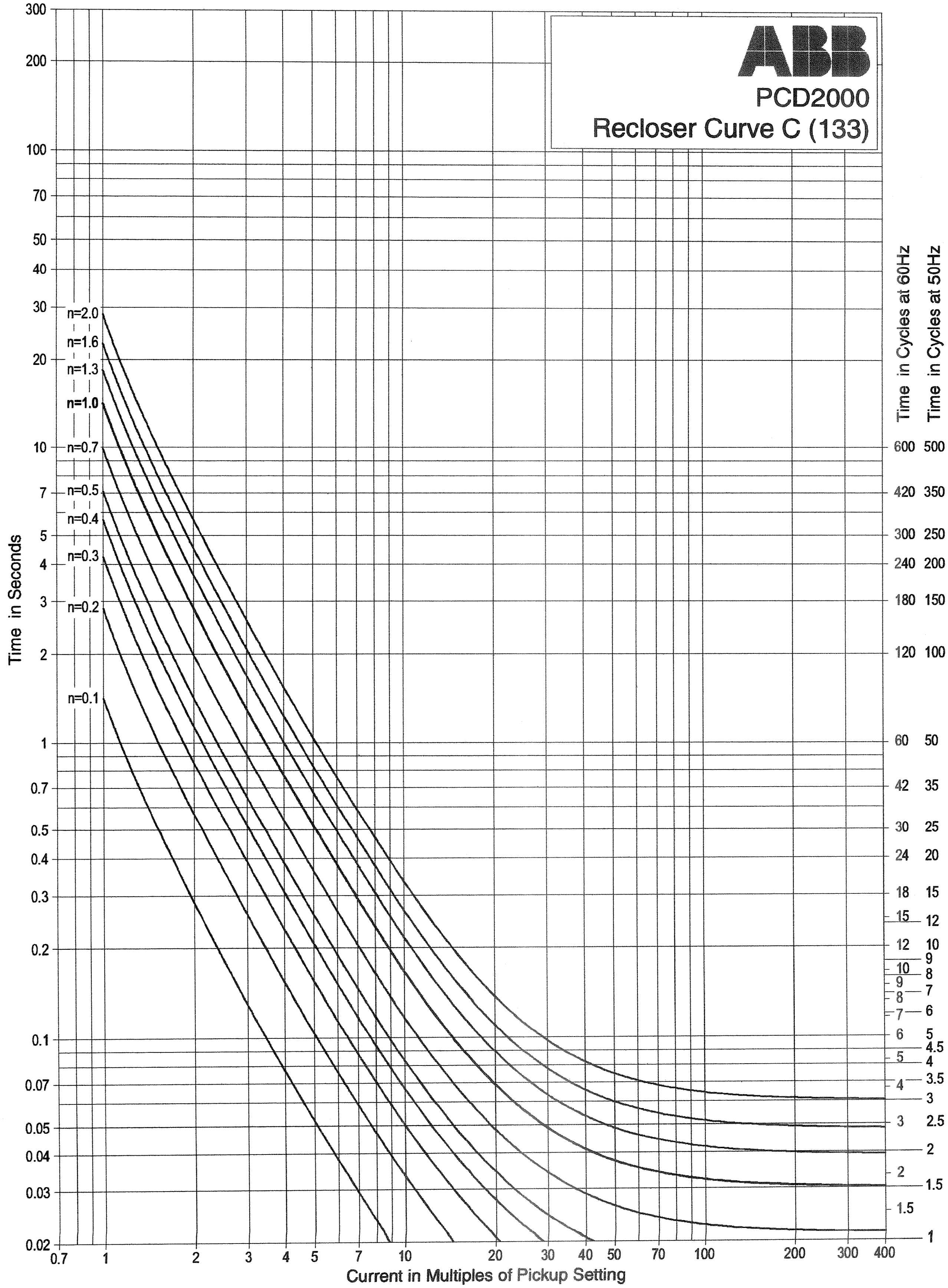


Figure 5-29. Recloser Curve D (116)

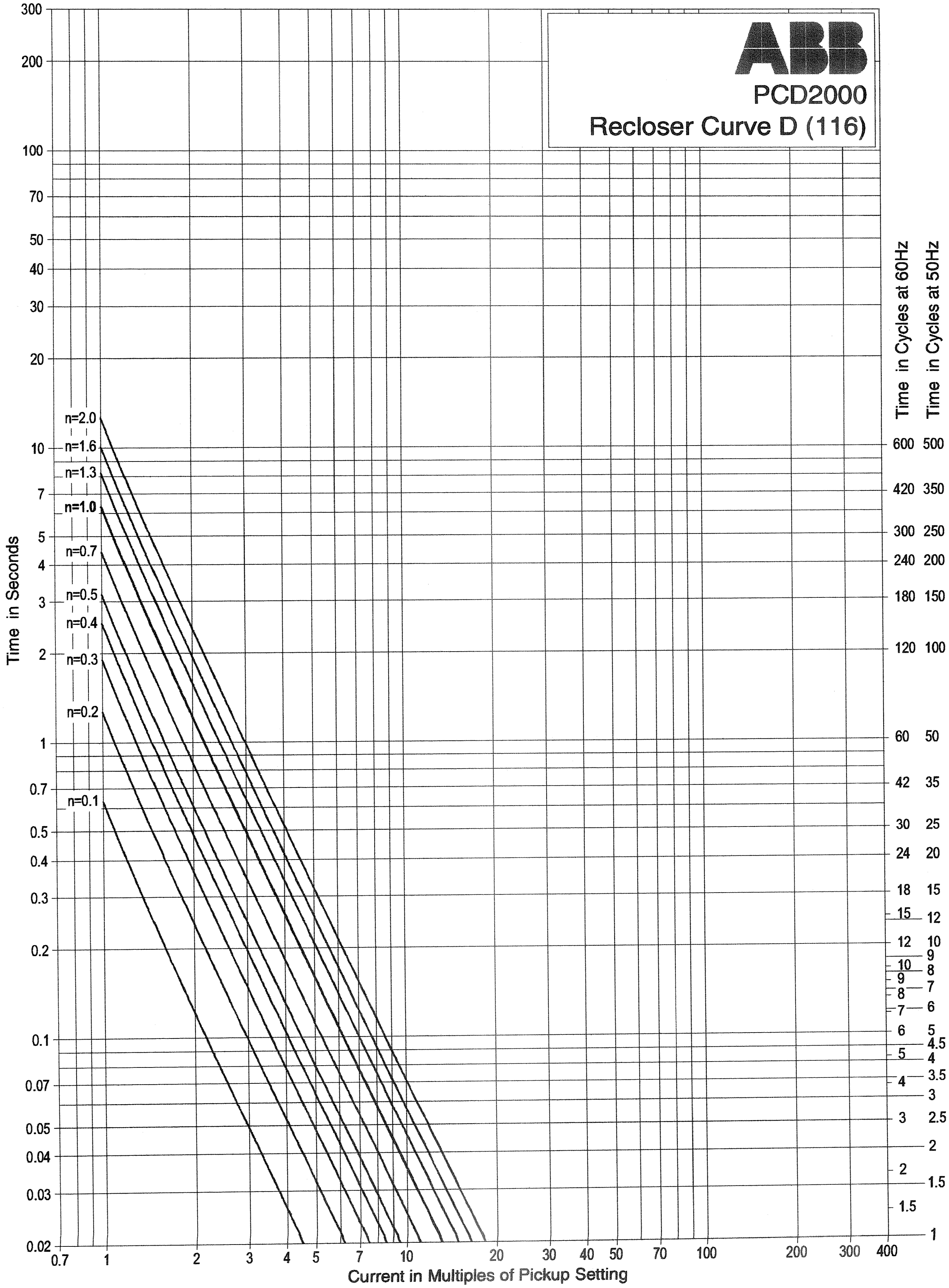


Figure 5-30. Recloser Curve E (132)

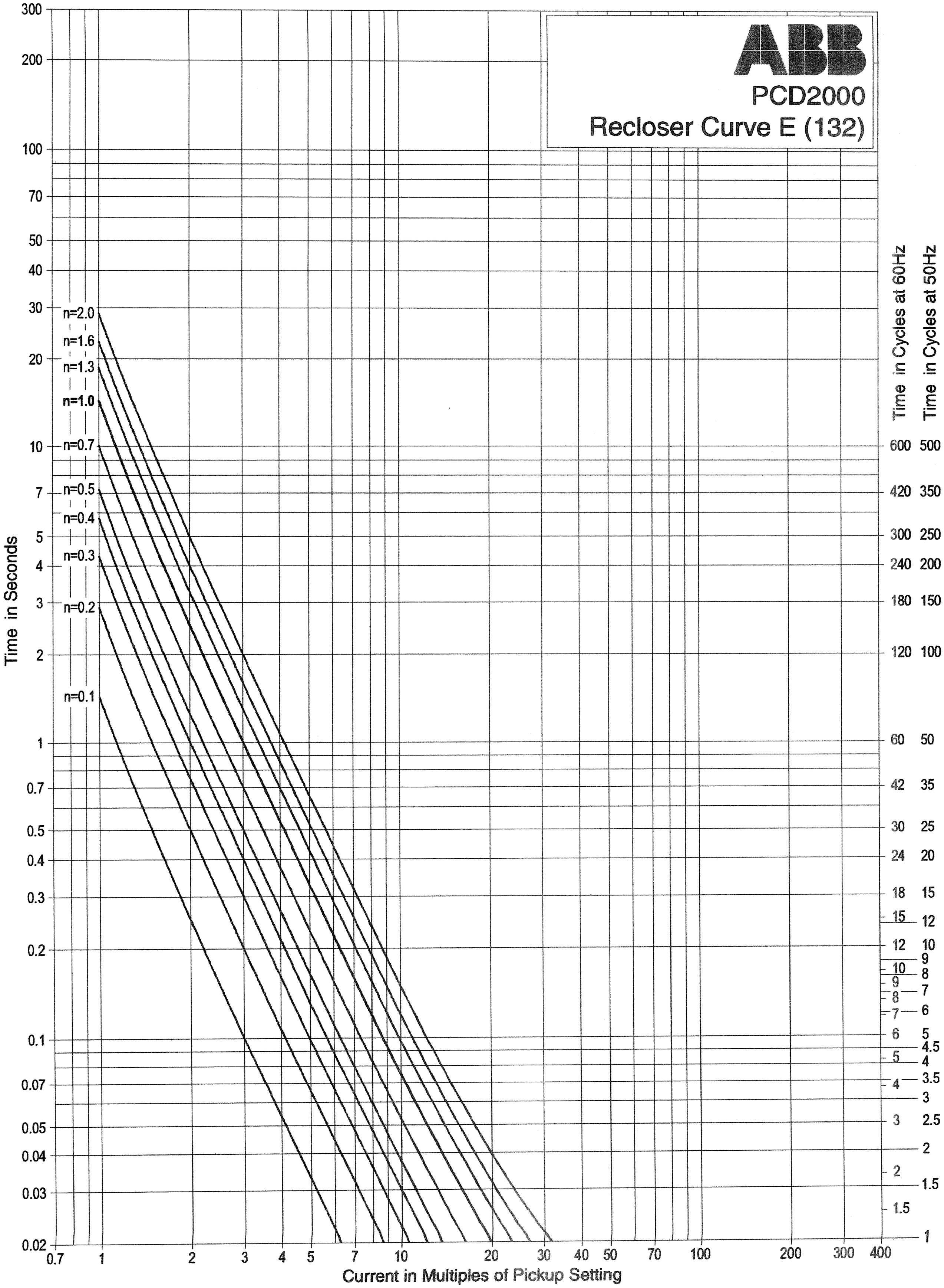


Figure 5-31. Recloser Curve K (162)

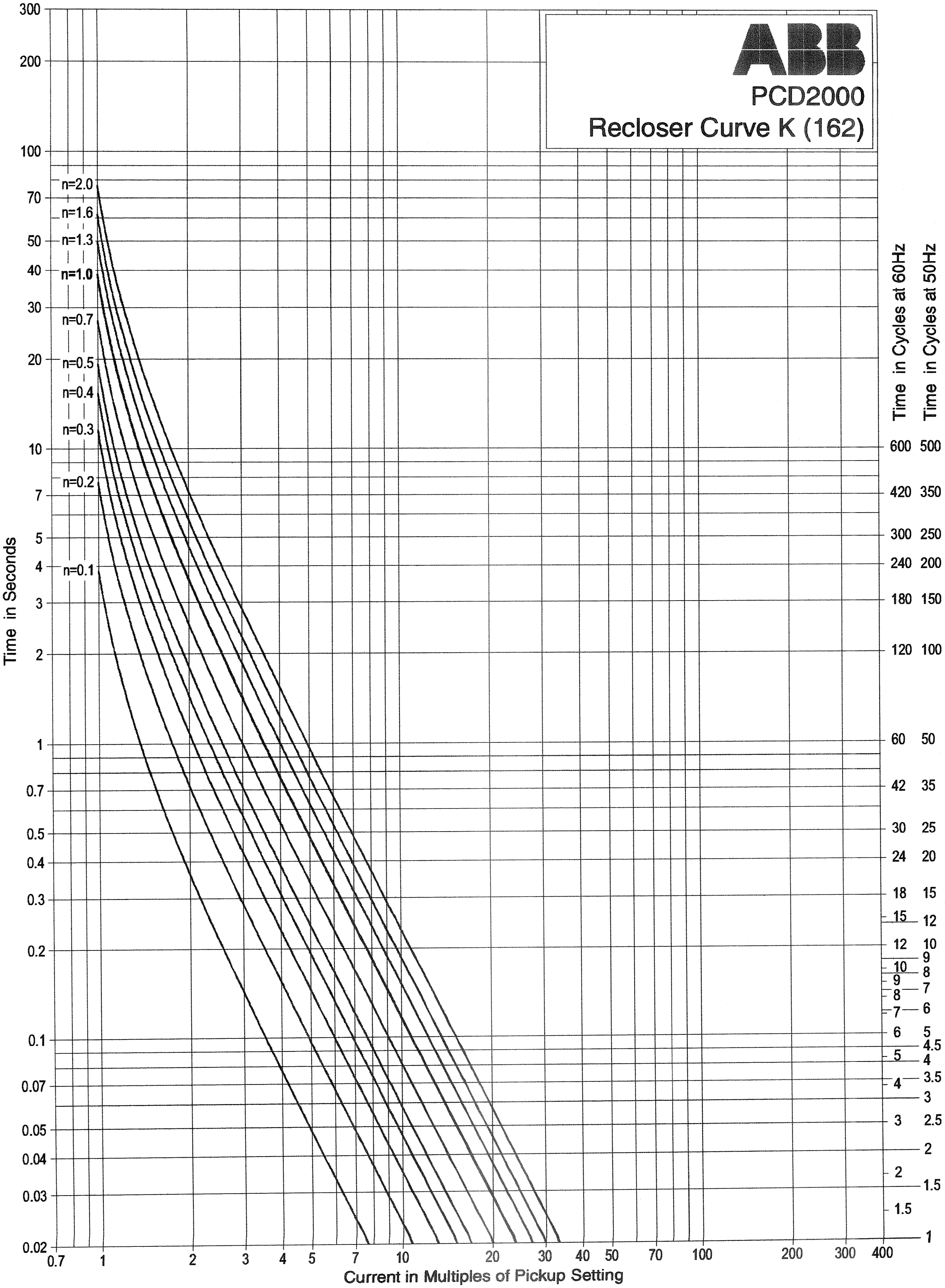


Figure 5-32. Recloser Curve N (104)

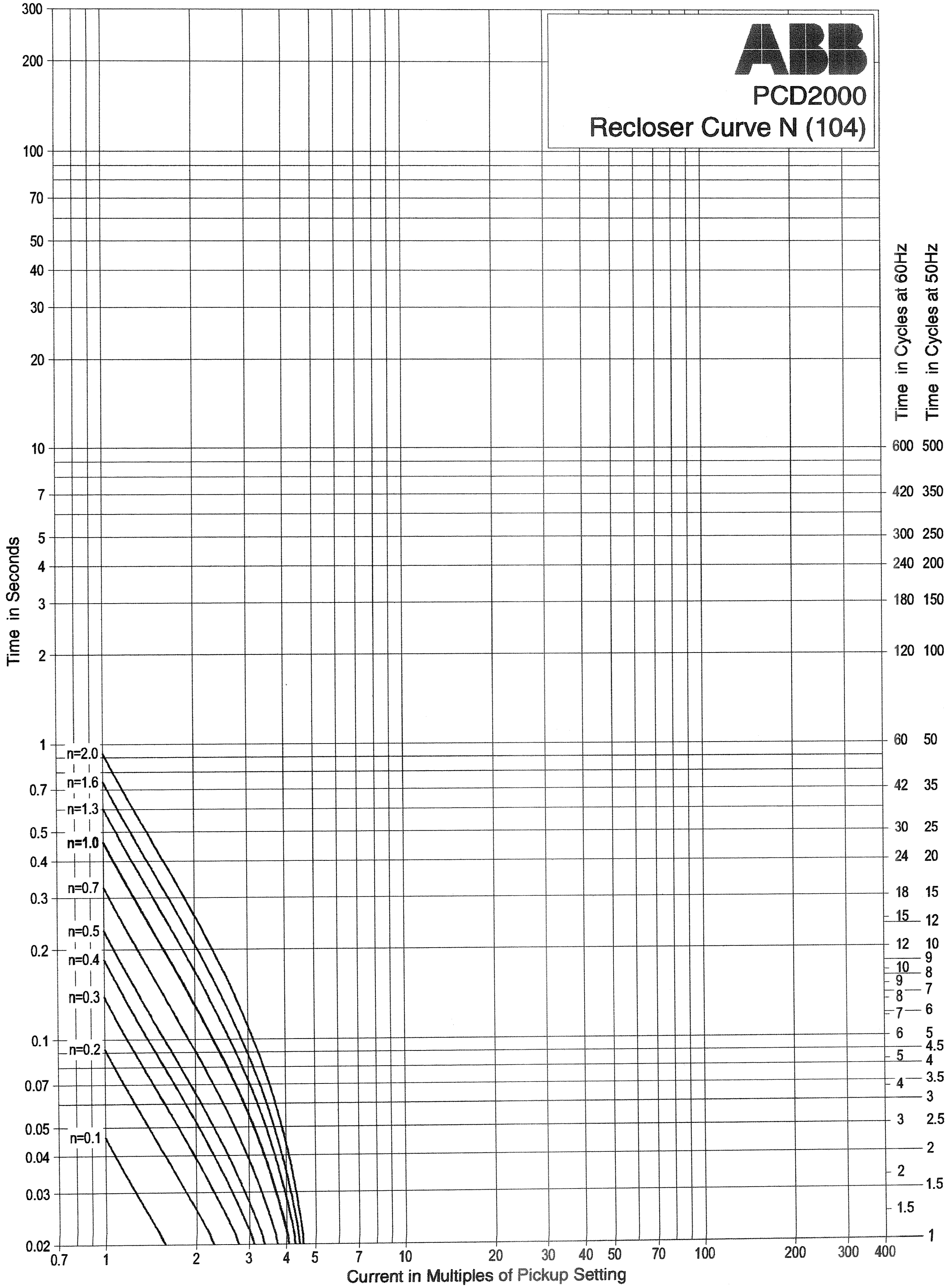


Figure 5-33. Recloser Curve R (105)

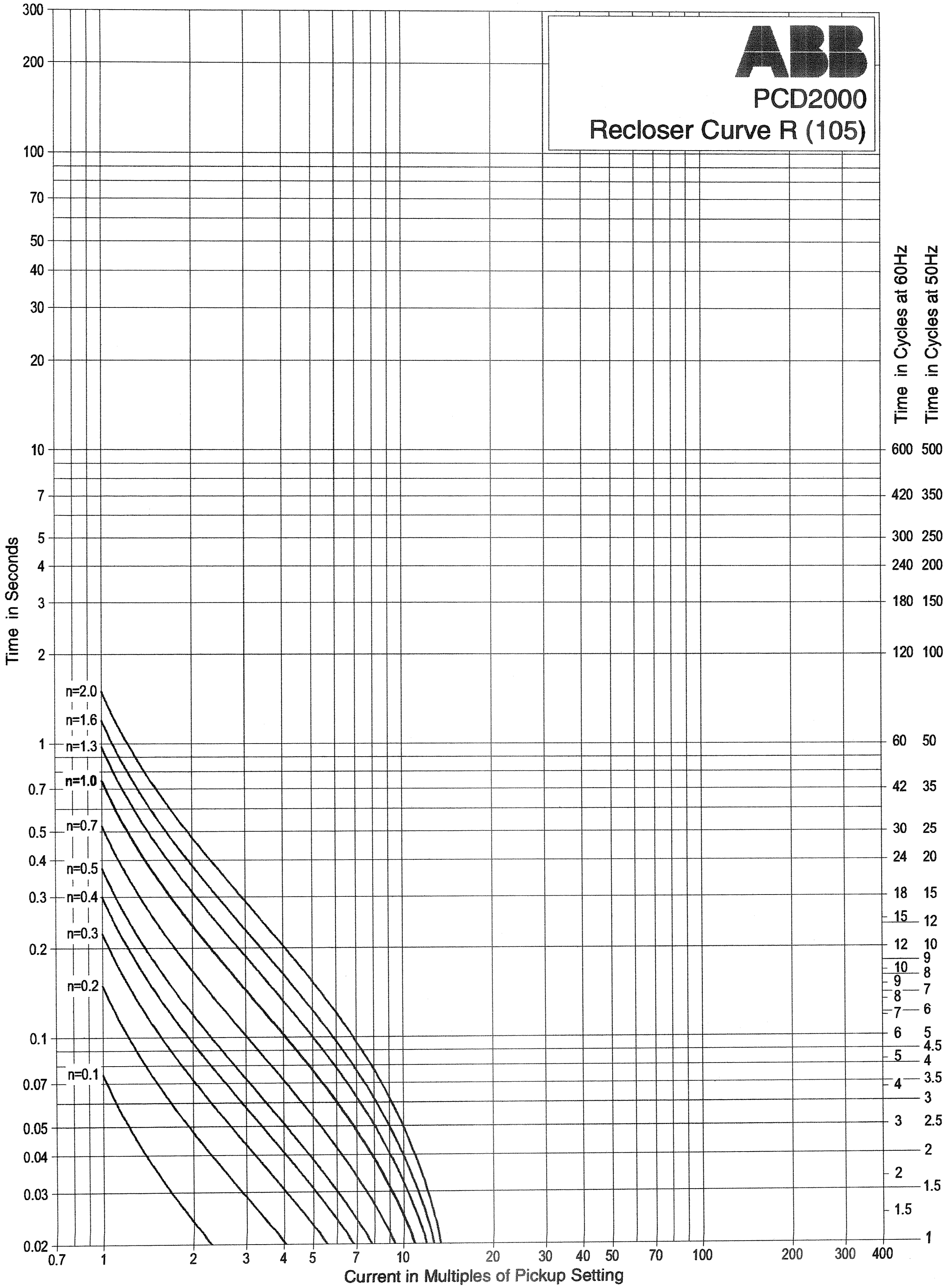


Figure 5-34. Recloser Curve W (138)

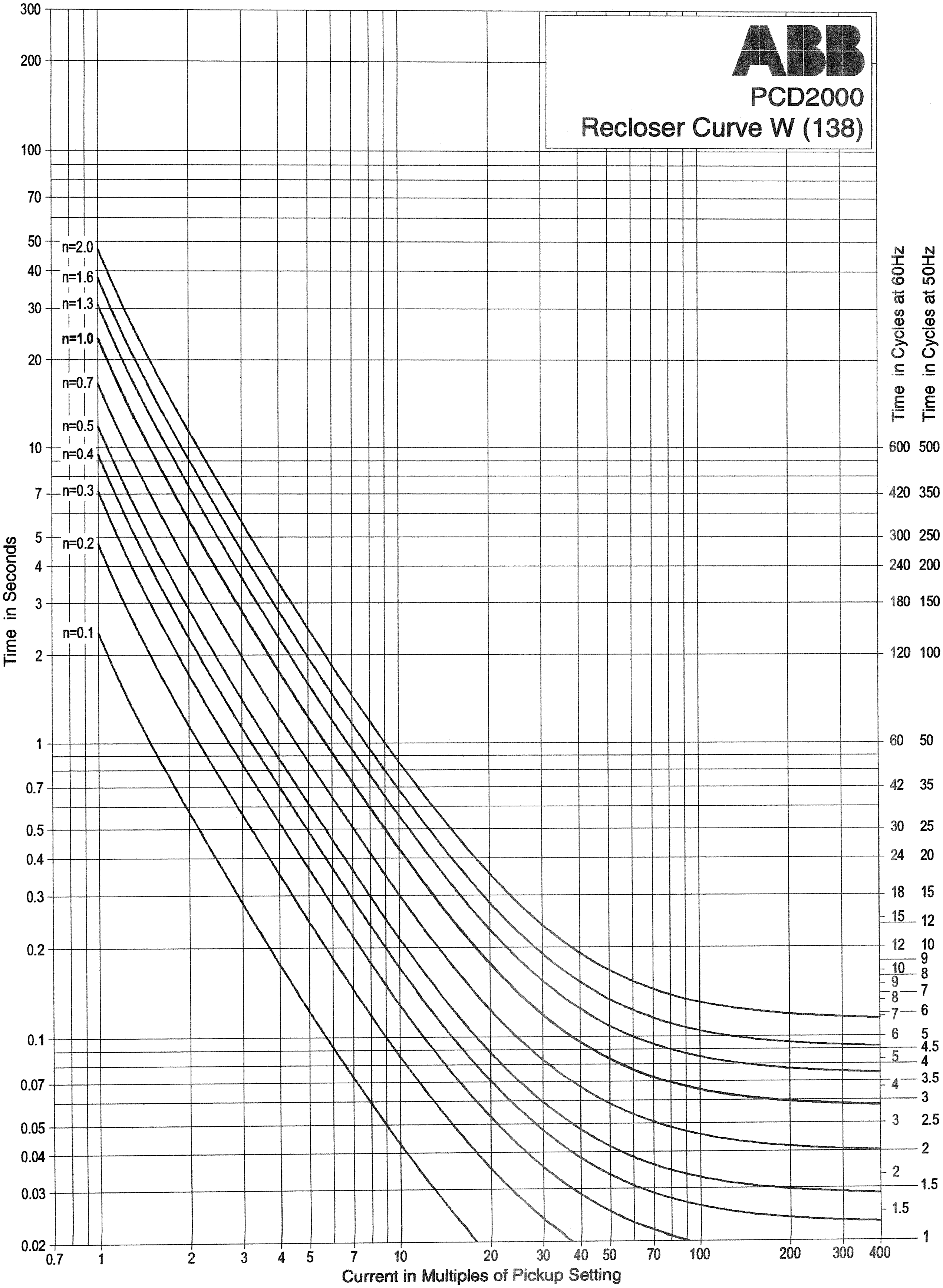


Figure 5-35. Recloser Curve 2 (135)

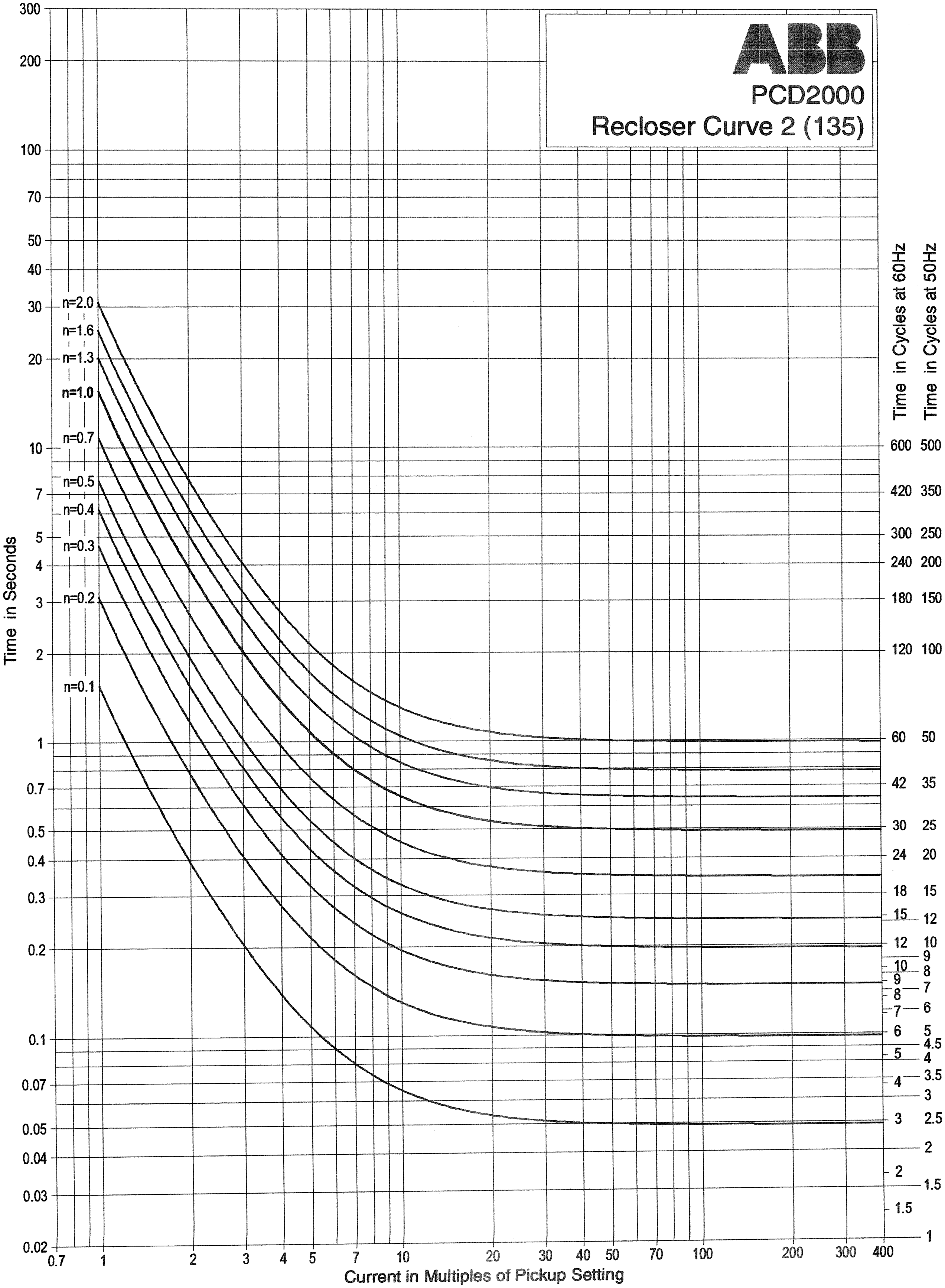


Figure 5-36. Recloser Curve 3 (140)

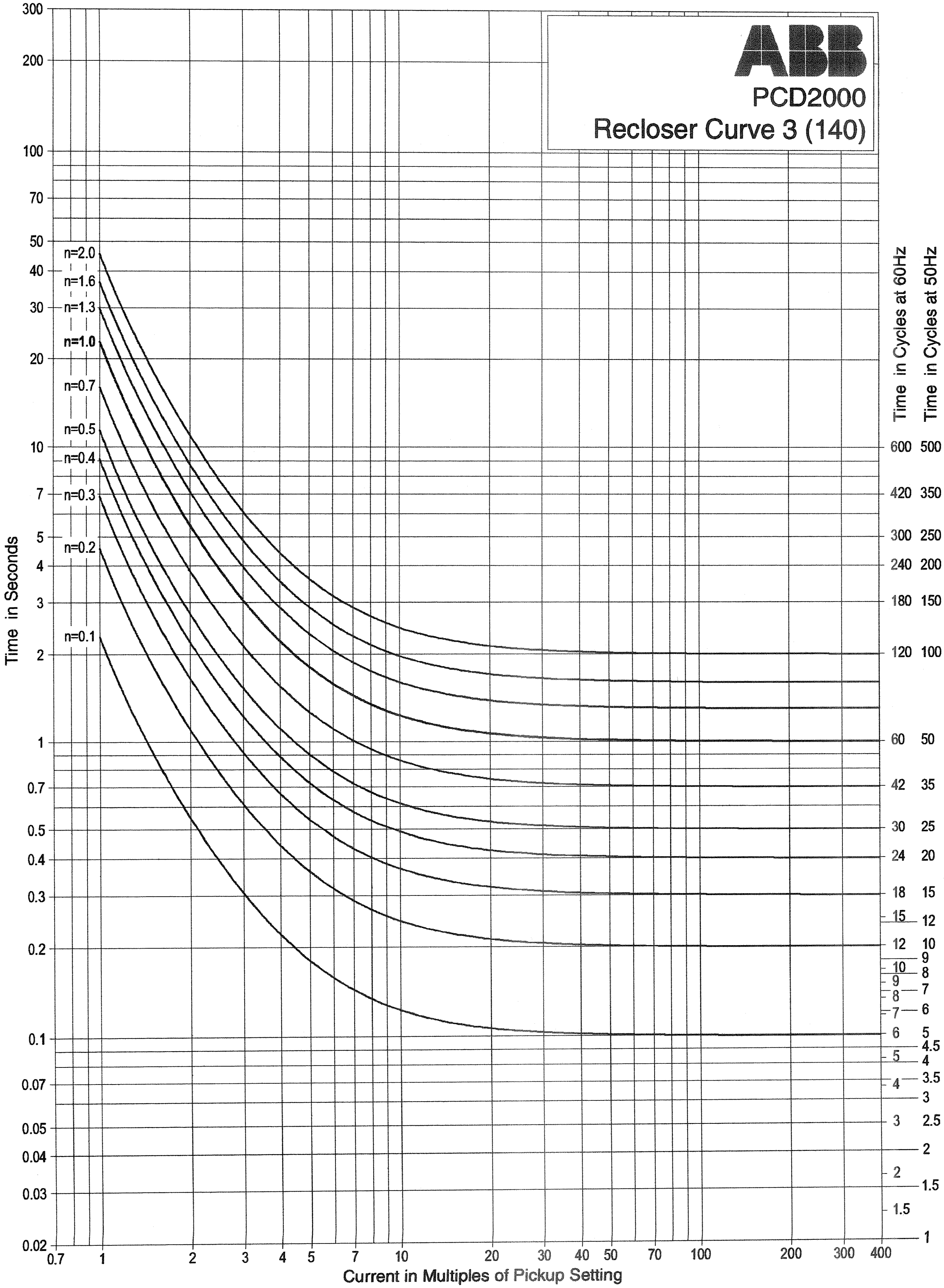


Figure 5-37. Recloser Curve 8 (113)

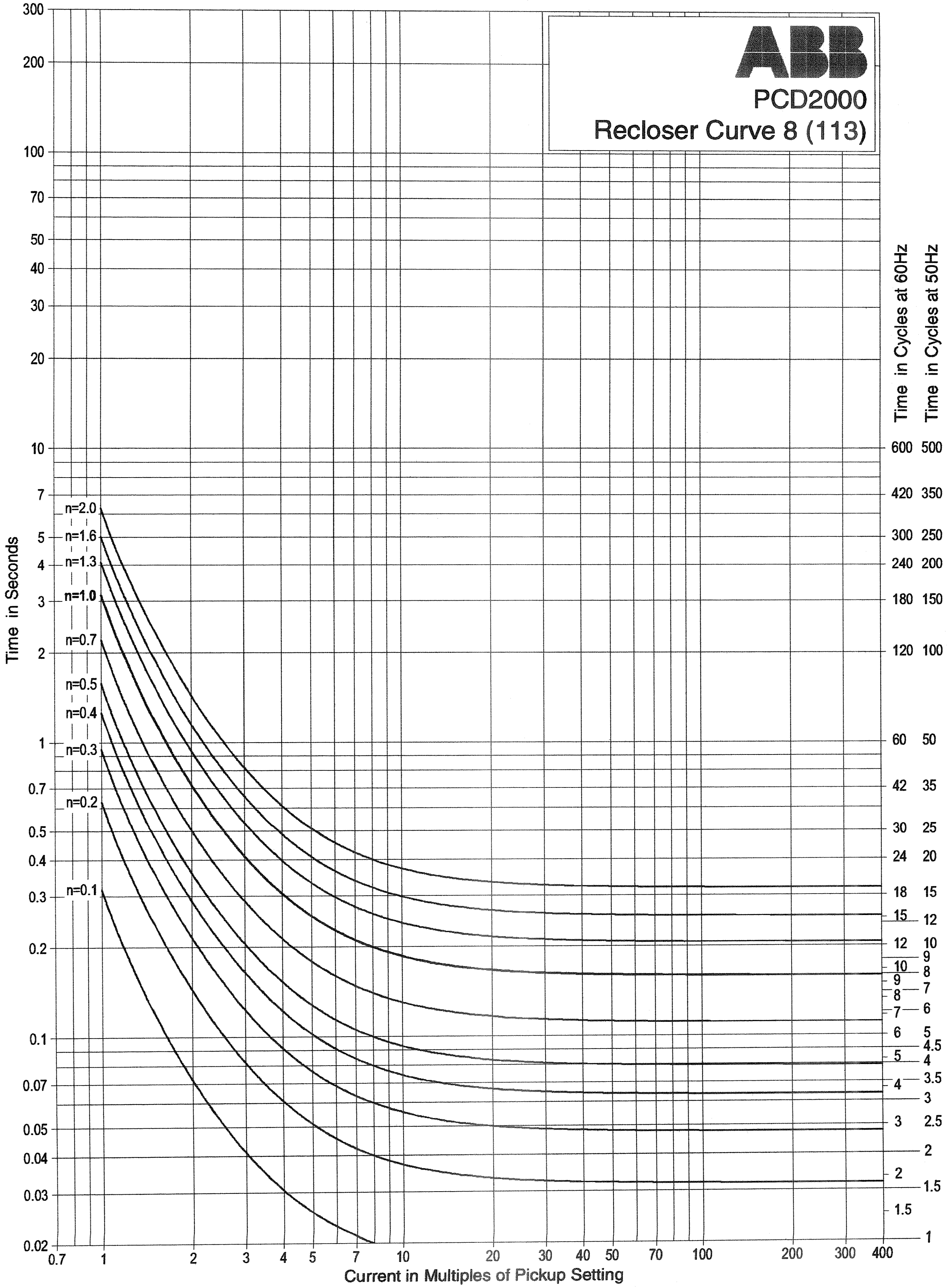


Figure 5-38. Recloser Curve 8*

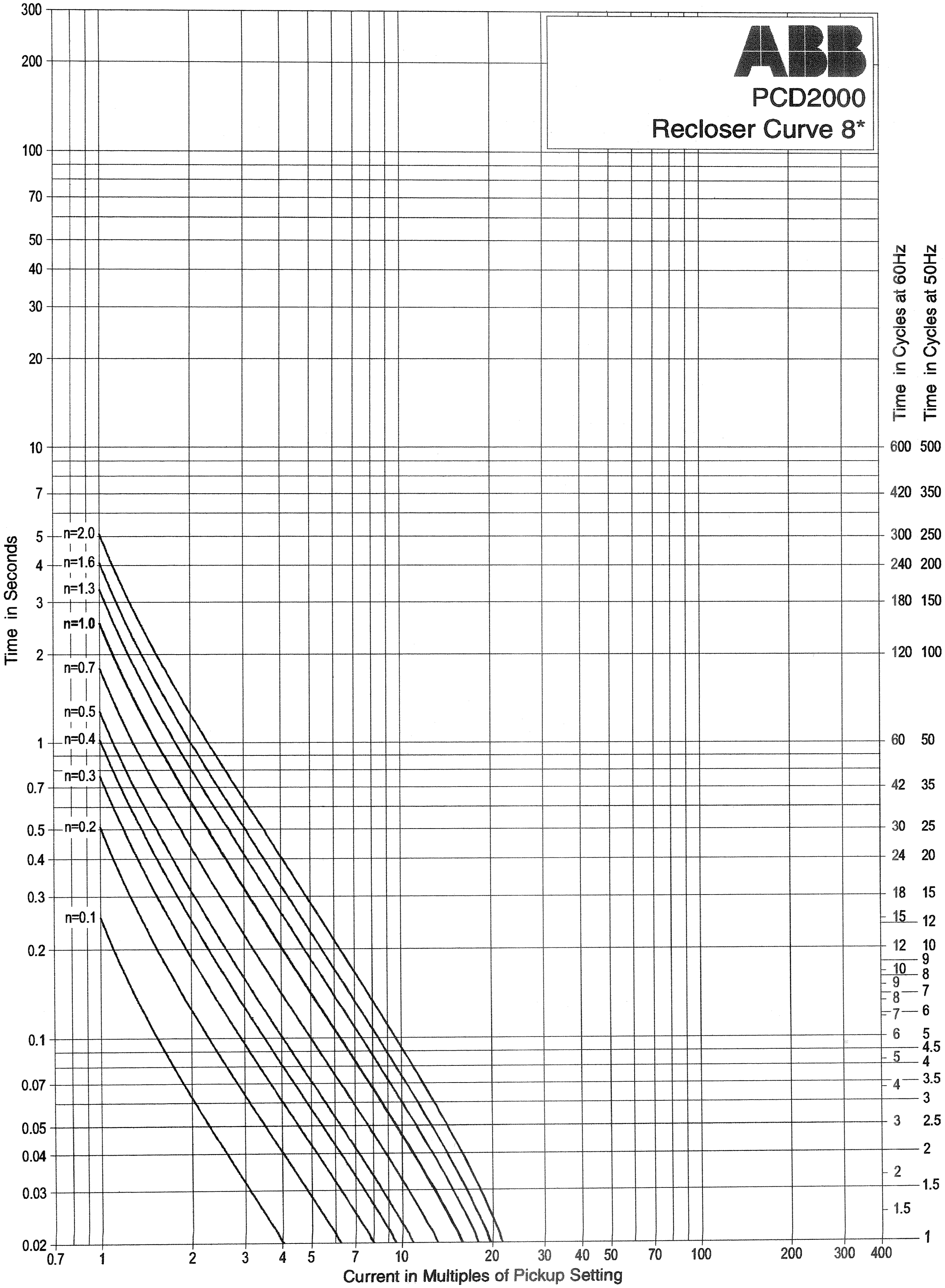


Figure 5-39. Recloser Curve 8+ (111)

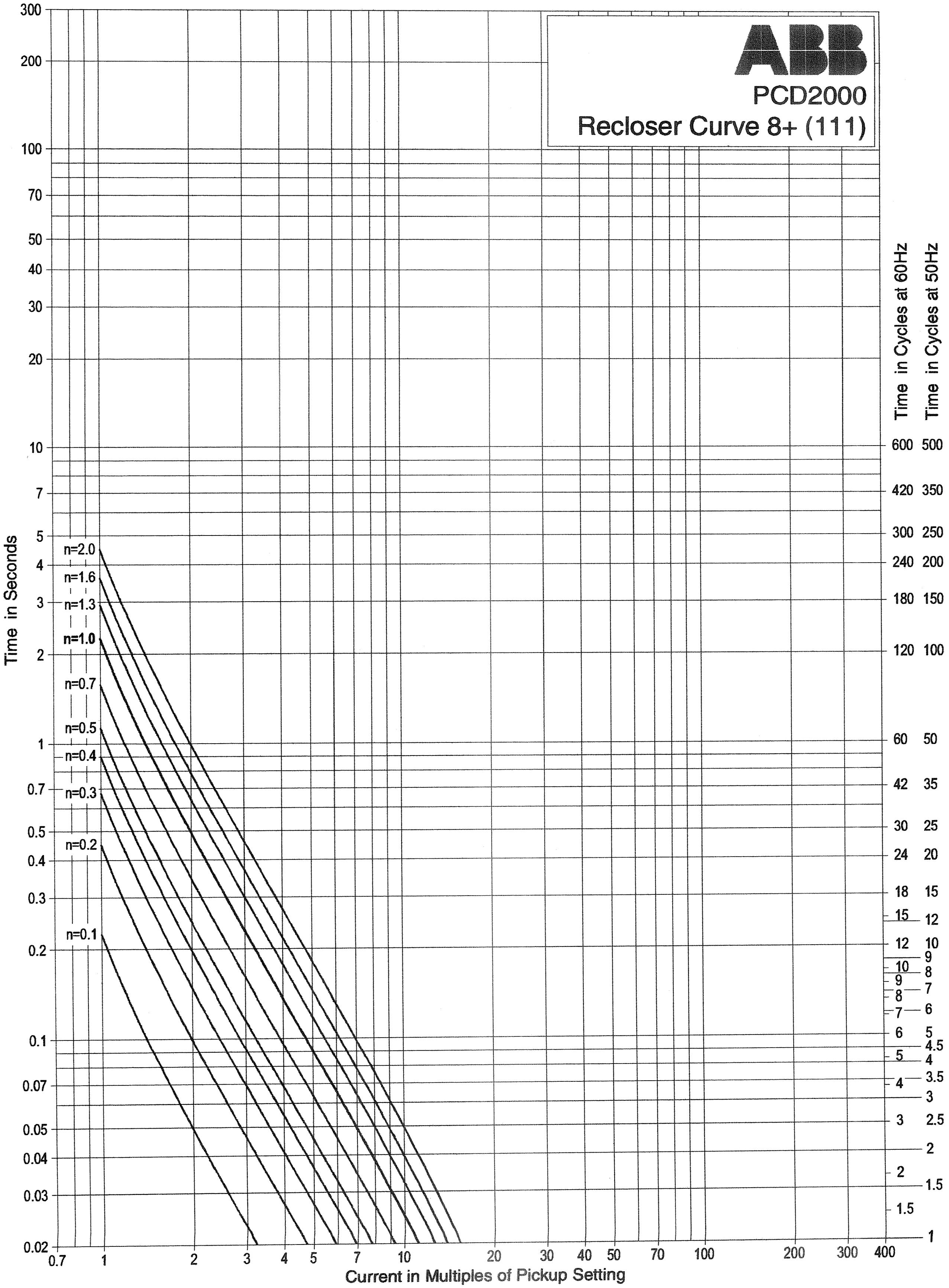


Figure 5-40. Recloser Curve 9 (131)

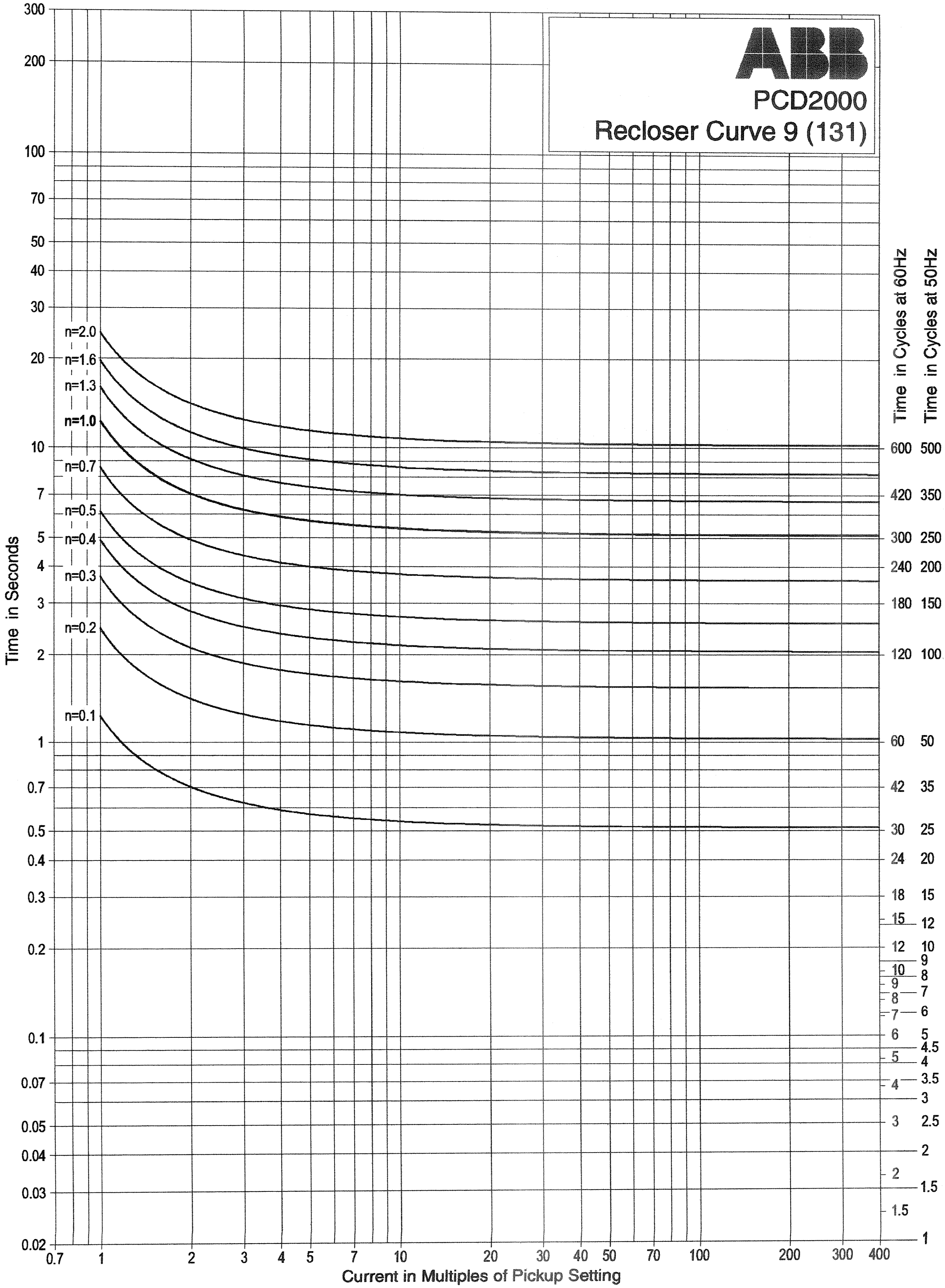
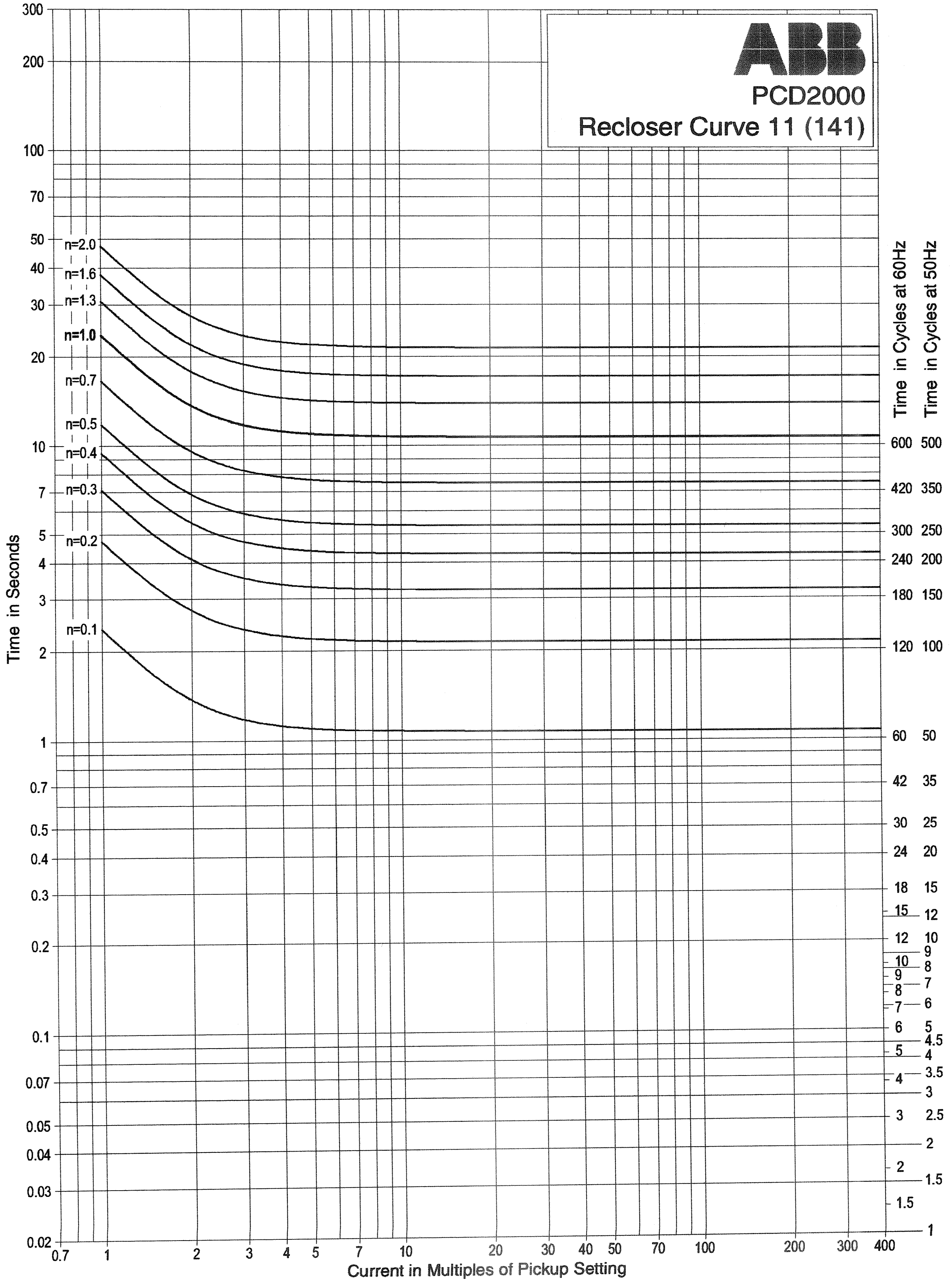


Figure 5-41. Recloser Curve 11 (141)



5.25 User-Defined Time Overcurrent Curves

An external PC-based program, CurveGen, can be used to create custom time-overcurrent curves for the PCD2000. With CurveGen you can program time-overcurrent curves other than the ones provided in the PCD2000.

The standard curve entered into the PCD2000 has the following form:

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

where M is the current in multiples of the pickup value; A, B, C, and P are coefficients to be defined by the user; and n is the time dial setting for a particular protection element that is using the curve..

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

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

For the second method, you use the CurveGen program to enter the series of time versus current points from an already defined curve. CurveGen then fits the four coefficients to these points. There are two ways to enter these points into the CurveGen program:

1. Enter all sampled points by hand.
2. 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, CurveGen fits a curve using the standard equation. 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 coefficients 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 PCD2000. 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 PCD2000. When you want to use a user defined curve, select "Transmit Programmable Curve Data" from the Programmable Curves Menu in WinPCD.

5.25.1 Using CurveGen

Click on the CurveGen 1.0 icon to run the CurveGen application.

From the Curve Data Worksheet the user has two options for entering the curve coefficients:

1. Manually enter the coefficients
2. Enter time/current points on the curve and let CurveGen calculate the coefficients

5.25.1.1 Manually Entering Coefficients

1. If desired, the user may enter a description in the Description field.
2. Under Standard, select ANSI or IEC.
3. Under Data Entry Method select Manually Enter Coefficients.
4. The user can now enter the known coefficients A, B, C and p.
5. Under Curve Series, select Default. Time Dial 1 through 10 will appear on the screen for ANSI or 0.05 to 1 for IEC. Any combination of valid time dials can be used.
6. Select Apply. CurveGen will display the graph. Under the Graph menu at the top of the screen the graph format can be changed and the graph can be printed for a clearer view.
7. If you are satisfied with the results, select Save As under File and type in a filename with a .crv extension. This file will be used for transmitting to the PCD2000.
8. The user also has the ability to save the worksheet. Select Save Worksheet As under File and type in a filename with a .wrk extension.

5.25.1.2 Compute Coefficients

1. If desired, the user may enter a description in the Description field.
2. Under Standard, select ANSI or IEC.
3. Under Data Entry Method select Compute Coefficients.
4. Choose the Compute Coefficients tab.
5. Using the mouse, place the cursor in Row 1, Column 1 (Current M).
6. Type in the multiple of tap current, M, and press the TAB key. Type in the corresponding time.
7. Press the TAB key again to enter a second point. Continue until a minimum of 5 data points are entered or 100 max. Please note that for ANSI or IEC type curves, the points you enter are equivalent to a time dial of 1.
8. After all points have been entered click on Solve. The computed coefficients will appear on the screen. To see these points on a graph, click on the [Apply] button.
9. Choose the Relay Data tab and notice 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 and 0.05 to 1 for IEC. Any combination of valid time dials can be used.
10. Select Apply. CurveGen will display the graph. Under the Graph menu at the top of the screen the graph format can be changed and the graph can be printed for a clearer view.
11. If you are satisfied with the results, select Save As under File and type in a filename with a .crv extension. This file will be used for transmitting to the PCD2000.
12. The user also has the ability to save the worksheet. Select Save Worksheet As under File and type in a filename with a .wrk extension.

6 Programming Inputs and Outputs

Using WinPCD, you can individually program the input contacts and output contacts to perform a variety of protection and control elements with the PCD2000.

6.1 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 marked (-). Double-ended inputs have two terminal connections, marked "+" and "–". The recognition time for the change in state of input is two (2) cycles.

Programmable contact inputs with factory default settings include the following:

- 52A Breaker Position: Breaker Closed (input closed)/Breaker Open (input open)
- 52B Breaker Position: Breaker Open (input closed)/Breaker Closed (input open)
- 43A Reclose Element: Enabled (input closed)/Disabled (input opened)

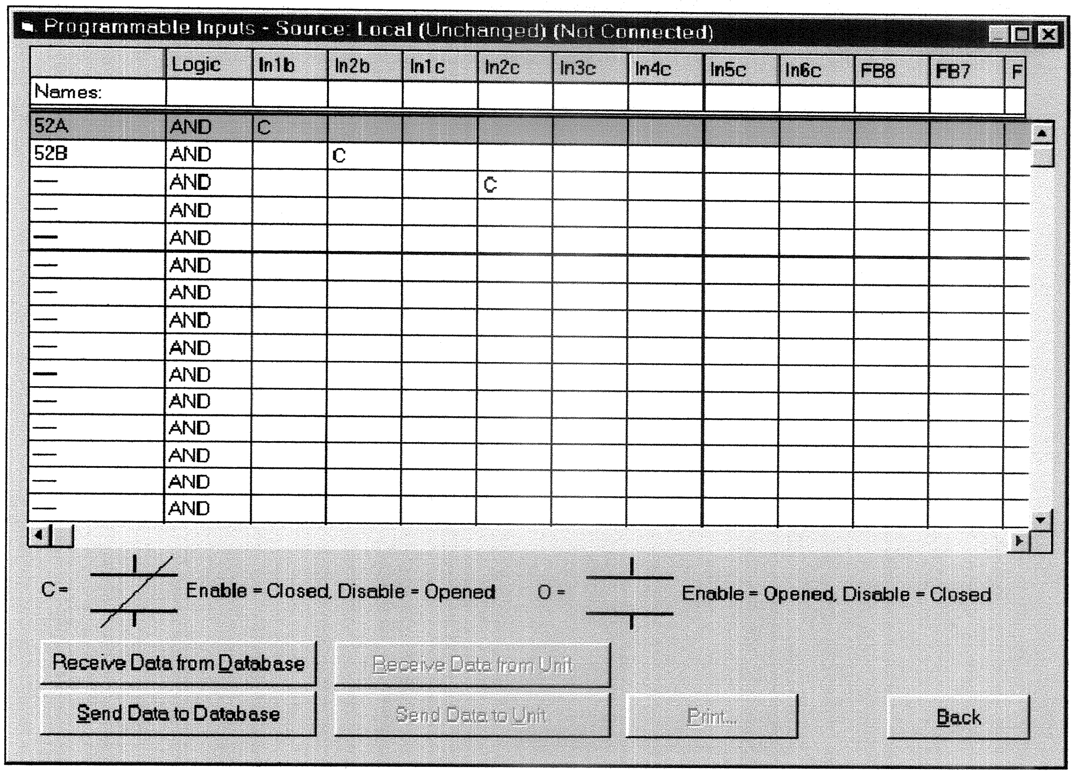
Up to 16 user-programmable contact inputs are available. The inputs are programmed via the WinPCD Program. Some logical inputs default to "HIGH" (activated) if they have not been mapped to a physical input, specifically: GRD, PH3, 46, 50-1, 50-2, 50-3, 67P, 67N, TCM, ZSC and SEF*.

The remaining logic inputs must be assigned to physical inputs for those functions to become operational (Enabled). The user-programmable inputs monitor, initiate, or actuate the logic functions shown in Table 6-1. The programmable inputs in the table are arranged in alphabetical order.

Use WinPCD and follow these steps to program the binary (contact) inputs:

1. From the WinPCD Main Menu, select "Change Settings."
2. From the Change Settings menu, select "Programmable Inputs."
3. The Programmable Input Map screen will appear (see Figure 6-1).
4. To change the listing of logical inputs:
   a. Use the arrow keys to highlight the logical input (leftmost column).
   b. Press the spacebar to display a list of possible logical inputs.
   c. Scroll through the list until the logical input you want is highlighted.
   d. Presses ENTER to change the contact or press ESC to close the list window without changing the current logical input.
5. To change the logic of a logical input:
   a. Use the arrow keys to highlight the logic value of a logical input.
   b. Press the spacebar to display a window with logic AND and OR.
   c. Highlight AND or OR.
   d. Presses ENTER to change the logic or press ESC to close the logic window without any changes.

Figure 6-1. Programmable Inputs Screen



6. To change the conditions of a logical input:
   a. Use the arrow keys to highlight the area across from the contact name and underneath the physical input you want.
   b. Press the spacebar to display a window with a blank, a "C," and an "O" (de-assigned, closed and open).
   c. Highlight the condition you want.
   d. Presses ENTER to change the condition 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 spacebar.
   c. A window appears prompting you to enter the new name. Type in the new name (up to 8 characters).
   d. Presses 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.

The label "C" is used when a dry contact is closed or a wet contact has voltage present enabling the desired function. The label "O" is used when a dry contact is opened or a wet contact has voltage removed enabling the desired function. Place the appropriate label "C" or "O" in the column under the desired contact input line. For example, based on the factory default settings of the PCD2000, control power must be applied to Input 1 (IN1) to Enable input logic contact 52A.

Table 6-1. Logical Input Functions

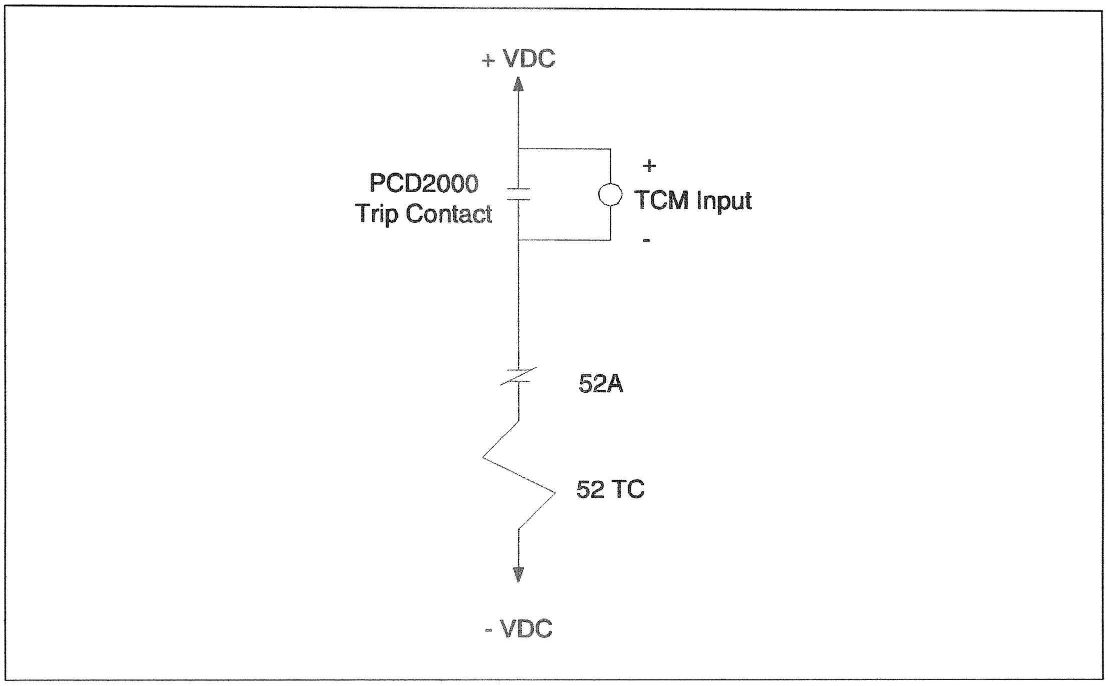
Logical Input	Description
----	Entry Not Used
43A	Reclose Function-Enabled/Disabled Supervises the PCD2000 reclosing function. When the 43A input is HIGH, the PCD2000 recloser is Enabled. When 43A is LOW, the recloser is Disabled. If the recloser is Disabled, a red "Recloser Out" target will illuminate on the front of the PCD2000. 43A defaults to HIGH (Enabled) when not programmed to a physical input or feedback term
46	Enables 46 Function Enables the 46 Negative Sequence time overcurrent element. Use to supervise (torque control) the negative sequence time overcurrent element. When the 46 input is HIGH, negative sequence time overcurrent protection is Enabled. 46 defaults to HIGH (Enabled) if not assigned to a physical input or feedback term.
50-1	Instantaneous 50P-1 & 50N-1 Enables the 50P-1 and 50N-1 elements. Use to supervise (torque control) phase and ground instantaneous overcurrent protection level 1. When the 50-1 input is HIGH, phase and ground instantaneous overcurrent protection level 1 is Enabled. 50-1 defaults to HIGH (Enabled) if not assigned to a physical input or feedback term.
50-2	Instantaneous 50P-2 & 50N-2 Enables 50P-2 & 50N-2. Use to supervise (torque control) phase and ground instantaneous overcurrent protection level 2. When the 50-2 input is a logical 1, phase and ground instantaneous overcurrent protection level 2 is Enabled. 50-2 defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.
50-3	Instantaneous 50P-3 & 50N-3 Enables 50P-3 & 50N-3. Use to supervise (torque control) phase and ground instantaneous overcurrent protection level 3. When the 50-3 input is a logical 1, phase and ground instantaneous overcurrent protection level 3 is Enabled. 50-3 defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.
52A	Breaker Position-Closed/Opened Assign this input to the physical input that is connected to the recloser 52A auxiliary contact. The PCD2000 requires this input along with the 52B logical input to determine recloser states for initiation of recloser close, trip failure, and close failure logical outputs. When 52A are a logical 1 and 52B is a logical 0, the PCD2000 logic assumes a closed recloser. When 52A are a logical 0 and 52B is a logical 1; the PCD2000 logic assumes an open recloser. If the 52A and 52B are at equal logic states, the PCD2000 will determine a "CB Status Unknown" state as displayed on the front panel HMI LCD display. 52A defaults to a logical 0 when not assigned to a physical input.
52aA 52aB 52aC	Phase A 52a Phase B 52a Phase C 52a Assign this input to the physical input that is connected to the recloser 52a auxiliary contact for the corresponding pole. (Exists only on units ordered with the single-phase tripping option.)
52B	Breaker Position-Opened/Closed Assign this input to the physical input that is connected to the recloser 52B auxiliary contact. The PCD2000 requires this input along with the 52A logical input to determine recloser states for initiation of recloser close, trip failure, and close failure logical outputs. See 52A for valid recloser operating states. 52B defaults to a logical 0 when not assigned to a physical input.

Logical Input	Description
52bA 52bB 52bC	Phase A 52b Phase B 52b Phase C 52b Assign this input to the physical input that is connected to the recloser 52b auxiliary contact for the corresponding pole. (Exists only on units ordered with the single-phase tripping option.)
67N	Enables 67N Function Enables the 67N Negative Sequence Directionally Controlled ground time overcurrent function. Use to supervise (torque control) the 67N time overcurrent element. When the 67N input is a logical 1, the 67N time overcurrent protection is Enabled. 67N defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.
67P	Enables 67P Function Enables the 67P Positive Sequence Directionally Controlled phase time overcurrent function. Use to supervise (torque control) the 67P time overcurrent element. When the 67P input is a logical 1, the 67P time overcurrent protection is Enabled. 67P defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.
79M	Multi-Shot Reclosing Enables a multi shot of reclosing when the PCD2000 determines that an external device has opened the recloser. When 79M is a logical 1, multi shot reclosing is Enabled. 79M defaults to logical 0 (Disabled) when not assigned to a physical input or feedback term. See Section 1 under "Reclosing" for more details.
79S	Single Shot Reclosing Enables a single shot of reclosing when the PCD2000 determines that an external device has opened the recloser. When 79S is a logical 1, single shot reclosing is Enabled. 79S default is logical 0 (Disabled) when not assigned to a physical input or feedback term. See Section 1 under "Reclosing" for more details.
ALT1	Enables Alternate 1 Settings When ALT1 is a logical 1 the Alternate 1 settings are placed into service if Alternate 1 Setting is set to "Enable" in configuration settings. ALT1 defaults to a logical 0 (Alternate 1 settings not active) if not assigned to a physical input or feedback term.
ALT2	Enables Alternate 2 Settings When ALT2 is a logical 1 the Alternate 2 settings are placed into service if Alternate 2 Setting is set to "Enable" in configuration settings. ALT2 defaults to a logical 0 (Alternate 2 settings not active) if not assigned to a physical input or feedback term.
ARCI	Timed Reclose Block Automatic Reclose Inhibit. This logical input stops the recloser open timer for the time in which it is a logical 1. When ARCI is returned to a logical 0 the open timer will continue where it was stopped. ARCI does not affect the recloser-reset timer. ARCI defaults to logical 0 (Disabled) when not connected to a physical input or feedback term.
BFI	Breaker Fail Initiate Assign this input to a physical input or feedback term for initiation of the Breaker Failure Trip logic. See Section 1 under "Breaker Failure Logic". It is typically connected to an external protective device with a BFI output contact. BFI defaults to a logical 0 (no input) when not assigned to a physical input or feedback term.
CLOSE	Close Initiated Initiates Close Output. Assign this input to a physical input for remote closing of the recloser from a control switch. When CLOSE is a logical 1, the LOGICAL OUTPUT "CLOSE" is asserted. CLOSE defaults to a logical 0 (Disabled) when not assigned to a physical input or feedback term.
CLOSEA CLOSEB CLOSEC	Direct Close A Direct Close B Direct Close C Initiates Close Output for the corresponding pole.
CLSBLK	Close Block When HIGH, all CLOSE outputs will be blocked.

Logical Input	Description
CRI	Resets Overcurrent Trip and All Reclose Counters Clear Reclose and Overcurrent Counters. Assign this input to a physical input or feedback term to remotely clear the Reclose and Overcurrent Counters. When CRI is a logical 1, the reclose and overcurrent counters are returned to 0. CRI defaults to a logical 0 (no clear) when not assigned to a physical input or feedback term.
ECI1	Event Capture Initiated Assign this input to a physical input to capture events from external devices. When ECI1 is a logical 1, an event called "ECI1" is logged in the operations record. ECI1 defaults to a logical 0 (no event) when not assigned to a physical input or feedback term.
ECI2	Event Capture Initiated As with ECI1, assign this input to a physical input to capture events from external devices. When ECI2 is a logical 1, an event called "ECI2" is logged in the operations record. ECI1 defaults to a logical 0 (no event) when not assigned to a physical input or feedback term.
ExtBFI	External Started Input This input is used to start the recloser failure tripping sequence. See Section 1 under "Breaker Failure Logic". It is typically assigned to the same physical input as the 52a contact. EXTBFI defaults to a logical 0 (no input) when not assigned to a physical input or feedback term.
GRD	Ground Torque Control Enables 51N/50N-1/50N-2. Use to supervise (torque control) all ground overcurrent protection except 50N-3. When the GRD input is a logical 1, all ground overcurrent protection except 50N-3 is enabled. GRD defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.
OPEN	Trip Initiated Initiates Trip Output. Assign this input to a physical input for remote opening of the recloser by a control switch. When OPEN is a logical 1, a trip is issued at the master trip output. OPEN defaults to a logical 0 (Disabled) when not assigned to a physical input or feedback term.
OPNBLK	Open Block Input to block all OPEN outputs.
PH3	Phase Torque Control Enables 51P/50P-1/50P-2. Use to supervise (torque control) all phase overcurrent protection except 50P-3. When the PH3 input is a logical 1, all phase overcurrent protection except 50P-3 is enabled. PH3 defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.
RBI	Remote Block Input Input to block all remote operational commands sent through a data port.
SCC	Spring Charging Contact Connect to a physical input to monitor a recloser spring. If the SCC input is a logical 1, a "Spring Charging" event is logged in the operations record. SCC defaults to a logical 0 (no spring charge event) when not assigned to a physical input or feedback term. SCC only functions when the PCD2000 determines a recloser open state.
SEF	Sensitive Earth Fault Enable Enables the sensitive earth fault function (available in Sensitive Earth Fault models only). Use to supervise (torque control) the SEF overcurrent element. When the SEF input is a logical 1, the SEF overcurrent protection is Enabled. SEF defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.
TAGMSG	Tag Message Input to cause the Tag Message to appear on the LCD display.

Logical Input	Description
TARC	Initiate Trip and Auto Reclose This input is used to issue a recloser trip and reclose. It is useful in the testing of the recloser trip and close circuits as well as the recloser logic and timing settings. When TARC is a logical 1, a trip and automatic reclose sequence is initiated. If the input is held at a logical 1, the PCD2000 will continue to trip and reclose through the recloser steps 79-1, 79-2, 79-3, etc., (See Recloser section for reclosing details). If TARC is pulsed at a logical 1, the trip and auto reclose will occur once unless TARC is pulsed again. TARC defaults to logical 0 (Disabled) when not assigned to a physical input or feedback term.
TCM	Trip Coil Monitoring Assign this to the physical input IN7 or IN8 to monitor continuity of the circuit breaker coil. See Figure 6-2 for typical trip coil monitoring connections. When input is a logical 1, TCM logic assumes breaker coil continuity. If a logical 0, recloser trip coil is failed and logical output TCFA (Trip Circuit Failure Alarm) is asserted. TCM is functional when the PCD2000 determines that the recloser is closed. TCM defaults to a logical 1 (recloser trip coil healthy) if not assigned to a physical input or feedback term.
TRIPA TRIPB TRIPC	Direct Trip A Direct Trip B Direct Trip C Input to cause the corresponding pole to trip. (Exists only in units ordered with the single-phase tripping option.)
ULI1 ULI2 ULI3 ULI4 ULI5 ULI6 ULI7 ULI8 ULI9	User Logical Input Asserts ULO1 User Logical Input Asserts ULO2 User Logical Input Asserts ULO3 User Logical Input Asserts ULO4 User Logical Input Asserts ULO5 User Logical Input Asserts ULO6 User Logical Input Asserts ULO7 User Logical Input Asserts ULO8 User Logical Input Asserts ULO9 Input is used to enhance the PCD2000 programmable logic capability. See "Advanced Programmable Logic" later in this section for details. ULIx defaults to a logical 0 (no input) when not assigned to a physical input or feedback term.
WCI	Waveform Capture Initiated Assign this input to either a physical input or feedback term for initiation of the oscillographic waveform capture. WCI can be used to capture waveform for other devices in the system that does not contain oscillographic capability. When WCI is a logical 1, the oscillographic waveform capture is initiated for the number of cycles programmed in the oscillographic settings. WCI defaults to a logical 0 (no event) when not assigned to a physical input or feedback term.
ZSC	Zone Sequence Coordination Enables Zone Sequence Coordination scheme. Allows external supervision of the Zone Sequence scheme. When the ZSC input is a logical 1, zone sequence is Enabled. ZSC defaults to a logical 1 (Enabled) if not assigned to a physical input or feedback term.

Figure 6-2. Trip Coil Monitoring



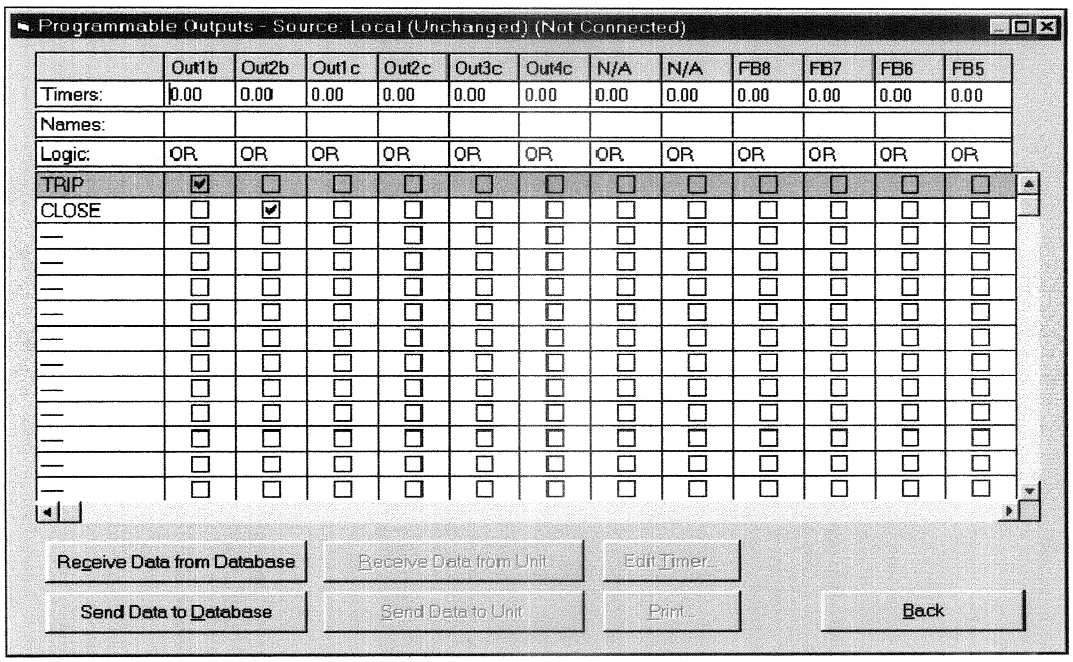
6.2 Programmable Outputs

All logical outputs except "ALARM" are a logical 0 when the PCD2000 is in a "no operation" state.

6.2.1 Programmable Output Contacts

Up to 15 user-programmable output contacts are available. Figure 6-3 shows the Change Programmable Outputs menu of the WinPCD program with no mappings. A check mark will appear where an output contact is mapped.

Figure 6-3. Programmable Outputs Default Screen



OUTPUT TIMERS: Additional time delay can be added to the function by means of the output timers. The time delay interval is adjustable from 0 to 60 seconds in 0.01 steps.

OUTPUT NAMES: Identifying names can be placed under each of the outputs in the screen shown in Figure 6-3.

6.2.2 Logical Output Types

The programmable logical outputs are sometimes referred to as alarms as listed below can have two different types of outputs for the same function. The first type is a **non-sealed-in** type. This type of logical output will be a logical 1 (logical output asserted) when the condition is present and a logical 0 (logical output de-asserted) when the condition ceases. It is sometimes referred to as a "real-time" output. The second type is a **sealed-in** type. This type of logical output will be a logical 1 (logical output asserted) when the condition is present and will remain a logical 1 when the condition ceases. It is reset by any of the following methods:

1. The front panel HMI "C" (clear) button is depressed once within a 5-second period. The user will eventually be prompted to reset seal-ins. See Section 5 for details.
2. The WinPCD program is used. Under "Main Menu," select "Miscellaneous Commands."

3. Depending on the communications protocol contained in the PCD2000, a command is issued to reset the individual seal-in outputs or all seal-in outputs.

An example of where seal-in bits are applied: The PCD2000 is connected directly onto a Modbus® communications network and a Programmable Logic Controller (PLC) are also on the network. The PLC obtains fault information from the PCD2000 over the Modbus® network for certain restoration scheme. Since this is a token passing type network, a fault may occur and extinguish before the token reaches the PCD2000. If the fault bit 51P for example, sensed by the PLC were a real time bit, the PLC would never see the change. The seal-in bit, 51P* can be used to alert the PLC to a fault even after the fault has extinguished. Once the PLC is finished with the logical output bit 51P*, it can reset the bit to a logical 0 via the communication network. This eliminates hard contact wiring between the relay and the PLC and assures that the PLC will always see a fault.

Some of the alarms listed below will have duplicate elements. For example, 50P-1 and 50P-1*. Notice that an asterisk (*) follows one of the elements. This is the indication of a logical output that is of the seal-in type as described above.

Table 6-2. Logical Output Functions

Logical Output	Description
----	Entry Not Used
27-1P 27-1P*	Single Phase Undervoltage Alarm Single Phase Under Voltage Seal In Goes HIGH when the undervoltage (27) element of any phase trips. 27-1P goes LOW when the voltage of all phases goes above the dropout level of the 27 element. 27-1P* remains HIGH until all sealed-in outputs are reset.
27-3P 27-3P*	Three Phase Under Voltage Three-Phase Under Voltage Seal In Goes HIGH when the voltages of all three phases drop below the 27 undervoltage setting.
27A 27A* 27B 27B* 27C 27C*	Undervoltage Phase A Undervoltage Phase A Seal-In Undervoltage Phase B Undervoltage Phase B Seal-In Undervoltage Phase C Undervoltage Phase C Seal-In Each output goes HIGH if the corresponding undervoltage (27) element trips. (Exists only in units ordered with the single-phase tripping option.)
32N 32N*	Negative Sequence Polarized Alarming Element 32N Trip Sealed-in Alarm Goes HIGH when the negative sequence current is within the 180-degree torque angle sector as set in the 32N-2 settings.
32NA	Alarm indicating 67N element is picked up Goes HIGH when the negative sequence current is within the 180-degree torque angle sector as set in the 67N settings. 32NA does not indicate that the 67N overcurrent element is picked up, it indicates only that the negative sequence current is in the angular operating zone. 32NA will not operate if the 67N overcurrent element is Disabled. For ground power directional supervision of other elements internal or external, use the 32N-2 logical output.
32P 32P*	Positive Sequence Polarized Alarming Element 32P Trip Sealed-in Alarm Goes HIGH when the positive sequence current is within the 180-degree torque angle sector as set in the 32P-2 settings.

Logical Output	Description
32PA	Alarm indicating 67P element is picked up Goes HIGH when the positive sequence current is within the 180-degree torque angle sector as set in the 67P settings. 32PA does not indicate that the 67P overcurrent element is picked up, it indicates only that the positive sequence current is in the angular operating zone. 32PA will not operate if the 67P overcurrent element is Disabled. For phase power directional supervision of other elements internal or external, use the 32P-2 logical output.
46 46*	Negative Sequence Overcurrent Negative Sequence Overcurrent Seal In Goes HIGH when the negative sequence time overcurrent element, 46, has timed out and energized.
50-1A 50-1A* 50-1B 50-1B* 50-1C 50-1C* 50-1N 50-1N*	Trip 50 1a Trip 50 1a Seal Trip 50 1b Trip 50 1b Seal Trip 50 1c Trip 50 1c Seal Trip 50 1n Trip 50 1n Seal Each output goes HIGH if the corresponding 50-1 element trips. (Exists only in units ordered with the single-phase tripping option.)
50-1D	50-1 Element Disable Goes HIGH when the torque controlled Programmable Input, 50-1, is mapped but not energized. This alarm indicates that the 50P-1 instantaneous unit is disabled form tripping. 50-1D will not operate if the 50P-1 element is disabled in the protective settings.
50-2A 50-2A* 50-2B 50-2B* 50-2C 50-2C* 50-2N 50-2N*	Trip 50 2a Trip 50 2a Seal Trip 50 2b Trip 50 2b Seal Trip 50 2c Trip 50 2c Seal Trip 50 2n Trip 50 2n Seal Each output goes HIGH if the corresponding 50-2 element trips. (Exists only in units ordered with the single-phase tripping option.)
50-2D	50-2 Element Disable Goes HIGH when the torque control Programmable Input, 50-2, is mapped but not energized. This alarm indicates that the 50P-2 instantaneous unit is disabled form tripping. 50-2D will not operate if the 50P-2 element is disabled in the protective settings.
50-3A 50-3A* 50-3B 50-3B* 50-3C 50-3C* 50-3N 50-3N*	Trip 50 3a Trip 50 3a Seal Trip 50 3b Trip 50 3b Seal Trip 50 3c Trip 50 3c Seal Trip 50 3n Trip 50 3n Seal Each output goes HIGH if the corresponding 50-3 element trips. (Exists only in units ordered with the single-phase tripping option.)
50N-1 50N-1*	1st Neutral Inst Overcurrent 1st Neutral Inst Overcurrent Seal In Goes HIGH when the low-set (level 1) neutral instantaneous overcurrent element, 50N-1, has timed out and energized.
50N-2 50N-2*	2nd Neutral Inst Overcurrent 2nd Neutral Inst Overcurrent Seal In Goes HIGH when the mid-set (level 2) neutral instantaneous overcurrent element, 50N-2, has timed out and energized.

Logical Output	Description
50N-3 50N-3*	3rd Neutral Inst Overcurrent 3rd Neutral Inst Overcurrent Seal In Goes HIGH when the high-set (level 3) neutral instantaneous overcurrent element, 50N-1, has timed out and energized.
50P-1 50P-1*	1st Phase Inst Overcurrent 1st Phase Inst Overcurrent Seal In Goes HIGH when the low-set (level 1) phase instantaneous overcurrent element, 50P-1, has timed out and energized.
50P-2 50P-2*	2nd Phase Inst Overcurrent 2nd Phase Inst Overcurrent Seal In Goes HIGH when the mid-set (level 2) phase instantaneous overcurrent element, 50P-2, has timed out and energized.
50P-3 50P-3*	3rd Phase Inst Overcurrent 3rd Phase Inst Overcurrent Seal In Goes HIGH when the high-set (level 3) phase instantaneous overcurrent element, 50P-1, has timed out and energized.
51A 51A* 51B 51B* 51C 51C* 51N 51N*	Trip 51a Trip 51a* Trip 51b Trip 51b* Trip 51c Trip 51c* Trip 1n Trip 1n* Each output goes HIGH if the corresponding 51 element trips. (Exists only in units ordered with the single-phase tripping option.)
51N 51N*	Neutral Time Overcurrent Neutral Time Overcurrent Seal In Goes HIGH when the neutral time overcurrent element, 51N, has timed out and energized.
51P 51P*	Phase Time Overcurrent Phase Time Overcurrent Seal In Goes HIGH when the phase time overcurrent element, 51P, has timed out and energized.
59 59*	Over Voltage Over Voltage Seal In Goes HIGH when the voltage of any phase rises above the 59 overvoltage setting
59-3P 59-3P*	3 Phase Overvoltage Alarm 3 Phase Overvoltage Alarm Seal-In Goes HIGH when the voltages of all three phases rise above the 59 overvoltage setting.
59A 59A* 59B 59B* 59C 59C*	Phase A Overvoltage Alarm Phase A Overvoltage Alarm Seal-In Phase B Overvoltage Alarm Phase B Overvoltage Alarm Seal-In Phase C Overvoltage Alarm Phase C Overvoltage Alarm Seal-In Each output goes HIGH if the corresponding voltage rises above the 59 overvoltage setting. (Exists only in units ordered with the single-phase tripping option.)

Logical Output	Description
67A 67A* 67B 67B* 67C 67C*	Trip 67a Trip 67a Seal Trip 67b Trip 67b Seal Trip 67c Trip 67c Seal Each output goes HIGH if the corresponding 67 element trips. (Exists only in units ordered with the single-phase tripping option.)
67N 67N*	Negative Sequence Polarized Neutral-Overcurrent 67N Trip Sealed-in Alarm Goes HIGH when the ground directional time overcurrent element, 67N, has timed out and energized.
67P 67P*	Positive Sequence Polarized Phase-Overcurrent 67P Trip Sealed-in Alarm Goes HIGH when the phase directional time overcurrent element, 67P, has timed out and energized.
79CA-1 79CA1*	Recloser Counter 1 Recloser Counter 1 Alarm Seal In Goes HIGH when the recloser has operated beyond the number of counts set in the 79 counter 1 alarm settings.
79CA-2 79CA2*	Recloser Counter 2 Recloser Counter 2 Alarm Seal In Goes HIGH when the recloser has operated beyond the number of counts set in the 79 counter 2 alarm settings. **Note:** Two recloser counter alarms are provided 79CA1 and 79CA2. They can be set to different thresholds or as typically applied; one can be reset to 0 on a monthly basis and the other on a yearly basis, this way recloser operations can be tracked on a monthly and yearly basis.
79DA	Recloser Disable Goes HIGH when the recloser is disabled either by the 43A logical input or when the 79-1 recloser sequence is set to lockout. This logical output operates in conjunction with the red front panel "Recloser Out" target.
79LOA	Recloser Lockout Goes HIGH when the PCD2000 recloser is in lockout.
LOCKA LOCKB LOCKC	Lockout A Lockout B Lockout C Each output goes HIGH if the corresponding pole is in lockout. (Exists only in units ordered with the single-phase tripping option.)
81O-1 81O-1*	Over Frequency (1st Stage) Over Frequency (1st Stage) Seal In Goes HIGH when the 81R-1 setting has been exceeded and the 81R-1 time delay has expired.
81O-2 81O-2*	Over Frequency (2nd Stage) Over Frequency (2nd Stage) Seal In Goes HIGH when the 81R-2 setting has been exceeded and the 81R-2 time delay has expired.
81R-1 81R-1*	Frequency Restore (1st Stage) Frequency Restore (1st Stage) Seal In Goes HIGH when the frequency setting 81R-1 has been met and the 81R-1 time delay has expired. 81R-1 does not activate the logical output "CLOSE". 81R-1 can be mapped to the logical input "CLOSE" via the feedback logic for operation. 81R-1 will only operate after an 81S-1 under frequency load shed (trip).

Logical Output	Description
81R-2 81R-2*	Frequency Restore (2nd Stage) Frequency Restore (2nd Stage) Seal In Goes HIGH when the frequency setting 81R-2 has been met and the 81R-2 time delay has expired. 81R-2 does not activate the logical output "CLOSE". 81R-2 can be mapped to the logical input "CLOSE" via the feedback logic for operation. 81R-2 will only operate after an 81S-2 under frequency load shed (trip).
81S-1 81S-1*	Frequency Shed (1st Stage) Frequency Load (1st Stage) Seal In Goes HIGH when the system frequency has dropped below the 81S-1 setting and the 81S-1 time delay has expired. 81S-1 does NOT activate the main trip contact of the PCD2000. 81S-1 must be mapped to the logical input "OPEN" via the feedback logic for operation of the main trip contact. See the Frequency Load Shed and Restoration section for more details.
81S-2 81S-2*	Frequency Shed (2nd Stage) Frequency Shed (2nd Stage) Seal In Goes HIGH when the system frequency has dropped below the 81S-2 and the 81S-2 time delay has expired. 81S-2 does not activate the main trip contact of the PCD2000. 81S-2 must be mapped to the logical input "OPEN" via the feedback logic for operation of the main trip contact. See the Frequency Load Shed and Restoration section for more details.
ALARM	Self Check Alarm Is normally HIGH, indicating that the PCD2000 is functioning normally. Goes LOW if the PCD2000 internal self-check indicates a problem. This logical output controls the dedicated, physical "Self Check Alarm" contact and also the front panel "G-NORMAL/R-FAIL" target.
BF Retrip BF Retrip*	Breaker Failure Re-Trip Breaker Failure Re-Trip Seal In Goes HIGH when the stand-alone Breaker Failure Trip function in the PCD2000 issues a ReTrip signal.
BF Trip BF Trip*	Breaker Failure Trip Breaker Failure Trip Seal In Goes HIGH when the stand-alone Breaker Failure Trip function in the PCD2000 issues a breaker failure trip.
BFA BFA*	Breaker Fail Breaker Failure Alarm Seal In Goes HIGH when the PCD2000 detects that the recloser failed to trip.
BFUA	Blown Fuse Goes HIGH when the voltage of any phase drops below 7 volts and no 51P or 51N overcurrent pickup condition exists. This Logical Output seals in after a blown fuse condition exists. It must be manually reset via the HMI or WinPCD after voltage has been restored.
BZA	Bus Zone Alarm
CLOSE	Fixed Close Goes HIGH when system conditions and the 79 settings conclude that an attempt should be made to close the recloser. It also goes HIGH if the logical input CLOSE goes HIGH, if the CLOSE button on the front panel is pressed, or if a close command is sent using WinPCD. CLOSE will remain HIGH until the Close Fail Timer expires or the 52A and 52B contacts indicate that the recloser has successfully closed. NOTE: This logical output must be programmed to control the physical output contact that is connected to the recloser close coil.
CLOSEA CLOSEB CLOSEC	Direct Close A Direct Close B Direct Close C Each output goes HIGH to close the corresponding pole. (Exists only in units ordered with the single-phase tripping option.)
CLTA	Cold Load Timer Goes HIGH when the Cold Load Timer is counting. Goes LOW when the Cold Load Timer expires.

Logical Output	Description
FAILA FAILB FAILC	Phase A Failure Phase B Failure Phase C Failure Each output goes HIGH to signal that the corresponding pole has failed. (Exists only in units ordered with the single-phase tripping option.)
GRD-D	Neutral Torque Control Disable Goes HIGH when a physical input (or feedback function) that has been programmed to control the ground torque control logical input (GRD) is not energized.
HPFA	High Power Factor Goes HIGH 60 seconds after the power factor rises above the Power Factor Alarm setting. If the measured value drops below the Alarm setting before the 60-second timer expires, the timer will reset.
KSI	Kilo Amp Summation Goes HIGH when the KSI sum has exceeded the KSI Counter Alarm setting.
LOAC LOAC*	Loss of AC Alarm Loss of AC Alarm Seal-In Goes HIGH is AC power is lost.
LOADA	Load Current Goes HIGH 60 seconds after any single phase of load current rises above the Load Alarm setting. If the measured value drops below the Alarm setting before the 60-second timer expires, the timer will reset.
LPFA	Low Power Factor Goes HIGH 60 seconds after the load power factor drops below the Power Factor Alarm setting. If the measured value drops below the Alarm setting before the 60-second timer expires, the timer will reset.
NDA	Neutral Peak Demand Goes HIGH 60 seconds after the demand current for the neutral input has exceeded the Neutral Demand Alarm setting. This alarm is based on the incremental demand values and not the instantaneous values (as are the load alarms).
NTA	Neutral Target Alarm Goes HIGH when Neutral Target Alarm is activated.
NVArA	Negative Var Goes HIGH 60 seconds after the negative 3-phase kiloVAR has exceeded the Negative kiloVAR Alarm setting. If the measured value drops below the Alarm setting before the 60-second timer expires, the timer will reset.
OCTC	Overcurrent Trip Counter Goes HIGH when the number of overcurrent trip operations has exceeded the Overcurrent Counter Alarm setting.
PATA	Phase A Target Goes HIGH when the red front panel phase A target LED is illuminated. Goes LOW when the front-panel target LED's are reset either by the front panel pushbutton "Target Reset" or by the WinPCD Program. This output is useful in remote communications and SCADA applications where faulted phase information is required.
PBTA	Phase B Target Goes HIGH when the red front panel phase B target LED is illuminated. Goes LOW when the front-panel target LED's are reset either by the front panel pushbutton "Target Reset" or by the WinPCD Program. This output is useful in remote communications and SCADA applications where faulted phase information is required.

Logical Output	Description
PCTA	Phase C Target Goes HIGH when the red front panel phase C target LED is illuminated. Goes LOW when the front-panel target LED's are reset either by the front panel pushbutton "Target Reset" or by the WinPCD Program. This output is useful in remote communications and SCADA applications where faulted phase information is required.
PDA	Phase Peak Demand Goes HIGH 60 seconds after the demand current for any phase has exceeded the Phase Demand Alarm setting. This alarm is based on the incremental demand values and not the instantaneous values as in the load alarms.
PH3-D	Phase Torque Control Disable Goes HIGH when a physical input (or feedback function) that has been programmed to control the phase torque control logical input (PH3) is not energized.
PTA	Phase Target Alarm Goes HIGH when Phase Target Alarm is activated.
PUA	Pickup Goes HIGH when any enabled overcurrent element is in pickup. Hence, it will respond to the overcurrent element that has the lowest pickup-level setting. It is instantaneous and ignores any overcurrent time-delays.
PVArA	Positive Var Goes HIGH 60 seconds after the positive 3-phase kiloVAR exceed the Positive kiloVAR Alarm setting. If the measured value drops below the Alarm setting before the 60-second timer expires, the timer will reset.
PWatt1	Positive Watt Alarm 1 Goes HIGH 60 seconds after the positive 3 phase kilowatts exceed the Positive Kilowatt Alarm 1 setting. If the measured value drops below the Alarm setting before the 60-second timer expires, the timer will reset.
PWatt2	Positive Watt Alarm 2 Goes HIGH 60 seconds after the positive 3 phase kilowatts exceed the Positive Kilowatt Alarm 2 setting. If the measured value drops below the Alarm setting before the 60-second timer expires, the timer will reset. **Note:** Two positive watt alarm logical outputs are provided: Pwatt1 and Pwatt2. If desired one alarm can be set to a different threshold than the other (for example, one can be used for alarming purposes and the other for tripping).
RBA	Remote Block Alarm Goes HIGH when Remote Block Alarm is activated.
SEF SEF*	Sensitive Earth Fault Trip Sensitive Earth Fault Trip Seal In Goes HIGH when the SEF element trips.
STC	Setting Table Change Goes HIGH when the "Change Settings" menu is entered via front panel HMI or remote WinPCD program.
TAGCLS	Tag Close Goes HIGH when the breaker/recloser is tagged closed.
TAGOPN	Tag Open Goes HIGH when the breaker/recloser is tagged open.
TCC	Tap Changer Cutout Goes HIGH when the PCD2000 recloser begins operation and remains HIGH until the last recloser operation is complete (reset time expires or recloser enters lockout state). When HIGH, the recloser in the PCD2000 is active. TCC can be used to block a tap changer during fault and recovery operations.

Logical Output	Description
TCFA	Trip Circuit Fail Goes HIGH when the PCD2000 determines that the recloser trip coil continuity has been broken. It is directly tied to the operation of the logical input TCM. When the TCM logical input is LOW, the TCFA logical output is HIGH, indicating a trip coil failure.
TRIP	Fixed Trip Goes HIGH when any enabled overcurrent protection element trips on any phase. It also goes HIGH if the logical input OPEN goes HIGH, if the OPEN button on the front panel is pressed, or if an open command is sent using WinPCD. NOTE: This logical output must be programmed to control the physical output contact that is connected to the recloser trip coil.
TRIPA TRIPA*	Single Pole Trip Phase A Single Pole Trip Phase A Seal In Goes HIGH when any enabled overcurrent protection element trips on phase A. Goes LOW when the measured phase A current drops below 90% of the lowest pickup setting of the enabled overcurrent elements.
TRIPB TRIPB*	Single Pole Trip Phase B Single Pole Trip Phase B Seal In Goes HIGH when any enabled overcurrent protection element trips on phase B. Goes LOW when the measured phase B current drops below 90% of the lowest pickup setting of the enabled overcurrent elements.
TRIPC TRIPC*	Single Pole Trip Phase C Single Pole Trip Phase C Seal In Goes HIGH when any enabled overcurrent protection element trips on phase C. Goes LOW when the measured phase C current drops below 90% of the lowest pickup setting of the enabled overcurrent elements.
ULO1 ULO2 ULO3 ULO4 ULO5 ULO6 ULO7 ULO8 ULO9	User Logical Output 1 User Logical Output 2 User Logical Output 3 User Logical Output 4 User Logical Output 5 User Logical Output 6 User Logical Output 7 User Logical Output 8 User Logical Output 9 Goes HIGH when the corresponding User Logical Input is HIGH.
VarDA	Var Demand Goes HIGH 60 seconds after the value of the three-phase demand VAR exceeds the Three Phase Demand Alarm setting. This alarm is based on the incremental demand values and not the instantaneous values as in the load alarms.
ZSC	Zone Sequence Coordination Goes HIGH when the Zone Sequence function is active. Zone Sequence must enabled in the "Configuration" menu. If a physical input (or feedback input) is programmed to the ZSC logical input, the ZSC logical output will go HIGH when the input is energized. If the ZSC logical input has not been programmed, it is always HIGH, and so the ZSC logical output is always HIGH.

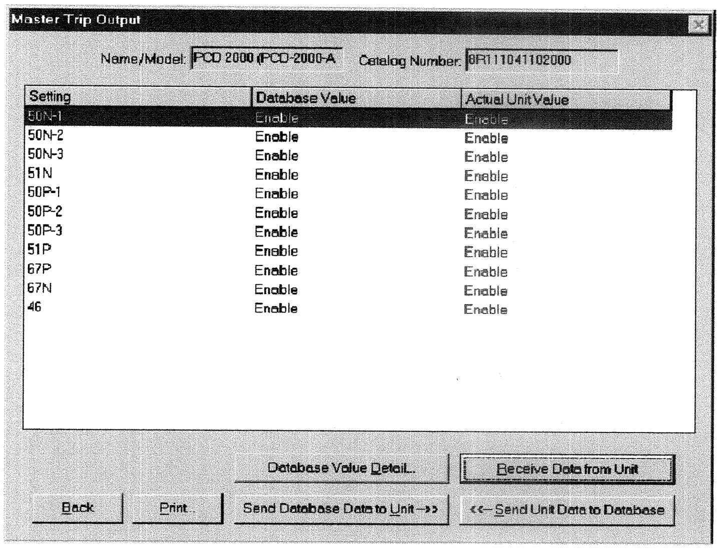
6.3 Programmable Master Trip Logical Output

The PCD2000 contains a "master trip" logical output. This output is actuated by the protective elements: 51P, 51N, 50P-1, 50P-2, 50P-3, 50N-1, 50N-2, 50N-3, 46, 67P, and 67N.

It is possible to eliminate any of the above listed protective elements from activating the master trip output using the WinPCD Program. Select "Master Trip Contact" from the "Change Settings" menu and place an "X" next to the elements desired to operate the master trip logical output and a space next to those not desired. Select "Send Settings" to complete the operation. Figure 6-4 shows a screen capture of the master trip programming.

These settings are useful where certain elements will be programmed to a different output contact for operation of a lockout relay or other auxiliary device.

Figure 6-4. Master Trip Contact Programming Window



The master trip logical output will drop out when the fault current on all phases drops to 90% of the lowest set time overcurrent element pickup AND the 52A and 52B breaker auxiliary contacts have changed state to the open position. The master trip logical output will stay sealed-in indefinitely until these cases are met.

6.4 Advanced Programming

6.4.1 Introduction

The advanced programmable logic features in the ABB PCD2000 series devices are designed to provide complex and easy to build logic functions. Virtually any desired logic scheme can be accomplished through the advanced programmable I/O features in the PCD2000. This section explains how to build complex logic schemes in the PCD2000.

6.4.2 User Logical Inputs/User Logical Outputs

User Logical Inputs (ULI's) and User Logical Outputs (ULO's) are variables in the relay to be defined by the user. A ULI is an undefined logical input seen in the relay input map. A ULO is an undefined logical output seen in the relay output map. A ULI in the input map is soft connected to the corresponding ULO in the output map. They can be considered "FEEDFORWARD" logic. When ULI1 goes HIGH, then ULO1 will automatically go HIGH.

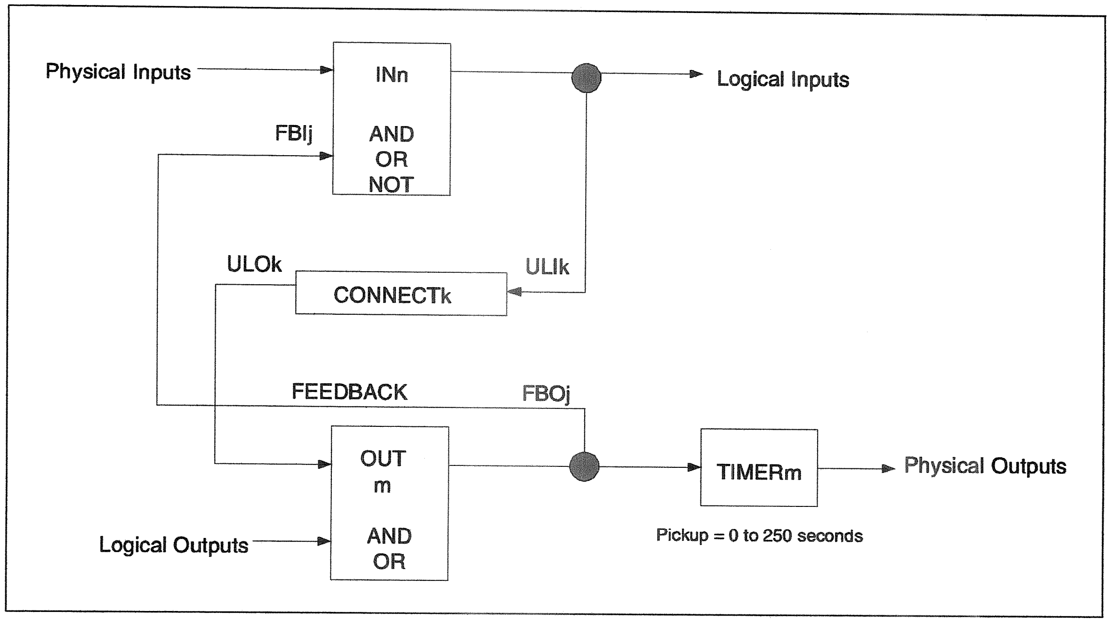
However, User Logical Inputs can also be disconnected from its corresponding User Logical Output via the "Change Settings" menu under "ULI/ULO Configuration". In this case, if ULI1 is disconnected from ULO1, and ULI1 goes HIGH, then ULO1 will not be affected. This is used primarily for applications where the user can SET or RESET a ULO for some control function. In this case the ULO will act as an S-R Flip Flop. ULO's can be SET or RESET via the HMI or through the various communications protocols. When forcing ULO's HIGH or LOW, it is recommended that the ULI-ULO connection be broken. Otherwise the ULI can adversely affect the ULO.

6.4.3 Feedbacks

Feedbacks are similar to ULI/ULO's but are used for Feedback Purposes. When Feedback Output 1 (FBO1) goes HIGH, then Feedback Input 1 (FB1) will automatically go HIGH.

The above definitions provide building blocks necessary to describe the logic features of the PCD2000.

Figure 6-5. PCD2000 Programmable Logic



6.4.4 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.

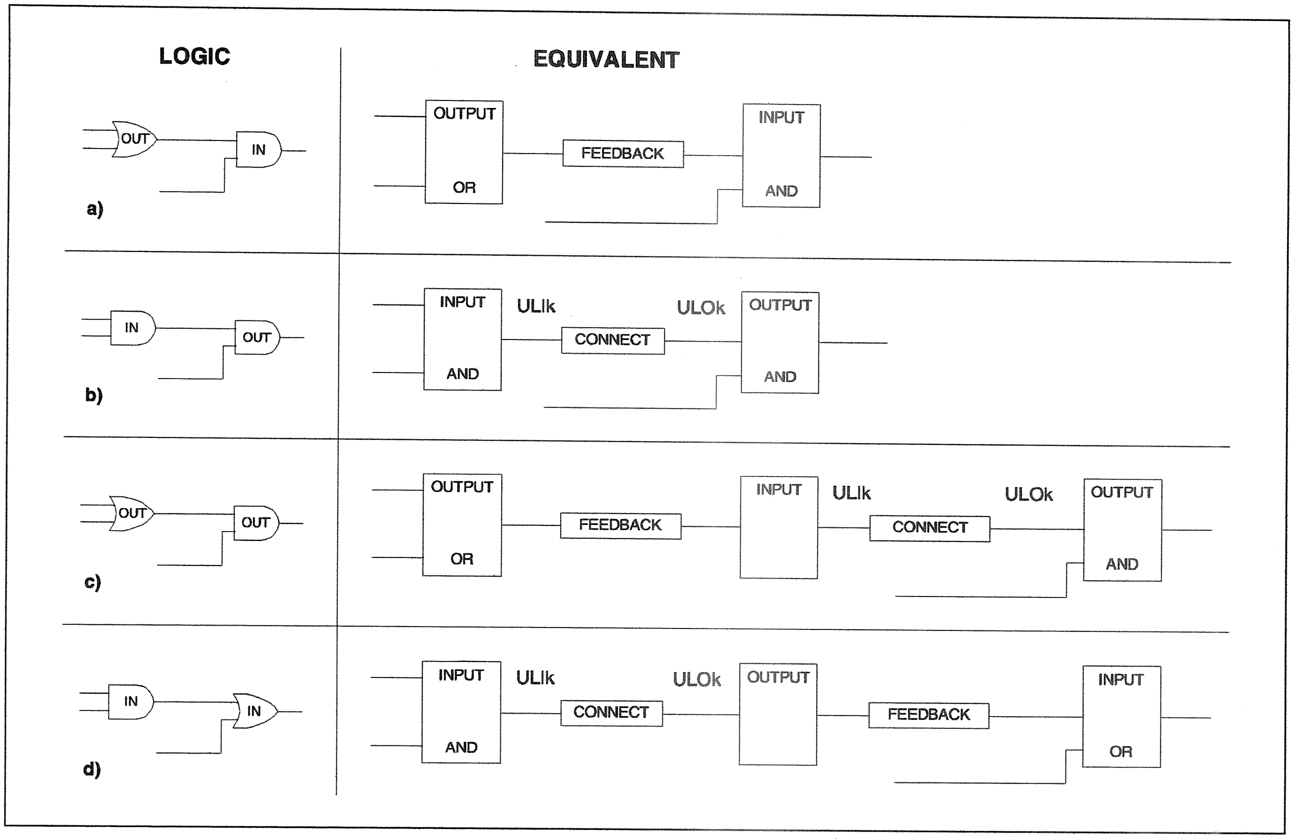
Label the gates as either Prog Input or a Prog Output depending on these rules:

- 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 FEEDBACK. See Figure 6-6 (row a).
- 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 6-6 (row b).
- 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 6-6 (row c).
- 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 6-6 (row d).

Figure 6-6. Equivalent Gates



6.4.4.1 Programmable Inputs

1. Using WinPCD, 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 Feedback, 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 Feedback columns that 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.

6.4.4.2 Programmable Outputs

1. Again using WinPCD, 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 Feedback in the top row. The type of gate, logical AND or logical 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 Feedback 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.

6.4.4.3 User Logical Inputs/Outputs Configuration

Again using WinPCD, 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.

6.5 Tagging Function

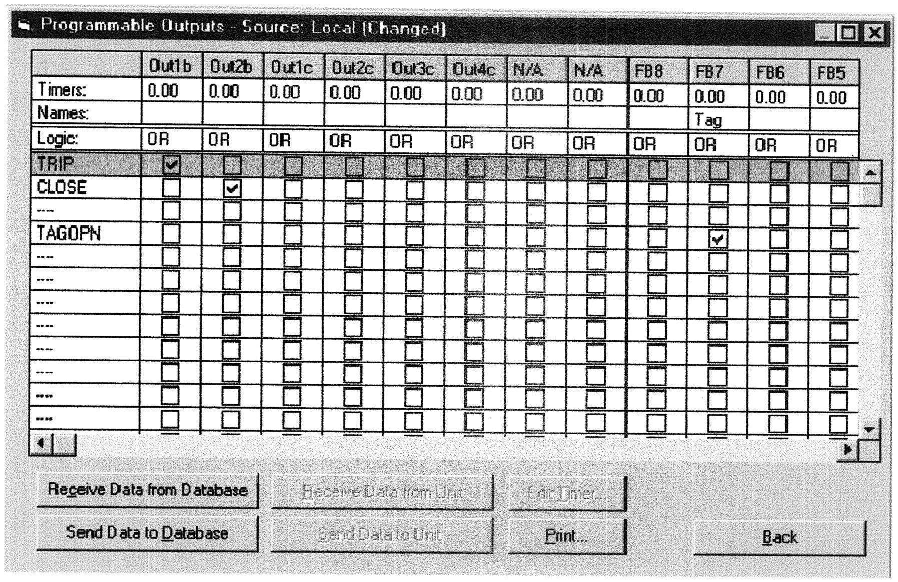
The tagging function in the PCD2000 is a customizable feature that can be tailored to meet each utility's specific needs. All PCD2000's include the ability to be tagged remotely from SCADA through one of the available protocols (DNP3.0 or Modbus®), from WinPCD programming software (which has dial up capability), or through a contact in the back of the control from a hardwired RTU. Optionally, for local tagging, the PCD2000 control can be supplied with a toggle switch, which is labeled "Hot Line Tag" and includes a large indicating light. For VR-3S's, the option for a local hot line tag switch includes circuitry to isolate any potential closing signal to the recloser.

With either remote or local tagging, the function is programmable in the device, using WinPCD software. You can program the unit to and to stay closed or open up upon the activation of tagging, or even to go to one of the alternate protection settings groups (to use a special curve). A common example follows – typically called hot line tagging.

Example:

1. The programmable input and output functions must be programmed according to the desired scheme. After the desired programming is achieved, send the data to the PCD2000 by pressing the "Send Data to Unit" and the "Send Data to Database" to keep a record in WinPCD.
2. For the programmable outputs, place a check in one of the feedback logical outputs (for this example, FB7, or feedback 7 is used). This causes the selected feedback contact to close when a remote signal to tag is sent to the unit from WinPCD or an RTU (see Figure 6-7).

Figure 6-7. Programmable Outputs for Tagging Function



	Out1b	Out2b	Out1c	Out2c	Out3c	Out4c	N/A	N/A	FB8	FB7	FB6	FB5
Timers:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Names:										Tag		
Logic:	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR
TRIP	[x]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
CLOSE	[ ]	[x]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
---	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TAGOPN	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[x]	[ ]	[ ]
---	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
---	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
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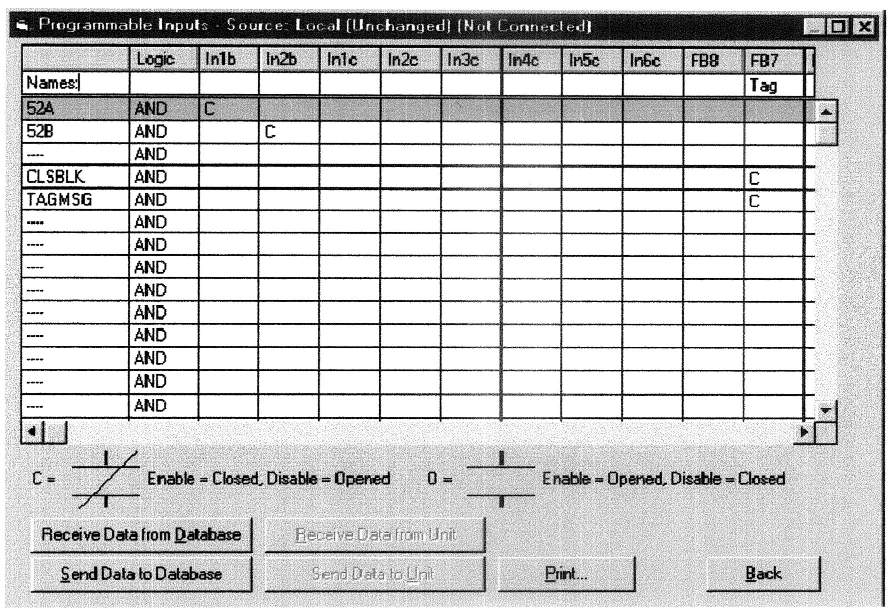
3. The next step is to program the programmable inputs. The **FB7 output** contact directly follows the programmable **FB7 input** contact, so when the output contact for FB7 closes, the programmable input contact for FB7 closes.
4. Looking at Figure 6-8 below, map the points shown to FB7. This dictates to the unit what action to take when the FB7 input contact closes.
5. In this example, map CLSBLK (block any close operation) to FB7 input. Finally, map the TAGMSG (LCD message indicating "Warning - Remote Tag Applied"). The unit will remain in this state until PCD2000 is untagged from the remote source.

Figure 6-8. Programmable Inputs for Tagging Function



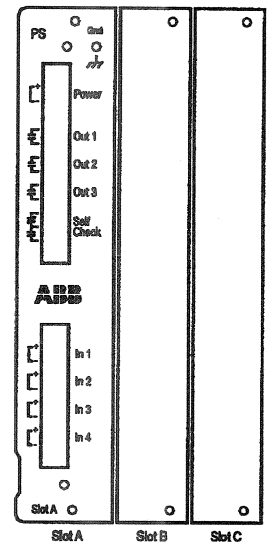
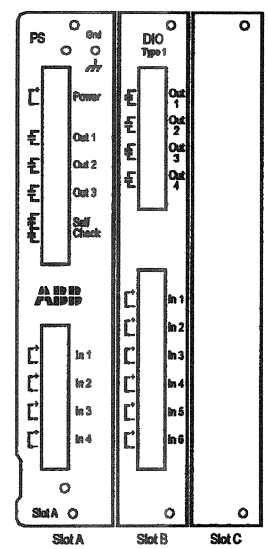
	Logic	In1b	In2b	In1c	In2c	In3c	In4c	In5c	In6c	FB8	FB7
Names:											Tag
52A	AND	C									
52B	AND		C								
----	AND										
CLSBLK	AND										C
TAGMSG	AND										C
----	AND										
----	AND										
----	AND										
----	AND										
----	AND										
----	AND										
----	AND										
----	AND										
----	AND										

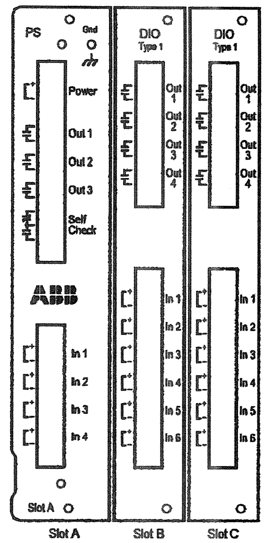
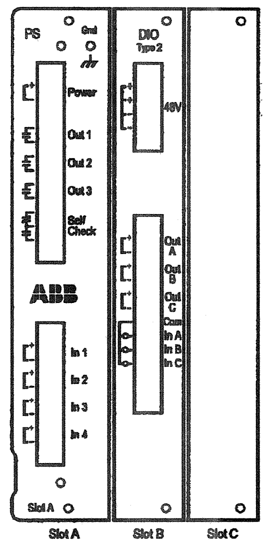
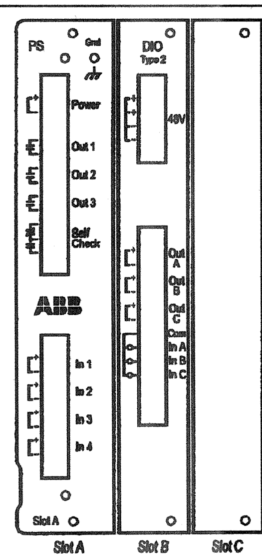
6. If the utility desires to put the unit into Alternate Protection Settings, a third selection is placed under TAGMSG, called ALT1 and a corresponding checkmark placed under FB7. There are many other logical functions that can be programmed in the PCD2000.

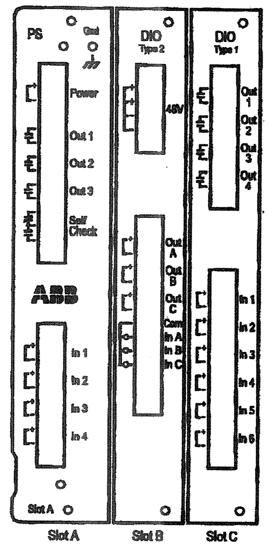
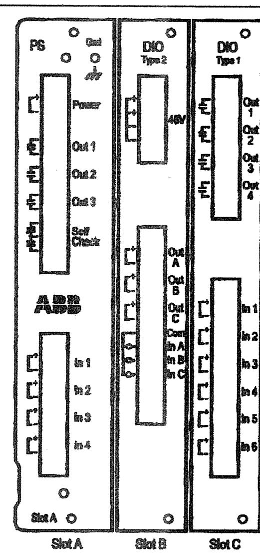
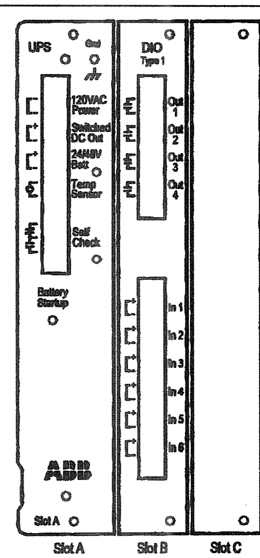
6.6 Default Inputs and Outputs

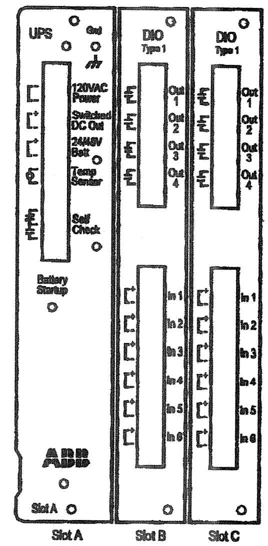
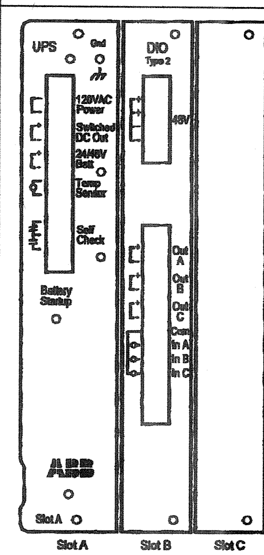
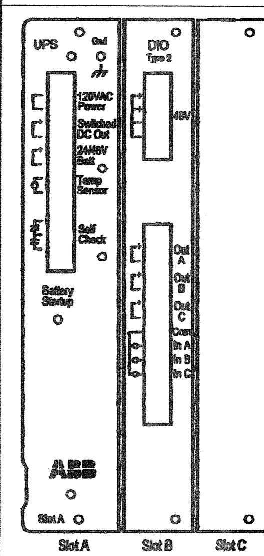
The default programming of the inputs and outputs varies depending on the options that were specified when the PCD2000 unit was ordered. Each row of Table 6-3 describes the defaults for the model specified in the first column of the row.

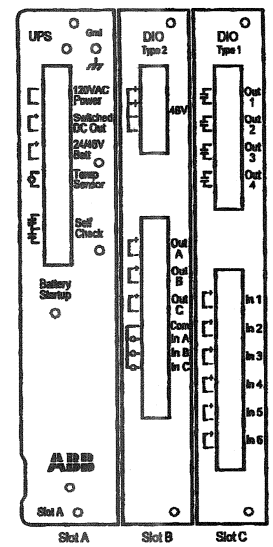
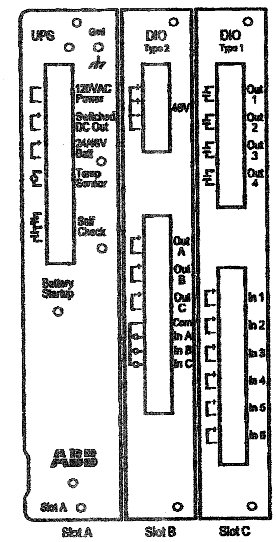
Table 6-3. Default Inputs and Outputs

Model Description	Default Inputs	Default Outputs	I/O Connections
xRxx-000x-xx-xxxx DC Power Supply No I/O Modules Total Inputs: 4 Total Outputs: 3	IN1a: 52a IN2a: 52b IN3a: 43a IN4a:	OUT1a: TRIP OUT2a: CLOSE OUT3a: 79LOA	
xRxx-001x-xx-xxxx DC Power Supply One Type 1 I/O Module Total Inputs: 10 Total Outputs: 7	IN1a: IN2a: IN3a: IN4a: IN1b: 52a IN2b: 52b IN3b: CLOSE IN4b: TRIP IN5b: 43a IN6b: GRD	OUT1a: 79DA OUT2a: RBA OUT3a: GRD-D OUT1b: TRIP OUT2b: CLOSE OUT3b: TCC OUT4b: 79LOA	

Model Description	Default Inputs	Default Outputs	I/O Connections
xRxx-002-xx-xxxx DC Power Supply Two Type 1 I/O Modules Total Inputs: 16 Total Outputs: 11	IN1a: IN2a: IN3a: IN4a: IN1b: 52a IN2b: 52b IN3b: CLOSE IN4b: TRIP IN5b: 43a IN6b: GRD IN1c: IN2c: IN3c: IN4c: IN5c: IN6c:	OUT1a: 79DA OUT2a: RBA OUT3a: GRD-D OUT1b: TRIP OUT2b: CLOSE OUT3b: TCC OUT4b: 79LOA OUT1c: OUT2c: OUT3c: OUT4c:	
xRxx-003-xx-x0xx DC Power Supply One Type 2 I/O Module Three-Phase Tripping Total Inputs: 6 Total Outputs: 5	IN1a: CLOSE IN2a: TRIP IN3a: 43a IN4a: GRD IN1b: 52a IN2b: 52b	OUT1a: 79DA OUT2a: RBA OUT3a: GRD-D OUT1b: TRIP OUT2b: CLOSE	
xRxx-003-xx-x1xx DC Power Supply One Type 2 I/O Module Single-Phase Tripping Total Inputs: 12 Total Outputs: 11	IN1a: CLOSE IN2a: TRIP IN3a: 43a IN4a: GRD IN1b: PhA 52a IN2b: PhB 52a IN3b: PhC 52a IN4b: PhA 52b IN5b: PhB 52b IN6b: PhC 52b IN7b: 52a IN8b: 52b	OUT1a: 79DA OUT2a: RBA OUT3a: GRD-D OUT1b: TRIPA OUT2b: CLOSEA OUT3b: TRIPB OUT4b: CLOSEB OUT5b: TRIPC OUT6b: CLOSEC OUT7b: TRIP OUT8b: CLOSE	

Model Description	Default Inputs	Default Outputs	I/O Connections
xRxx-004-xx-x0xx DC Power Supply One Type 1 I/O Module, One Type 2 I/O Module Three-Phase Tripping Total Inputs: 12 Total Outputs: 9	IN1a: CLOSE IN2a: TRIP IN3a: 43a IN4a: GRD IN1b: 52a IN2b: 52b IN1c: IN2c: IN3c: IN4c: IN5c: IN6c:	OUT1a: 79DA OUT2a: RBA OUT3a: GRD-D OUT1b: TRIP OUT2b: CLOSE OUT1c: OUT2c: OUT3c: OUT4c:	
xRxx-004-xx-x1xx DC Power Supply One Type 1 I/O Module, One Type 2 I/O Module Single-Phase Tripping Total Inputs: 16 Total Outputs: 15	IN1a: CLOSE IN2a: TRIP IN3a: 43a IN4a: GRD IN1b: PhA 52a IN2b: PhB 52a IN3b: PhC 52a IN4b: PhA 52b IN5b: PhB 52b IN6b: PhC 52b IN7b: 52a IN8b: 52b IN1c: IN2c: IN3c: IN4c:	OUT1a: 79DA OUT2a: RBA OUT3a: GRD-D OUT1b: TRIPA OUT2b: CLOSEA OUT3b: TRIPB OUT4b: CLOSEB OUT5b: TRIPC OUT6b: CLOSEC OUT7b: TRIP OUT8b: CLOSE OUT1c: OUT2c: OUT3c: OUT4c:	
xRxx-101x-xx-xxxx AC Power Supply One Type 1 I/O Module Total Inputs: 6 Total Outputs: 4	IN1b: 52a IN2b: 52b IN3b: CLOSE IN4b: TRIP IN5b: 43a IN6b: GRD	OUT1b: TRIP OUT2b: CLOSE OUT3b: TCC OUT4b: 79LOA	

Model Description	Default Inputs	Default Outputs	I/O Connections
xRxx-102-xx-xxxx AC Power Supply Two Type 1 I/O Modules Total Inputs: 12 Total Outputs: 8	IN1b: 52a IN2b: 52b IN3b: CLOSE IN4b: TRIP IN5b: 43a IN6b: GRD IN1c: IN2c: IN3c: IN4c: IN5c: IN6c:	OUT1b: TRIP OUT2b: CLOSE OUT3b: TCC OUT4b: 79LOA OUT1c: 79DA OUT2c: RBA OUT3c: GRD-D OUT4c:	
xRxx-103-xx-x0xx AC Power Supply One Type 2 I/O Module Three-Phase Tripping Total Inputs: 2 Total Outputs: 2	IN1b: 52a IN2b: 52b	OUT1b: TRIP OUT2b: CLOSE	
xRxx-103-xx-x1xx AC Power Supply One Type 2 I/O Module Single-Phase Tripping Total Inputs: 8 Total Outputs: 8	IN1b: PhA 52a IN2b: PhB 52a IN3b: PhC 52a IN4b: PhA 52b IN5b: PhB 52b IN6b: PhC 52b IN7b: 52a IN8b: 52b	OUT1b: TRIPA OUT2b: CLOSEA OUT3b: TRIPB OUT4b: CLOSEB OUT5b: TRIPC OUT6b: CLOSEC OUT7b: TRIP OUT8b: CLOSE	

Model Description	Default Inputs	Default Outputs	I/O Connections
xRxx-104-xx-x0xx AC Power Supply One Type 1 I/O Module, One Type 2 I/O Module Three-Phase Tripping Total Inputs: 8 Total Outputs: 6	IN1b: 52a IN2b: 52b IN1c: IN2c: IN3c: IN4c: IN5c: IN6c:	OUT1b: TRIP OUT2b: CLOSE OUT1c: OUT2c: OUT3c: OUT4c:	
xRxx-104-xx-x1xx AC Power Supply One Type 1 I/O Module, One Type 2 I/O Module Single-Phase Tripping Total Inputs: 14 Total Outputs: 12	IN1b: PhA 52a IN2b: PhB 52a IN3b: PhC 52a IN4b: PhA 52b IN5b: PhB 52b IN6b: PhC 52b IN7b: 52a IN8b: 52b IN1c: IN2c: IN3c: IN4c: IN5c: IN6c:	OUT1b: TRIPA OUT2b: CLOSEA OUT3b: TRIPB OUT4b: CLOSEB OUT5b: TRIPC OUT6b: CLOSEC OUT7b: TRIP OUT8b: CLOSE OUT1c: OUT2c: OUT3c: OUT4c:	

7 Monitoring

The PCD2000 contains a complete voltage and current metering package that calculates sequence components, real and reactive power flow, power factor, demand, and minimum/maximum values. The proper setting of the Voltage Transformer (VT) and Current Transformer (CT) configurations and ratios are extremely important for proper metering operation. The VT and CT configuration (wye or delta) and ratio settings are contained in the "Configuration Settings" menu. Load magnitudes for current are displayed by default on the LCD display (if applicable). All metered values using the metering menu in the PCD2000 or by using WinPCD can be displayed in the WinPCD metering screen. The voltage values displayed are phase to neutral for wye connected VT's and phase to phase for delta connected VT's. A setting is required in the Configuration Menu to display in either L-L or L-N. Voltage V_{A-N} or V_{A-B} for delta VT's is always shown at 0 degrees and is used as a reference for all other voltage and current phase angles. The calculated sequence voltage components V1 and V2 are derived from the line voltages regardless of VT configuration. If a balanced condition is assumed then: in a delta system, the angle of the positive sequence voltage (V_1) leads V_{A-B} by 330 degrees. In a wye system the angle of the positive sequence voltage (V_1) equals V_{A-N}. The metering screen can be used to verify proper and healthy connections to the voltage and current input sensors of the PCD2000.

7.1 Load Metering

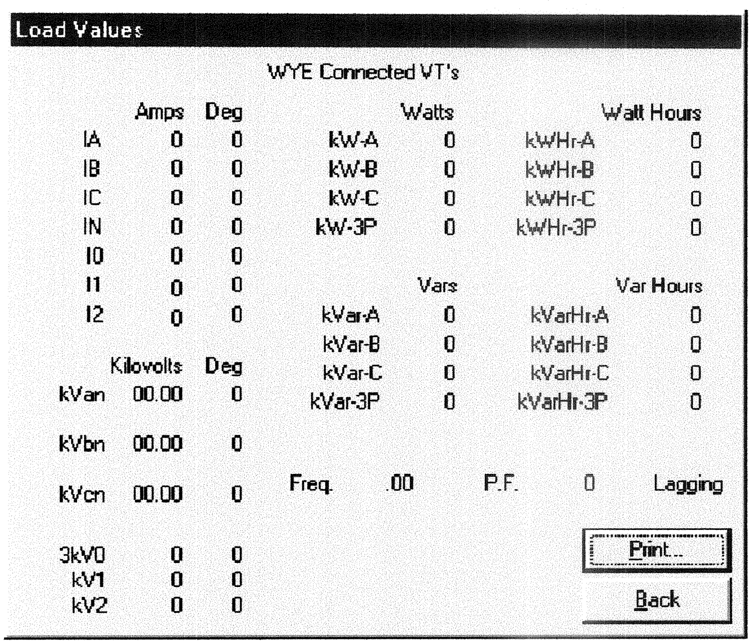
The following load values are contained in the PCD2000 and are accessible via the HMI or Win PCD program:

All phase angles are referenced to V_{A-N} that is set to be zero degrees.

- Phase Currents: Magnitude and Phase Angle
  - Wye - I_{A-N}, I_{B-N}, I_{C-N}
  - Delta - I_{A-B}, I_{B-C}, I_{C-A}
- Ground Current: Magnitude and Phase Angle
  - Wye - I_N
- Kilovolts: Magnitude and Phase Angle
  - Wye - V_{A-N}, V_{B-N}, V_{C-N}
  - Delta - V_{A-B}, V_{B-C}, V_{C-A}
- Kilowatts (or Megawatts):
  - Single Phase - kW-A, kW-B, kW-C
  - Three Phase for Wye and Delta connected VTs - kW-3P
- KiloVARs (or MegaVARs):
  - Single Phase - kVAR-A, kVAR-B, kVAR-C
  - Three Phase for Wye and Delta connected VTs - kVAR-3P
- Kilowatt-hours (or Megawatt-hours):
  - Single Phase - kWHr-A, kWHr-B, kWHr-C

  - Three Phase for Wye and Delta connected VTs - kWHr-3P
- KiloVAR-hours (or MegaVAR-hours):
  - Single Phase - kVARHr-A, kVARHr-B, kVARHr-C
  - Three Phase for Wye and Delta connected VTs - kVARHr-3P
- Kilovolt Sequence Components: Magnitude and Phase Angle
  - Positive Sequence - kV1
  - Negative sequence - kV2
- Current Sequence Components: Magnitude and Phase Angle
  - Positive Sequence - I1
  - Negative Sequence - I2
  - Zero Sequence I0
- Power Factor
  - Leading
  - Lagging
- Frequency
  - 50 Hz
  - 60 Hz

Figure 7-1. Load Metering Window in WinPCD



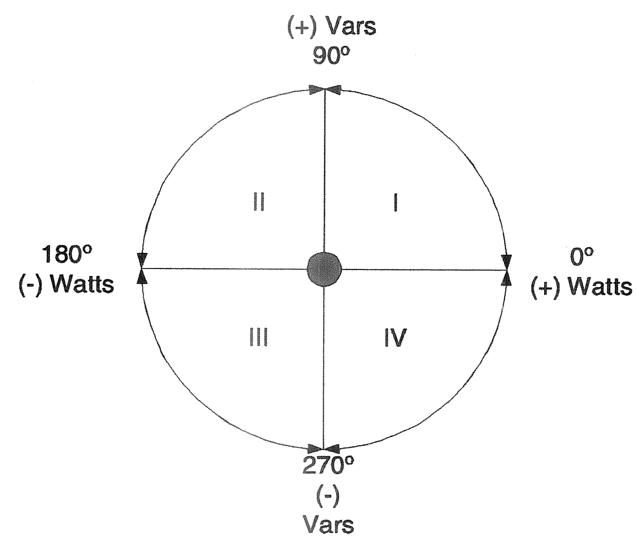
7.2 Energy Meter Rollover

The Watthour and VARhour energy meters can be set to display Kilowatt-hours or Megawatt-hours. This setting is made in the Configuration menu.

Depending on the magnitude of the power flow seen by the PCD2000 and the time period between meter readings, it may be necessary to switch the meter mode to megawatt-hours to avoid energy meter rollover. Meter rollover is the point at which the PCD2000 watthour meter has reached its maximum count and returns to zero to begin incrementing again. The roll over point for the energy meters is 6,000,000 kilowatt-hours (kiloVAR-hours) in the kWHr mode and 2,000,000,000 megawatt-hours (megaVAR-hours) in the MWHr mode.

The energy meters are capable of reading negative power. If the magnitudes are positive, the meters will increment, if negative they will decrement. Figure 7-2 outlines the metering conventions used in the PCD2000.

Figure 7-2. Metering Conventions Used in the PCD2000



The update rate of the energy meters is based on the "Demand Constant" setting (see Demand Meter section) as set in the "Configurations" settings. The meters will update every 1/15 of the Demand Constant. For example: if the Demand Constant is set to 15 minutes the energy meters will update every 1 minute (15min x 1/15 = 1 min).

The watt-hour and VAR-hour meters can be reset to 0 through the local Human Machine Interface (HMI) by pressing "C" three times in the "Reset Energy Meters" found in the "Meter" menu.

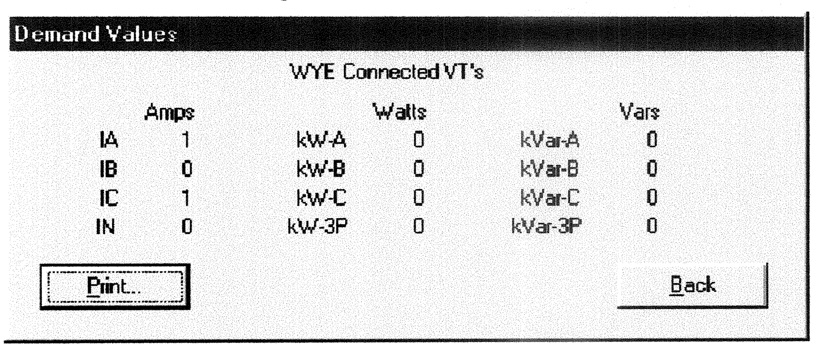
7.3 Demand Metering

Demand metering typically is used for analysis of equipment loading and system planning. The demand values in the PCD2000 are accessible via the HMI or Win PCD program. The following are the measurements taken by the demand meter:

- Phase Currents: Magnitude
  - Wye and Delta connections - I_A, I_B, I_C
- Ground Current: Magnitude
  - Wye connection - I_N
- Kilowatts:
  - Single Phase kW-A, kW-B, kW-C
  - Three Phase for Wye and Delta connected VTs - kW-3P
- KiloVARs:
  - Single Phase - kVAR-A, kVAR-B, kVAR-C
  - Three Phase for Wye and Delta connected VTs - kVAR-3P

The demand meter takes a snapshot of the load every 1/15 x Demand Constant minutes. Demand currents are averaged using a log10 function over the period of the Demand Constant Interval to replicate thermal demand ammeters. The demand kilowatts and kiloVARs are averaged values that are calculated by sampling the kilowatt-hours and kiloVAR-hours every "Demand Constant" interval. The Demand Constant interval is a setting made in the "Configuration" settings and is the time period between demand meter updates. Current utility or industrial practice usually dictates the setting of the demand constant interval.

Figure 7-3. Demand Metering Window in WinPCD



7.4 Minimum and Maximum Metering

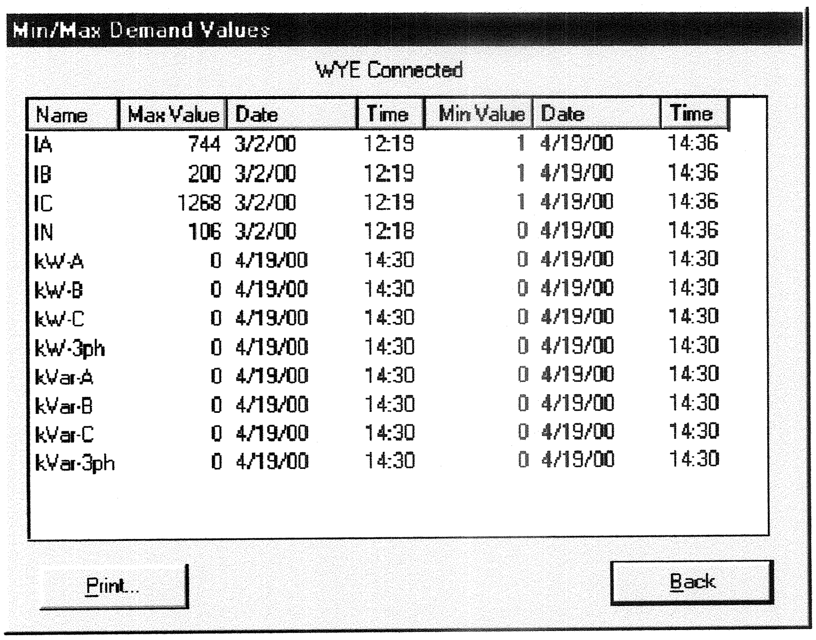
During each demand interval described the PCD2000 also captures and stores minimum and maximum values for the measurements listed below. It functions as a standard minimum and maximum meter. When a new maximum or minimum value is determined, the old value is replaced. A time stamp in the following format, (date: month/day/year and time: hour:minute), is placed with the latest minimum and maximum values.

The minimum and maximum metering can be reset to 0 through the local Human Machine Interface (HMI) by pressing "C" three times in the "Reset Energy Meters" found in the "Meter" menu.

The minimum and maximum meter measures:

- Phase Currents: Magnitude
  - Wye and Delta connection
    - Max IA, Max IB, Max IC
    - Min I_A, Min I_B, Min I_C
- Ground Current: Magnitude
  - Wye and Delta connection
    - Max I_N; Min I_N
- Kilowatts:
  - Single Phase
    - Max kW-A, Max kW-B, Max kW-C;
    - Min kW-A, Min kW-B, Min kW-C
  - Three Phase for Wye and Delta connected VTs
    - Max kW-3P; Min kW-3P
- KiloVARs:
  - Single Phase
    - Max kVAR-A, Max kVAR-B, Max kVAR-C;
    - Min kVAR-A, Min kVAR-B, Min kVAR-C
  - Three Phase for Wye and Delta connected VTs
    - Max kVAR-3P; Min kVAR-3P

Figure 7-4. Min/Max Demand Metering Window in WinPCD



Min/Max Demand Values

WYE Connected

Name	Max Value	Date	Time	Min Value	Date	Time
IA	744	3/2/00	12:19	1	4/19/00	14:36
IB	200	3/2/00	12:19	1	4/19/00	14:36
IC	1268	3/2/00	12:19	1	4/19/00	14:36
IN	106	3/2/00	12:18	0	4/19/00	14:36
kW-A	0	4/19/00	14:30	0	4/19/00	14:30
kW-B	0	4/19/00	14:30	0	4/19/00	14:30
kW-C	0	4/19/00	14:30	0	4/19/00	14:30
kW-3ph	0	4/19/00	14:30	0	4/19/00	14:30
kVar-A	0	4/19/00	14:30	0	4/19/00	14:30
kVar-B	0	4/19/00	14:30	0	4/19/00	14:30
kVar-C	0	4/19/00	14:30	0	4/19/00	14:30
kVar-3ph	0	4/19/00	14:30	0	4/19/00	14:30

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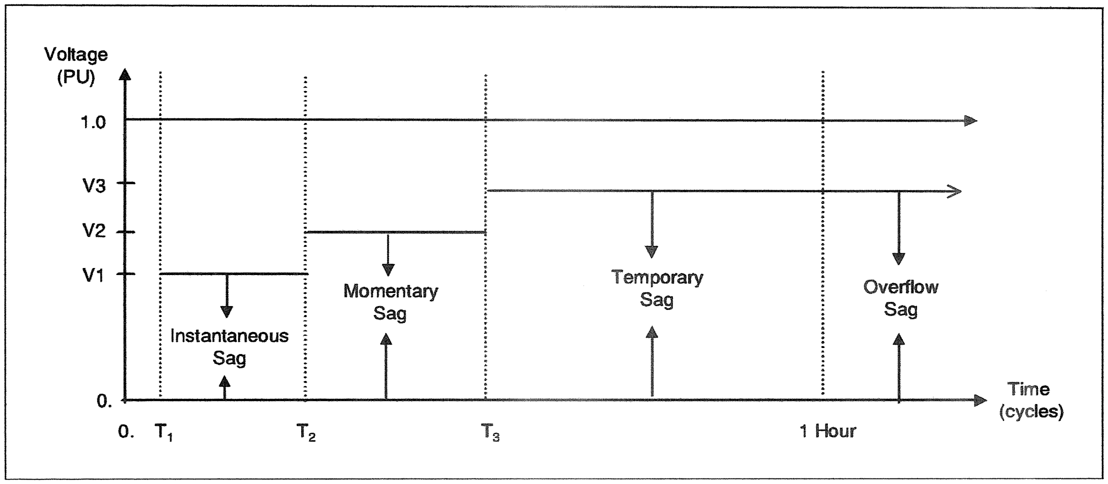
7.5 Power Quality Functions

7.5.1 Voltage Sag Calculation Unit

The voltage sag calculation unit monitors all three-phase voltages independently and records events where the voltage drops below a threshold for a specified period of time. Voltage sags are implemented according to the IEEE 1159 standard.

Four non-overlapping time and magnitude regions are defined for voltage sags as shown below in Figure 7-5.

Figure 7-5. Voltage Sag Operational Regions



The voltage sag element is implemented with separate processing for each sag event. The voltage sag element for each event processes rms voltage measurements from all three phases independently every quarter cycle. Pickup thresholds are the same on each phase within an event.

A voltage sag on a particular phase goes into pickup when rms voltage drops below the rms voltage threshold. This pickup time is also the event start time. Whenever the element is in pickup (rms voltage is below threshold) the minimum quarter cycle rms voltage detected is stored for the event. The event ends when the rms voltage returns above the pickup threshold. The event is triggered (stored permanently) if the duration of the event falls within the lower and upper time window.

The adjustable rms voltage thresholds adhere to the following relationship:

$$V1 \leq V2 \leq V3$$

The upper time limit of the temporary sag operating region is not adjustable and is set to 1 hour. Any event longer than the upper coded limit is classified as overflow and the duration of the event is set equal to the upper limit.

Table 7-1. Voltage Sag Settings

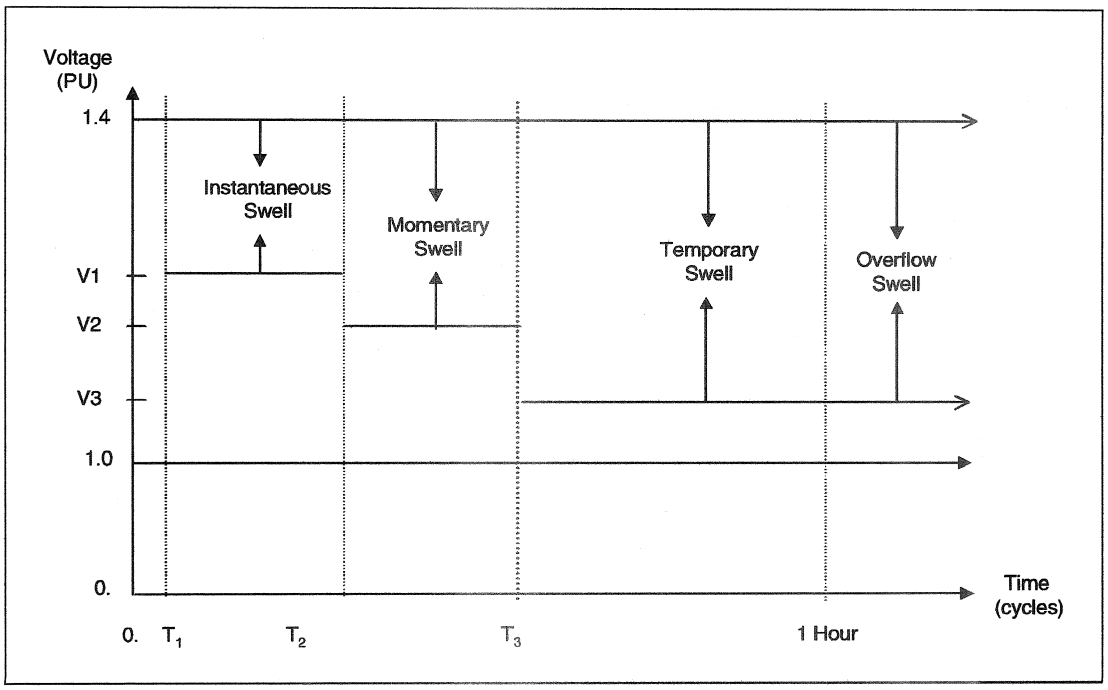
HMI Abbreviation	Description
Sag Unit	Choice of whether voltage sag unit is Enabled or Disabled (default).
Sag V1 (pu)	Instantaneous pickup voltage magnitude (in pu RMS volts). Range is 0.1 to 0.9, default is 0.8.
Sag T1 (c)	Instantaneous lower trigger threshold (in cycles). Range is 0.5 to 50, default is 3. Note that if Sag T1 is set higher than Sag T2 or Sag T3, then Sag T2 and Sag T3 are set equal to the new Sag T1.
Sag V2 (pu)	Temporary pickup voltage magnitude (in pu RMS volts). Range is the Sag V1 setting to 0.9, default is 0.8.
Sag T2 (c)	Upper instantaneous/lower momentary time trigger (in cycles). Range is 10 to 180, default is 30. Note that if Sag T2 is set higher than Sag T3, then Sag T3 is set equal to the new Sag T2. If Sag T2 is set lower than Sag T1, the entered Sag T2 is rejected.
Sag V3 (pu)	Temporary pickup voltage magnitude (in pu RMS volts). Range is the Sag V2 setting to 0.9, default is 0.8.
Sag T3 (s)	Upper momentary/lower temporary time trigger (in seconds). Range is 2 to 60, default is 3. Note that if Sag T3 is set lower than Sag T2, the entered Sag T3 is rejected.

7.5.2 Voltage Swell Calculation Unit

The voltage swell unit monitors all three phases independently and records any event where the voltage rises above a user defined threshold for a user specified period of time. Voltage swells are implemented according to the IEEE 1159 standard.

Four non-overlapping time and magnitude regions are defined for voltage swells as shown below in Figure 7-6.

Figure 7-6. Voltage Swell Operational Regions



The voltage swell element is implemented with separate processing for each voltage swell event. The voltage swell element processes rms voltage measurements from all three phases independently every quarter cycle. Pickup thresholds are the same on each phase within an event.

A voltage swell on a particular phase goes into pickup when rms voltage rises above the rms voltage threshold. This pickup time is also the event start time. While the element is in pickup (rms voltage is above threshold) the maximum quarter cycle rms voltage detected is stored for the event. The event ends when the rms voltage returns below the pickup threshold. The event is triggered (stored permanently) if the duration of the event falls within the lower and upper time window.

The tunable rms voltage thresholds must adhere to the following relationship:

$$V1 \geq V2 \geq V3$$

The upper limit on each operating region is limited by saturation that is typically 1.4 pu. The upper time limit of the temporary swell operating region is not adjustable and is set to 1 hour. Any event longer than the upper coded limit is classified as overflow and the duration of the event is set equal to the upper limit.

Table 7-2. Voltage Swell Settings

HMI Abbreviation	Description
Swell Unit	Choice of whether voltage swell unit is enabled or disabled (default).
Swell V1 (pu)	Instantaneous pickup voltage magnitude (in pu RMS volts). Range is 1.0 to 1.4, default is 1.2.
Swell T1 (c)	Instantaneous lower trigger threshold (in cycles). Range is 0.5 to 50, default is 0.5. Note that if Swell T1 is set higher than Swell T2 or Swell T3, then Swell T2 and Swell T3 are set equal to the new Swell T1.
Swell V2 (pu)	Temporary pickup voltage magnitude (in pu RMS volts). Range is 1.0 to the Swell V1 setting, default is 1.2.
Swell T2 (c)	Upper instantaneous/lower momentary time trigger (in cycles). Range is 10 to 180, default is 10. Note that if Swell T2 is set higher than Swell T3, then Swell T3 is set equal to the new Swell T2. If Swell T2 is set lower than Swell T1 the entered Swell T2 is rejected.
Swell V3 (pu)	Temporary pickup voltage magnitude (in pu RMS volts). Range is 1.0 to the Swell V2 setting, default is 1.2.
Swell T3 (s)	Upper momentary/lower temporary time trigger (in seconds). Range is 2 to 60, default is 2. Note that if Swell T3 is set lower than Swell T2, the entered Swell T3 is rejected.

7.5.3 PQ Oscillographics

Oscillographic records can be triggered for any PQ event type. Oscillographic triggers are set using the remote tunable parameters program. The trigger point is the time when a PQ functional unit picks up due to a voltage threshold violation. In other words, the oscillographic record captures the waveform at the start of the event. In some circumstances it is possible that an oscillographic record is captured due to the voltage violation but the PQ record is not triggered because the event does not violate the minimum time constraint for the event type.

Oscillographic records are stored in the same format and structure as fault oscillographic records.

7.6 Definitions

The definitions shown in this section are referred to as common terms used in metering. For additional definitions see the current version of ANSI C12.1 Code for Electricity Metering - Definitions Section and ANSI/IEEE 100-1988 Standard Dictionary of Electrical and Electronics Terms.

Active Power - for balanced three-phase systems it is the product of the voltage, the current and the cosine of the phase angle between them, expressed in watts:

$$Watts = \sqrt{3}\, E_L I_L \cos\theta$$

For unbalanced systems it is the square root of the apparent power squared minus the reactive power squared:

$$Watts = \sqrt{(VA)^2 - (RVA)^2}$$

Or the active power can be calculated for each phase to and then added to obtain the total active power:

$$Watts = W_A + W_B + W_C$$

Ammeter - an instrument for measuring the magnitude of an electric current flow expressed in amperes.

Ampere - the practical unit of electric current, one-ampere is the current caused to flow through a resistance of 1 ohm by 1 volt.

Ampere-Hour - the average quantity of electric current flowing in a circuit for one hour.

Apparent Power - the product of the RMS voltage and the RMS current in a balanced three-phase system, expressed in volt-amperes (VA):

$$VA = \sqrt{3}\, E_L I_L$$

For unbalanced systems apparent power is the square root of the sum of the squares of the active and reactive powers:

$$VA = \sqrt{(W)^2 + (RVA)^2}$$

Automatic Meter Reading (AMR) - the reading of meters from a remote location from where the meter is installed. Wireless radio and telephone are common methods for obtaining this data. AMR is the initial step to feeder automation.

Balanced Load - the term balanced load is used to indicate equal currents in all phases and relatively equal voltage between phases and between each phase and neutral with approximately equal watts in each phase of the load.

Base Load - the normal minimum load of a feeder load that is carried over a 24-hour day.

Burden - the load, expressed in volt-amperes (VA) at a specified power factor placed on instrument transformer secondary by a connected device.

Capacitance - electric current flow is the movement of electrons in a conductor with voltage applied to that conductor. As these electrons move current flow produces as long as the voltage is applied to allow storage of energy whenever two conductors are in close proximity but separated by an insulator or dielectric material. In an alternating voltage between the conductors the capacitive energy is transferred to and from the dielectric materials resulting in an alternating current flow in the circuit.

Capacitive Reactance - reactance due to capacitance, expressed in ohms. The capacitive reactance varies indirectly with frequency.

Circular Mil - the area of a circle whose diameter is one mil (1/1000 in.), it is a unit of area equal to $\pi/4$ or 0.7854 square mil. The area of a circle in circular mils is equal to the square of its diameter in mils.

Clockwise Rotation - movement of electrical voltage and/or current in the same direction as the front view as hands on a clock.

Conductance - the ability of a substance or body to pass an electric current, conductance is the reciprocal of resistance.

Conductor Losses - the watts consumed in the wires or conductors of an electric circuit. Power that heats wires doing no useful work, it may be calculated for I^2R where I is the conductor current and R is the circuit resistance.

Connected Load - the sum of the continuous ratings of the connected load consuming apparatus.

Counter-Clockwise Rotation - the movement of voltage and/or current in the same direction opposite that of the front view of hands on a clock.

Cutout - a means of disconnecting an electric circuit, the cutout generally consists of a fuse block and latching device or switch.

Demand - the average value of power or related quantity over a specified interval of time. Demand is expressed in kilowatts, kilovolt-amperes, kilovars, or other suitable units. The interval may be 5, 15, 30 or 60 minutes.

Demand, Maximum - the highest demand measured over a selected period of time also called peak demand.

Demand, Rolling Interval - a method of measuring power or other quantity by taking measurements within fixed intervals of the demand period. This method can be used to determine total demand, average demand, maximum demand, and average maximum demand during the full interval.

Demand Delay - the programmable amount of time before demand calculations is restarted after a power outage. Also referred to a Cold Load Pickup and Demand Forgiveness.

Demand Interval Synchronization - physical linking of meters to synchronize the demand intervals of all meters.

Demand Meter - a metering device that indicates or record the demand, maximum demand or both. Demand involves both an electrical factor and a time factor with a mechanism responsive to each of these factors as well as a recording mechanism.

Electrical Degree - the 1/360th part of one complete alternating current cycle.

Electric Meter - a device that measures and record the summation of an electrical quantity over a period of time.

Energy - the integral of active power with respect to time.

Ground - a conducting connection whether intentional or accidental between an electric circuit or equipment and earth. It is used for establishing and maintaining the potential of the earth.

Grounding Conductor - a conductor used to connect any equipment device or wiring system with a grounding electrode or electrodes.

Grounding Electrode - a conductor embedded in the earth used for maintaining ground potential on conductors connected to it and for dissipating into the earth current conducted to it.

Hertz - the unit of frequency of an alternating current or voltage, it is the number of cycles (positive or negative) occurring in one second.

Impedance - the total opposing effect to the flow of current in an alternating current circuit. Impedance may consist of resistance or resistance and reactance, determined in ohms from the effective value of the total circuit voltage divided by the effective value of total circuit current.

Inductance - any conductor that is carrying current is cut by the flux of its own field when current changes in value. A voltage is induced in the conductor by definition of Lenz's law opposes the change in current in the conductor. Therefore, if current decreases the induced voltage will try to maintain the current, if current increases the induced voltage tends to keep the current down. In alternating current circuits the current is constantly changing so the inductive effect is considerable. Changing current produces changing flux producing induced voltage. The induced voltage opposes the change in applied voltage consequently the opposition to the change in current. As current changes more rapidly with increasing frequency the inductive effect also increases with frequency. Inductance is expressed in henrys (L).

Inductive Reactance - inductance has a definite current limiting effect on alternating current. This effect is directly proportional to the magnitude of the inductance and is also proportional to the rate of change of current that is a function of the frequency of the supply voltage. The total limiting effect of inductance on current may be calculated by the following equation, where X_L inductive reactance is expressed in ohms, f frequency in hertz and L inductance in henrys.

$$X_L = 2\pi fL$$

Kilo - a prefix meaning one thousand of a specified unit (kilowatt), 1,000 watts = 1 kilowatt.

KVA - the abbreviation for kilovolt-ampere, equal to 1,000 volt-amperes.

Kirchhoff's Laws - Kirchhoff's laws are used in solving for the various unknown values of current, voltage and resistance of complex circuits. Kirchhoff's laws are used in conjunction with Ohm's law, where the voltage law is adapted from series circuits and the current law is adapted from parallel circuits.

Kirchhoff's Voltage Law states; the sum of the voltage drops around a circuit is equal to the supply voltage or voltages and that the algebraic sum of the voltages around a circuit is equal to zero.

$$E_S = E_1 + E_2 + E_3$$
$$E_S - E_1 - E_2 - E_3 = 0$$

Kirchhoff's Current Law states; the sum of the currents flowing into a junction point is equal to the sum of the currents flowing away from the junction point and that any junction of conductors the algebraic sum of the currents is zero.

$$I_{TOTAL} = I_1 + I_2 + I_3$$
$$I_{TOTAL} - I_1 - I_2 - I_3 = 0$$

Lagging Current - an alternating current that in each half-cycle, reaches its maximum value a fraction of a cycle later than the maximum value of the voltage which produces it.

Leading Current - an alternating current that in each half-cycle reaches its maximum value a fraction of a cycle sooner than the maximum value of the voltage, which produces it.

Lenz's Law - the induced current in a conductor as a result of an induced voltage is such that the change in magnetic flux due to it is opposite to the change in flux that caused the induced voltage.

Mega - a prefix meaning on million of a specified unit (megawatt), 1,000,000 watts = 1 megawatt.

Memory - electronic devices that store electronic instructions and data.

Volatile memories can be written to and read from repeatedly. Random access memories (RAM) require uninterrupted power to retain their contents.

Read Only Memories (ROM) are programmed once and may be read repeatedly. They do not require constant power to retain their contents. ROMs are typically used to store firmware in dedicated systems.

Micro - a prefix meaning on millionth part of a specified unit (microhm), 0.000001 ohm = 1 microhm.

Ohm - the unit of electrical resistance, it is the resistance, that allows one ampere to flow when the impressed electromotive force is one volt.

Ohm's Law - Ohm's law states; the current that flows in an electrical circuit is directly proportional to the electromotive force impressed on the circuit and inversely proportional to the impedance in an alternating current circuit.

Optical Port - a communication interface on a metering device that allows the transfer of information while providing electrical isolation and metering security.

Peak Load - the maximum demand on an electric system during any particular period. Units may be kilowatts or megawatts.

Percent Error - the percent error of a meter is the difference between its percent registration and one hundred percent.

Phase Angle - the phase angle or phase difference between a sinusoidal voltage and a sinusoidal current is defined as the number of electrical degrees between the beginning of the cycle of voltage and the beginning of the cycle of current.

Phase Sequence - the order in which the instantaneous values of the voltages or currents of a polyphase system reach their maximum positive values.

Phasor - a complex number associated with sinusoidally varying electrical quantities such that the absolute value of the complex number corresponds to either the peak amplitude or RMS value of the quantity and the phase to the phase angle at zero time. Phasors are used to represent sinusoidal voltages and currents by plotting on rectangular coordinates.

Phasor Diagram - a phasor diagram contains two or more phasors drawn, showing the relative magnitude and phase, or time, relationships among the various voltages and currents.

Power Factor - for balanced three-phase systems it is the product of the cosine of phase angle between the voltage and the current:

$$PF = \cos\theta$$

In an unbalanced three-phase system it is the ratio of the active power to the apparent power:

$$PF = \frac{W}{VA}$$

Pulse - an electrical signal, which departs from an initial level for a limited duration of time and returns to the original level. Example: a sudden change in voltage or current produced by the opening or closing of a contact.

Q-Hour Meter - an electric meter that measures the quantity obtained by lagging the applied voltage to a meter by 60 degrees.

Reactance - the measure of opposition to current flow in an electric circuit caused by the circuit properties of the inductance and capacitance, normally expressed in ohms.

Reactive Power - reactive power is the product of the voltage, the current and the sine of the phase angle between them with the current taken as reference. With non-sinusoidal quantities it is the sum of all the harmonic components each determined as above. In a polyphase circuit it is the sum of the reactive powers of the individual phases.

Reactive Volt-Amperes - for balanced three-phase systems it is the product of the voltage, the current and the sine of the phase angle between them, expressed in VARs:

$$VARs = \sqrt{3}\, E_L I_L \sin\theta$$

An unbalanced AC circuit reactive volt-amperes is the square root of the apparent power squared minus the active power squared:

$$VAR = \sqrt{(VA)^2 - (W)^2}$$

Resistance - the opposition offered by a substance or body to the passage through an electric current. Resistance it the reciprocal of conductance. Resistance in an AC circuit has the same effect in a DC circuit. Alternating current flowing through a resistance results in a power loss in the resistor. This loss is expressed the same as in direct current and is equal to I^2R.

VAR - the term used for volt-amperes reactive.

VARhour Meter - an electric meter that measures and registers the integral with respect to time of the reactive power of the circuit in which it is connected, the unit of measure is kilovarhour.

Volt - the unit of electromotive force or potential difference, where one volt will cause one ampere to flow when impressed across a one-ohm resistor.

Volt-Ampere - volt-amperes in a balanced system is the product of volts and the total current that flows because of the voltage, expressed in VA:

$$VA = \sqrt{3}\, E_L I_L$$

In an unbalanced circuit VA is equal to the square root of active power squared plus reactive volt-amperes squared:

$$VA = \sqrt{(W)^2 + (RVA)^2}$$

Watt - the unit of active power that is defined as the rate energy is delivered to a circuit. It is the power expended when a current of one ampere flows through a resistance of one ohm.

Watthour - a unit of electric energy that is consumed in one-hour when the average power during the hour is one watt.

Watthour Meter - an electric meter that measures and registers the integral with respect to time of the active power of the circuit that it is connected. This power integral is the energy delivered to the circuit during the interval over which the integration extends and the unit in which it is measured is usually the kilowatthour.

8 Records

The PCD2000 provides fault and operations records. It also provides a list of records not yet reported.

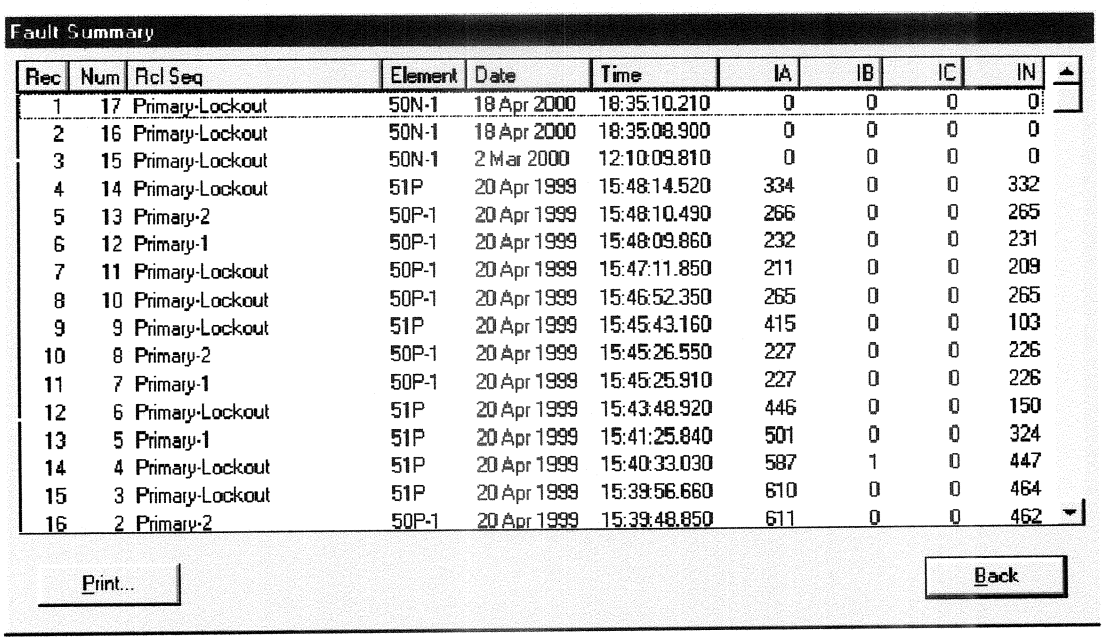
8.1 Fault Summary

The PCD2000 provides a summary of the last 128 faults. The Fault Summary includes the:

- Record number (most recent listed first as "1")
- Fault number (numbered in order occurred)
- Enabled settings table and recloser sequence number (1, 2, 3, 4 or L for lockout)
- Tripping element
- Date and time
- Phase and neutral currents (magnitude only)

After a fault, the MMI continuously displays the apparent distance to the fault in miles and the fault currents (magnitude only) until the targets are reset. Save the Fault Summary as a file via the WinPCD.

Figure 8-1. Fault Summary Window in WinPCD



Fault Summary

Rec	Num	Rcl Seq	Element	Date	Time	IA	IB	IC	IN
1	17	Primary-Lockout	50N-1	18 Apr 2000	18:35:10.210	0	0	0	0
2	16	Primary-Lockout	50N-1	18 Apr 2000	18:35:08.900	0	0	0	0
3	15	Primary-Lockout	50N-1	2 Mar 2000	12:10:09.810	0	0	0	0
4	14	Primary-Lockout	51P	20 Apr 1999	15:48:14.520	334	0	0	332
5	13	Primary-2	50P-1	20 Apr 1999	15:48:10.490	266	0	0	265
6	12	Primary-1	50P-1	20 Apr 1999	15:48:09.860	232	0	0	231
7	11	Primary-Lockout	50P-1	20 Apr 1999	15:47:11.850	211	0	0	209
8	10	Primary-Lockout	50P-1	20 Apr 1999	15:46:52.350	265	0	0	265
9	9	Primary-Lockout	51P	20 Apr 1999	15:45:43.160	415	0	0	103
10	8	Primary-2	50P-1	20 Apr 1999	15:45:26.550	227	0	0	226
11	7	Primary-1	50P-1	20 Apr 1999	15:45:25.910	227	0	0	226
12	6	Primary-Lockout	51P	20 Apr 1999	15:43:48.920	446	0	0	150
13	5	Primary-1	51P	20 Apr 1999	15:41:25.840	501	0	0	324
14	4	Primary-Lockout	51P	20 Apr 1999	15:40:33.030	587	1	0	447
15	3	Primary-Lockout	51P	20 Apr 1999	15:39:56.660	610	0	0	464
16	2	Primary-2	50P-1	20 Apr 1999	15:39:48.850	611	0	0	462

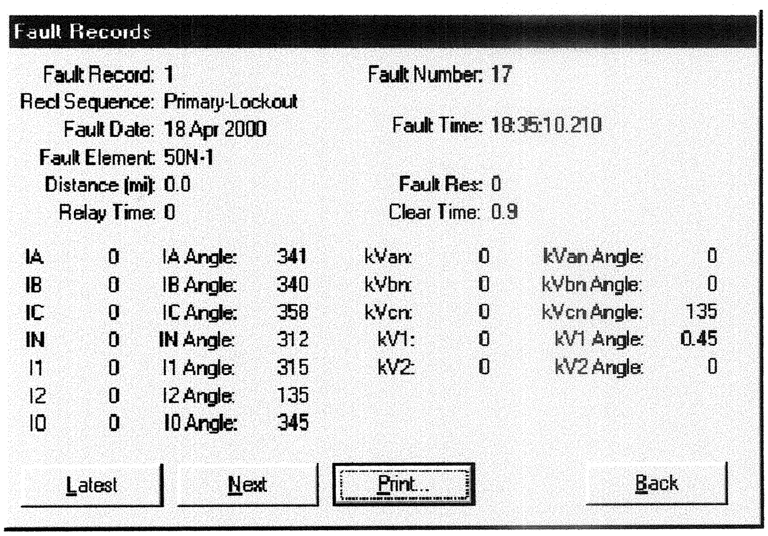
8.2 Fault Record

The Fault Record contains the last 128 faults. The Fault Record displays one fault at a time and includes the following information:

- Record number
- Fault number
- Reclose sequence number and enabled settings table
- Date and time
- Tripping element
- Apparent distance to the fault in miles
- Fault resistance
- Relay operate time
- Breaker clearing time
- Phase and neutral currents (magnitude and angle)
- Positive, negative and zero sequence currents (magnitude and angle)
- Phase voltages (magnitude and angle)
- Positive and negative sequence voltages (magnitude and angle)

Save the Fault Record as a file by using WinPCD.

Figure 8-2. Fault Record Window in WinPCD



8.3 Operations Record

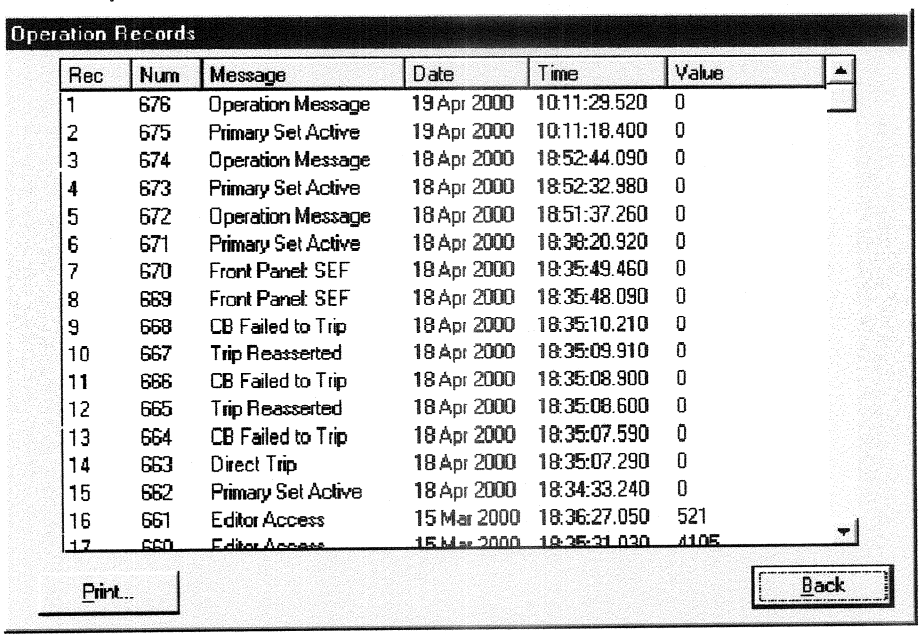
The PCD2000 provides an operations log in which any operation within the PCD2000 is recorded. This includes internal operations such as logical tripping elements and relay failures. The operations recorder also logs external events such as settings changes, circuit breaker operations, and logical input operations. During a fault the operations recorder does not know or care what element actually tripped and cleared the fault. It only knows that certain logical element became active and logs them with a time stamp. It is very possible that many elements may be logged for a specific fault but only one was responsible for fault clearing. See the Fault Records for the element responsible for fault clearing. A complete listing of all the possible operations logs is listed along with a description in Table 8-2. For detailed definitions to the actual logical elements (51P, 27-1P, 81S-1, etc.) see the Programmable Outputs section. It is important to note that the operations record logs only those elements that change state. These states can change by actual events or by "forcing" an event to occur via the Operations Menu. See the Operations Menu section for complete details on forcing events.

Using WinPCD, the existing operations records can be saved to a file on a disk. Simply scroll down to the least recent operations record, hit 'ESC' and select "Save to a Disk."

Multiple methods can be used to obtain operations information from the PCD2000.

1. The front panel MMI Main Menu item "Records" is accessed.
2. The WinPCD menu item "Records" is accessed. Figure 8-3 shows a sample record obtained through the WinPCD program.
3. Depending on the communications protocol contained in the PCD2000, a command is issued to send the operations records.

Figure 8-3. Operations Records Window in WinPCD



Rec	Num	Message	Date	Time	Value
1	676	Operation Message	19 Apr 2000	10:11:29.520	0
2	675	Primary Set Active	19 Apr 2000	10:11:18.400	0
3	674	Operation Message	18 Apr 2000	18:52:44.090	0
4	673	Primary Set Active	18 Apr 2000	18:52:32.980	0
5	672	Operation Message	18 Apr 2000	18:51:37.260	0
6	671	Primary Set Active	18 Apr 2000	18:38:20.920	0
7	670	Front Panel: SEF	18 Apr 2000	18:35:49.460	0
8	669	Front Panel: SEF	18 Apr 2000	18:35:48.090	0
9	668	CB Failed to Trip	18 Apr 2000	18:35:10.210	0
10	667	Trip Reasserted	18 Apr 2000	18:35:09.910	0
11	666	CB Failed to Trip	18 Apr 2000	18:35:08.900	0
12	665	Trip Reasserted	18 Apr 2000	18:35:08.600	0
13	664	CB Failed to Trip	18 Apr 2000	18:35:07.590	0
14	663	Direct Trip	18 Apr 2000	18:35:07.290	0
15	662	Primary Set Active	18 Apr 2000	18:34:33.240	0
16	661	Editor Access	15 Mar 2000	18:36:27.050	521

As can be seen in Figure 8-3, the operations records may contain a value associated with them. This value is a decimal number that further defines the occurrence. "Editor Access" and "Self Test Failure" logs will include a value. To interpret this number it must first be converted to binary. The binary bit pattern when compared to Table 8-1 will show what occurred. Notice in Table 8-1 that the values for "Editor Access" and "Self Test Failure" mean different things. For example: if the Operations Log records an "Editor Access" with a value of 256 it will not mean the same as a "Self Test Failure" value of 256".

The Operations Record contains the last 512 operations. The Operations Record includes the:

- Record number (most recent listed as "1")
- Operation number (numbered sequentially in order of occurrence)
- Description of the operation
- Date and time of the operation

When the operation number reaches 9999, the screen resets to 0001.

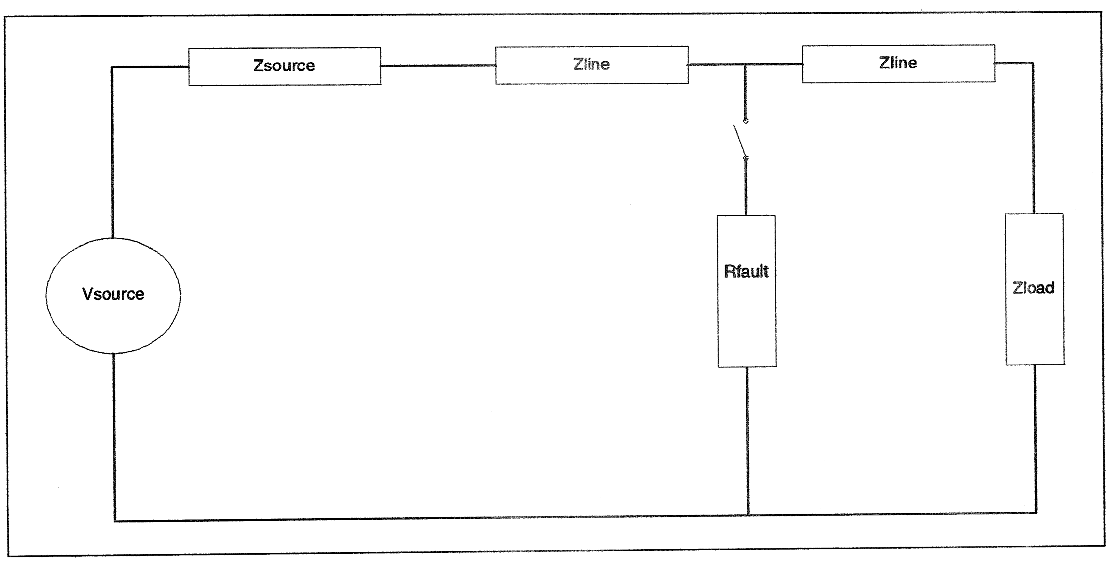
8.4 Fault Locator

The PCD2000 fault algorithm is used to calculate estimated fault resistance and apparent distance to the fault. This calculation is performed by comparing the prefault current and voltage to the fault current and voltage and by analyzing the positive and zero sequence reactance per mile. Three to six cycles of fault current are needed to analyze the fault values. The system parameters are used to estimate the source impedance (known impedance) and source voltage. The fault values are used to estimate the load impedance (estimated impedance) and determine fault type. The known impedance and estimated impedance are used to easily calculate the fault impedance. Once the fault impedance is calculated, the distance to fault can be readily calculated using the fault impedance, the line impedance and the line length.

The Fault algorithm is designed to be used on a homogenous radial three-phase distribution line without many taps. Therefore, the unit is not intended to be used on a distribution line with many different types of conductors because the algorithm will not be as accurate.

Fault data may not be accurate for a close-into-fault condition where there is no prefault power flow. In the case of closing into a fault during a reclose sequence, the apparent distance to the fault in miles for the first fault appears on the first line of the LCD for the entire reclose sequence. The fault records also display the original fault distance in each record of that reclose sequence. The algorithm for the fault locator is most applicable to a radial three-phase feeder.

Figure 8-4. Fault Locator



8.5 Self-Test Status

The PCD2000 provides continuous self-testing of its power supply voltages, its memory elements and 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 NORMAL STATUS light (LED) and system failure is indicated by the red FAIL STATUS light (or by the green NORMAL STATUS light not being lit in the case of a loss of control power).

Self-Test Failures are recorded as a decimal number in the Operations Record. After converting this number to binary, the binary bit pattern indicates the Self-Test Failure or Editor Access Status involved. The 1s 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 8-1 to reveal the failure. See the examples below for further explanation.

If the self-test fails, the PCD2000 is no longer providing protection. Replace the unit as soon as possible.

Table 8-1. Operations Record Value Information

Bit Position	Self-Test Failure	Editor Access Status	Decimal Value
0	CPU RAM	INTERRUPT LOGGING	1
1	CPU EPROM	REMOTE EDIT DISABLE = 1	2
2	CPU NVRAM	LOCAL EDIT DISABLED = 1	4
3	CPU EEPROM	FRONT MMI EDIT ACTIVE	8
4	NOT USED	FRONT COMM PORT EDIT ACTIVE	16
5	NOT USED	REAR COMM PORT EDIT ACTIVE	32
6	NOT USED	REAR AUX COMM PORT EDIT ACTIVE	64
7	NOT USED	REAL TIME CLOCK EDITED	128
8	DSP ROM	PROGRAMMABLE I/O EDITED	256
9	DSP INTERNAL RAM	PRIMARY SET EDITED	512
10	DSP EXTERNAL RAM	ALTERNATE1 SETTINGS EDITED	1024
11	DSP ANALOG/DIGITAL CONVETER	ALTERNATE2 SETTINGS EDITED	2048
12	DSP +/-15, + 12 V POWER SUPPLIES	CONFIGURATION SETTINGS EDITED	4096
13		COUNTER SETTINGS EDITED	8192
14	DSP STALL or +5 V POWER SUPPLY	ALARM SETTINGS EDITED	16384
15	DSP TO CPU COMMUNICATIONS	COMMUNICATIONS SETTINGS EDITED	32768

Examples of bit interpretation are shown below.

8.5.1 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.

8.5.2 Example of an Editor Access

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

The 1s 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.

8.6 PCD2000 Settings Tables Diagnostics

Three copies of each settings table are stored in a nonvolatile memory device, 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 the nonvolatile memory device.

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 PCD2000 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.

8.7 Operations Log Listing

Table 8-2 lists and describes all possible entries in the Operations Log.

Table 8-2. Operations Log Entry Descriptions

Log Entry	Description
27-1P Alarm	Indicates that the single phase undervoltage element, 27-1P, has operated. This log indicates only that the programmable logical output, 27-1P, has operated.
27-3P Alarm	Indicates that the three phase voltage element, 27-3P, has operated. This log indicates only that the programmable logical output, 27-3P, has operated.
32N Trip	Indicates that the ground directional power element, 32N, has operated.
32P Trip	Indicates that the phase directional power element, 32P, has operated.
46 Trip	Indicates that the negative sequence time overcurrent element, 46 has timed out and operated. It is possible that this may not have been the actual tripping element.
46 Unit Disabled	Indicates that the programmable input, "46" transitioned from a logical 1 to a logical 0, disabling the negative sequence time overcurrent element if used. This log indicates the state of the "46" input only.
46 Unit Enabled	Indicates that the programmable input, "46" transitioned from a logical 0 to a logical 1, enabling the negative sequence time overcurrent element if used. This log indicates the state of the "46" input only.
50N-1 Trip	Indicates that the ground instantaneous overcurrent element, 50N-1 has timed out and operated. It is possible that this may not have been the actual tripping element.
50N-2 Trip	Indicates that the ground instantaneous overcurrent element, 50N-2 has timed out and operated. It is possible that this may not have been the actual tripping element.

Log Entry	Description
50N-3 Trip	Indicates that the ground instantaneous overcurrent element, 50N-3 has operated. It is possible that this may not have been the actual tripping element.
50P/N-1 Disabled	Indicates that the "50-1" programmable input was de-asserted and the active 50P-1 and 50N-1 instantaneous overcurrent elements disabled. The "50-1" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "50-1" logical input is forced open in the Operations Menu. This record indicates the state of the "50-1" input only. This log will appear even if the 50P-1 and 50N-1 elements are disabled in the active settings group.
50P/N-1 Enabled	Indicates that the "50-1" programmable input was asserted and the active the 50P-1 and 50N-1 instantaneous overcurrent elements enabled. The "50-1" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "50-1" logical input is forced open in the Operations Menu. This record indicates the state of the "50-1" input only. This log will appear even if the 50P-1 and 50N-1 elements are disabled in the active settings group.
50P/N-2 Disabled	Indicates that the "50-2" programmable input was de-asserted and the active the 50P-2 and 50N-2 instantaneous overcurrent elements disabled. The "50-2" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "50-2" logical input is forced open in the Operations Menu. This record indicates the state of the "50-2" input only. This log will appear even if the 50P-2 and 50N-2 elements are disabled in the active settings group.
50P/N-2 Enabled	Indicates that the "50-2" programmable input was asserted and the active the 50P-2 and 50N-2 instantaneous overcurrent elements enabled. The "50-2" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "50-2" logical input is forced open in the Operations Menu. This record indicates the state of the "50-2" input only. This log will appear even if the 50P-2 and 50N-2 elements are disabled in the active settings group.
50P/N-3 Disabled	Indicates that the "50-3" programmable input was de-asserted and the active the 50P-3 and 50N-3 instantaneous overcurrent elements disabled. The "50-3" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "50-3" logical input is forced open in the Operations Menu. This record indicates the state of the "50-3" input only. This log will appear even if the 50P-3 and 50N-3 elements are disabled in the active settings group.
50P/N-3 Enabled	Indicates that the "50-3" programmable input was asserted and the active the 50P-3 and 50N-3 instantaneous overcurrent elements enabled. The "50-3" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "50-3" logical input is forced open in the Operations Menu. This record indicates the state of the "50-3" input only. This log will appear even if the 50P-3 and 50N-3 elements are disabled in the active settings group.
50P-1 Trip	Indicates that the phase instantaneous overcurrent element, 50P-1 has timed out and operated. It is possible that this may not have been the actual tripping element.
50P-2 Trip	Indicates that the phase instantaneous overcurrent element, 50P-2 has timed out and operated. It is possible that this may not have been the actual tripping element.
50P-3 Trip	Indicates that the phase instantaneous overcurrent element, 50P-3 has operated. It is possible that this may not have been the actual tripping element.
51N Trip	Indicates that the ground time overcurrent element, 51N has timed out and operated. It is possible that this may not have been the actual tripping element.
51P Trip	Indicates that the phase time overcurrent element, 51P has timed out and operated. It is possible that this may not have been the actual tripping element.
52a Closed	Indicates the state of the programmable logic input "52A". This record indicates the state of the programmable input "52A" only. It does not imply an actual breaker state. The "52A Closed" record indicates that the "52A" logical input was at a logical 1 at the time of the logging.
52a Opened	Indicates the state of the programmable logic input "52A". This record indicates the state of the programmable input "52A" only. It does not imply an actual breaker state. The "52A Opened" record indicates that the "52A" logical input was at a logical 0 at the time of the logging.

Log Entry	Description
52b Closed	Indicates the state of the programmable logic input "52B". This record indicates the state of the programmable input "52B" only. It does not imply an actual breaker state. The "52B Closed" record indicates that the "52B" logical input was at a logical 1 at the time of the logging.
52b Opened	Indicates the state of the programmable logic input "52B". This record indicates the state of the programmable input "52B" only. It does not imply an actual breaker state. The "52B Opened" record indicates that the "52B" logical input was at a logical 0 at the time of the logging.
59 Alarm	Indicates that the overvoltage element, 59, has operated. This log indicates only that the programmable logical output, 59, has operated.
67 Unit Disabled	Indicates that the programmable input, "67N" transitioned from a logical 1 to a logical 0, disabling the ground directional time overcurrent element if used. This log indicates the state of the "67N" input only.
67N Trip	Indicates that the directional ground time overcurrent element, 67N has timed out and operated. It is possible that this may not have been the actual tripping element.
67N Unit Enabled	Indicates that the programmable input, "67N" transitioned from a logical 0 to a logical 1, enabling the ground directional time overcurrent element if used. This log indicates the state of the "67N" input only.
67P Trip	Indicates that the directional phase time overcurrent element, 67P has timed out and operated. It is possible that this may not have been the actual tripping element.
67P-1 67P-2 67P-3	67P-1 Fault Issued 67P-2 Fault Issued 67P-3 Fault Issued
67P Unit Disabled	Indicates that the programmable input, "67P" transitioned from a logical 1 to a logical 0, disabling the phase directional time overcurrent element if used. This log indicates the state of the "67P" input only.
67P Unit Enabled	Indicates that the programmable input, "67P" transitioned from a logical 0 to a logical 1, enabling the phase directional time overcurrent element if used. This log indicates the state of the "67P" input only.
79 Counter 1 Alarm	Indicates that the number of reclose operations has exceeded the Reclose Counter 1 Alarm setting.
79 Counter 2 Alarm	Indicates that the number of reclose operations has exceeded the Reclose Counter 2 Alarm setting.
79M Input Disabled	Indicates the state of the multi shot reclose,"79M", programmable input. This record will appear when the "79M" input transitions from a logical 1 to a logical 0.
79M Input Enabled	Indicates the state of the multi shot reclose,"79M", programmable input. This record will appear when the "79M" input transitions from a logical 0 to a logical 1.
79S Input Disabled	Indicates the state of the single shot reclose,"79S", programmable input. This record will appear when the "79S" input transitions from a logical 1 to a logical 0.
79S Input Enabled	Indicates the state of the single shot reclose,"79S", programmable input. This record will appear when the "79S" input transitions from a logical 0 to a logical 1.
79V Block	Indicates that one or more phases of voltage fell below the 79V threshold setting. Will log a 79V Block only during a reclose operation.
81O-1 Overfrequency	Indicates that the overfrequency module 1 element, 81O-1, has timed out and operated. This log indicates only that the programmable logical output, 81O-1, has operated.
81O-2 Overfrequency	Indicates that the overfrequency module 2 element, 81O-2, has timed out and operated. This log indicates only that the programmable logical output, 81O-2, has operated.
81R-1 Restore	Indicates that the frequency restoration module 1 element, 81R-1, has timed out and operated. This log indicates only that the programmable logical output, 81R-1, has operated.
81R-2 Restore	Indicates that the frequency restoration module 1 element, 81R-2, has timed out and operated. This log indicates only that the programmable logical output, 81R-2, has operated.

Log Entry	Description
81S-1 Trip	Indicates that the frequency load shed module 1 element, 81S-1, has timed out and operated. This log indicates only that the programmable logical output, 81S-1, has operated.
81S-2 Trip	Indicates that the frequency load shed module 2 element, 81S-2, has timed out and operated. This log indicates only that the programmable logical output, 81S-2, has operated.
81V Block	Indicates that one or more phases of voltage fell below the 81V threshold setting.
Accumulated KSI	Indicates that the KSI summation has exceeded the KSI Alarm setting.
Alt 1 Set Active	Indicates that a transition from a Alternate 2 or Primary settings group took place and that the Alternate 1 settings are active at this point in the record.
Alt 2 Set Active	Indicates that a transition from a Alternate 1 or Primary settings group took place and that the Alternate 2 settings are active at this point in the record.
ARC Blocked	Indicates that the programmable input Auto Reclose Timer Block, "ARCI", transitioned from a logical 0 to a logical 1.
ARC Enabled	Indicates that the programmable input Auto Reclose Timer Block, "ARCI", transitioned from a logical 1 to a logical 0.
BATRAM Failure	Indicates a failure of the PCD2000 Battery Backed-up Random Access Memory. Contact ABB technical support at this time.
BFT Operation	Indicates operation of the Breaker Failure Trip (BFT) logical output.
Blown Fuse Alarm	Indicates that "BFUA" programmable logical output has operated.
Breaker Closed	Indicates that a "CLOSE BREAKER" command was entered from the Operations Menu.
Breaker Opened	Indicates that a "TRIP BREAKER" command was entered from the Operations Menu.
CB Failed to Close	Indicates the Close Fail Timer has expired.
CB Failed to Trip	Indicates the Trip Fail Timer has expired.
CB Pops Closed	Indicates that the circuit breaker has closed after a CB fail to close state has occurred. This could have only occurred external to the PCD2000 or a "Close" command issued via the PCD2000 MMI or WinPCD program.
CB Pops Open	Indicates that the circuit breaker has opened after a CB fail to trip state has occurred. This open state could have occurred when the breaker finally opened (slow breaker) or when manually opened.
CB Slow to Trip	Indicates that the "Slow Breaker Time" setting in the configuration settings has expired.
CB State Unknown	Indicates that the 52A and 52B circuit breaker auxiliary contact inputs to the PCD2000 are in an invalid state.
Cold Load Alarm	Logs when the cold load timer is counting down.
Control Power Fail	Indicates that the control power has dropped below the control power operating threshold as outlined in the Specifications section
CRI Input Closed	Indicates that the programmable input Clear Reclose and Overcurrent Counters, "CRI", transitioned from a logical 0 to a logical 1.
CRI Input Opened	Indicates that the programmable input Clear Reclose and Overcurrent Counters, "CRI", transitioned from a logical 1 to a logical 0.
DSP Failure	Indicates a failure of the PCD2000 Digital Signal Processor. Contact ABB technical support at this time.
Editor Access	Indicates that a settings change has been made.
EEPROM Failure	Indicates a failure of the PCD2000 Non-Volatile Memory. Contact ABB technical support at this time.
Event Cap 1 Init	Indicates that the programmable input "ECI1" was asserted and an event capture taken. The data from the event is stored in the Fault Records.
Event Cap 1 Reset	Indicates that the programmable input "ECI1" was de-asserted.

Log Entry	Description
Event Cap 2 Init	Indicates that the programmable input "ECI2" was asserted and an event capture taken. The data from the event is stored in the Fault Records.
Event Cap 2 Reset	Indicates that the programmable input "ECI2" was de-asserted.
Ext Close Disabled	Indicates that the programmable input "Close" was de-asserted.
Ext Close Enabled	Indicates that the programmable input "Close" was asserted. This record indicates the state of the programmable input "Close" only. It does not imply an actual breaker close.
Ext Trip Disabled	Indicates that the programmable input "Open" was de-asserted.
Ext Trip Enabled	Indicates that the programmable input "Open" was asserted. This record indicates the state of the programmable input "Open" only. It does not imply an actual breaker trip.
Ext. Trip & ARC	Indicates that the TARC (Trip and Auto Reclose) logical Input became a logical 1 and the relay went through the reclose cycle.
Ext. Trip CB Stuck	Indicates that the 52A contact opened and the 52B contact closed but current is still flowing through the relay.
External Close	Indicates that the PCD2000 saw the breaker close via the 52A and 52B Programmable Logic inputs, but the relay did not cause the breaker to open.
External Trip	Indicates that the PCD2000 saw the breaker open via the 52A and 52B Programmable Logic inputs, but the relay did not cause the breaker to open.
Grnd. TC Disabled	Indicates that the "GRD" programmable input was de-asserted and the active ground overcurrent elements disabled. The "GRD" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "GRD" logical input is forced open in the Operations Menu. This record indicates the state of the "GRD" input only.
Grnd. TC Enabled	Indicates that the "GRD" programmable input was asserted and the active ground overcurrent elements enabled. The "GRD" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "GRD" logical input is forced Closed in the Operations Menu. This record indicates the state of the "GRD" input only.
High PF Alarm	Indicates that the power factor has risen above the High Power Factor Alarm setting.
KVAr Demand Alarm	Indicates that the demand KiloVArs have exceeded the Demand KiloVAr Alarm setting.
Load Alarm	Indicates that the load current has exceeded the Load Current Alarm setting.
Low PF Alarm	Indicates that the power factor has gone below the Low Power Factor Alarm setting.
Neg. KVAr Alarm	Indicates that the negative KiloVArs have exceeded the negative KiloVAr Alarm setting.
Neutral Demand Alarm	Indicates that the neutral demand current has exceeded the Neutral Demand Current Alarm setting.
OC Trip Counter	Indicates that the Overcurrent Trip Counter has exceeded the Overcurrent Trip Counter Alarm setting.
Phase Demand Alarm	Indicates that the phase demand current has exceeded the Phase Demand Current Alarm setting.
Phase TC Disabled	Indicates that the "PH3" programmable input was de-asserted and the active phase overcurrent elements disabled. The "PH3" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "PH3" logical input is forced open in the Operations Menu. This record indicates the state of the "PH3" input only.
Phase TC Enabled	Indicates that the "PH3" programmable input was asserted and the active phase overcurrent elements enabled. The "PH3" programmable input must be assigned to a physical input or feedback term for this record to appear. It will also appear if the "PH3" logical input is forced closed in the Operations Menu. This record indicates the state of the "PH3" input only.
Pos Watt Alarm 1	Indicates that the positive kilowatts have exceeded the Positive Kilowatt Alarm 1 setting.
Pos Watt Alarm 2	Indicates that the positive kilowatts have exceeded the Positive Kilowatt Alarm 2 setting.
Pos. KVAr Alarm	Indicates that the positive KiloVArs have exceeded the Positive KiloVAr Alarm setting.

Log Entry	Description
Primary Set Active	Indicates that a transition from an Alternate settings group took place and that the Primary settings are active at this point in the record.
RAM Failure	Indicates a failure of the PCD2000 Random Access Memory. Contact ABB technical support at this time.
Reclose Initiated	Indicates that the PCD2000 has entered into the reclose sequence.
Recloser Disabled	Indicates that the 43A programmable input became de-asserted or was mapped to a non active physical input or feedback term. This record indicates the state of the "43A" input only. This log will appear even if the Recloser is disabled at 79-1 in the active settings group.
Recloser Enabled	Indicates that the "43A" programmable input became asserted or was unmapped to a physical input or feedback term. This record indicates the state of the "43A" input only. This log will appear even if the Recloser is disabled at 79-1 in the active settings group.
Recloser Lockout	Indicates a recloser lockout state.
ReTrip Operation	Indicates operation of the ReTrip logical output.
ROM Failure	Indicates a failure of the PCD2000 Read Only Memory. Contact ABB technical support at this time.
SEF Disabled	Indicates that the Sensitive Earth Fault programmable logic input, "SEF" has transitioned from a logical 1 to a logical 0 disabling the SEF element if used. (SEF model only.)
SEF Enabled	Indicates that the Sensitive Earth Fault programmable logic input, "SEF" has transitioned from a logical 0 to a logical 1 enabling the SEF element if used. (SEF model only.)
Self Test Failed	Indicates a failure of the PCD2000 during the self check procedure.
Springs Charged	Indicates the state of the Spring Charging Contact, "SCC", programmable input. This record will appear when the "SCC" input transitions from a logical 0 to a logical 1.
Springs Discharged	Indicates the state of the Spring Charging Contact, "SCC", programmable input. This record will appear when the "SCC" input transitions from a logical 1 to a logical 0.
Supervisory Disable	Indicates that the logical input "Local/SupV" has transitioned from a logical 1 to a logical 0.
Supervisory Enabled	Indicates that the logical input "Local/SupV" has transitioned from a logical 0 to a logical 1.
TARC Closed	Indicates that the programmable input Trip and Auto Reclose, "TARC", transitioned from a logical 0 to a logical 1. Logs when an External Trip and Auto reclose occurred.
TARC Opened	Indicates that the programmable input Trip and Auto Reclose, "TARC", transitioned from a logical 1 to a logical 0.
TCM Input Closed	Indicates the state of the Trip Circuit Monitor, "TCM," programmable input. This record will appear when the "TCM" input transitions from a logical 0 to a logical 1.
TCM Input Opened	Indicates the state of the Trip Circuit Monitor, "TCM," programmable input. This record will appear when the "TCM" input transitions from a logical 1 to a logical 0.
Trip Coil Failure	Indicates that the logical input "TCM" indicated a trip coil failure.
ULI1 Input Closed	Indicates that the User Logical Input, ULI1, transitioned from a logical 0 to a logical 1.
ULI1 Input Opened	Indicates that the User Logical Input, ULI1, transitioned from a logical 1 to a logical 0.
ULI2 Input Closed	Indicates that the User Logical Input, ULI2, transitioned from a logical 0 to a logical 1.
ULI2 Input Opened	Indicates that the User Logical Input, ULI2, transitioned from a logical 1 to a logical 0.
ULI3 Input Closed	Indicates that the User Logical Input, ULI3, transitioned from a logical 0 to a logical 1.
ULI3 Input Opened	Indicates that the User Logical Input, ULI3, transitioned from a logical 1 to a logical 0.
ULI4 Input Closed	Indicates that the User Logical Input, ULI4, transitioned from a logical 0 to a logical 1.
ULI4 Input Opened	Indicates that the User Logical Input, ULI4, transitioned from a logical 1 to a logical 0.
ULI5 Input Closed	Indicates that the User Logical Input, ULI5, transitioned from a logical 0 to a logical 1.
ULI5 Input Opened	Indicates that the User Logical Input, ULI5, transitioned from a logical 1 to a logical 0.

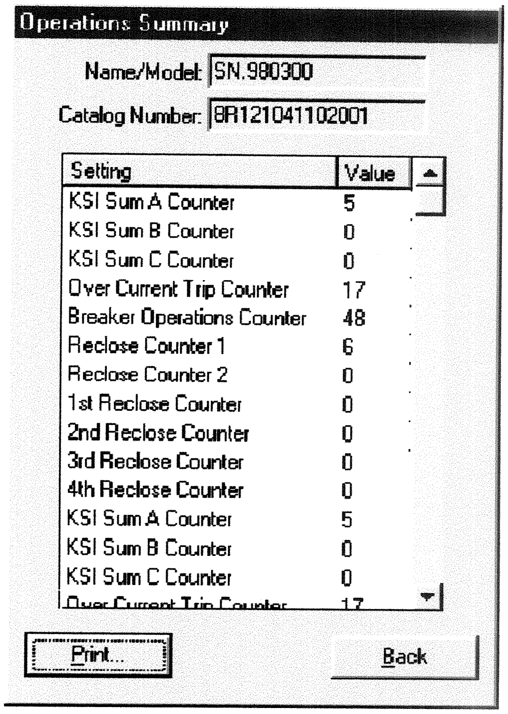
Log Entry	Description
ULI6 Input Closed	Indicates that the User Logical Input, ULI6, transitioned from a logical 0 to a logical 1.
ULI6 Input Opened	Indicates that the User Logical Input, ULI6, transitioned from a logical 1 to a logical 0.
ULI7 Input Closed	Indicates that the User Logical Input, ULI7, transitioned from a logical 0 to a logical 1.
ULI7 Input Opened	Indicates that the User Logical Input, ULI7, transitioned from a logical 1 to a logical 0.
ULI8 Input Closed	Indicates that the User Logical Input, ULI8, transitioned from a logical 0 to a logical 1.
ULI8 Input Opened	Indicates that the User Logical Input, ULI8, transitioned from a logical 1 to a logical 0.
ULI9 Input Closed	Indicates that the User Logical Input, ULI9, transitioned from a logical 0 to a logical 1.
ULI9 Input Opened	Indicates that the User Logical Input, ULI9, transitioned from a logical 1 to a logical 0.
Wave Cap Init	Indicates that the programmable input "WCI" was asserted and an oscillographic record stored. The data from the event is stored in the Waveform Capture Records.
Wave Cap Reset	Indicates that the programmable input "WCI" was de-asserted.
Zone Seq. Disabled	Indicates that the programmable input "ZSC" was de-asserted and the Zone Sequence Coordination function was disabled. This record indicates the state of the "ZSC" input only. This log will appear even if the Zone Sequence Coordination function is disabled in the Configuration settings.
Zone Seq. Enabled	Indicates that the programmable input "ZSC" was asserted and the Zone Sequence Coordination function was enabled. This record indicates the state of the "ZSC" input only. This log will appear even if the Zone Sequence Coordination function is disabled in the Configuration settings.
Zone Step	Indicates that a zone sequence coordination operation occurred.

8.8 Operations Summary

The Operations Summary includes:

- Summation of breaker interruption duty on a per-phase basis in KSI (thousand symmetrical amperes)
- Number of overcurrent trips
- Total number of reclosures (both counters)
- Number of breaker operations (overcurrent, load current and no load)
- Number of successful reclosings by reclosure sequence number (1st, 2nd, 3rd and 4th) Save the Operations Summary as a file via the WinPCD.

Figure 8-5. Operations Summary Window in WinPCD



8.9 Unreported Records

When a SCADA application polls a relay, it sends the fault and operations information to the Unreported Fault and Operations Records. At the same time the information also appears in the Fault and Operations Records. Records remain in the Unreported Records until either SCADA downloads the information, or you physically view the Unreported Records screen. When SCADA downloads the information, the entire Unreported Records is cleared, the record counter on the Unreported Records Status screen drops to 0 and access to the Unreported Records 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 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.

In this manner, the Unreported Records helps by showing the faults and operations records that 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 were reported and which remain in the Unreported Records.

Figure 8-6. Unreported Fault Records Window in WinPCD

Unreported Fault Records

Rec	Num	Rcl Seq	Element	Date	Time	IA	IB	IC	IN
1	42	Primary-1	50P-1	2 Jun 1998	15:02:06.690	158	152	779	634
2	43	Primary-2	50P-1	2 Jun 1998	15:02:11.860	158	152	843	694
3	44	Primary-3	50P-1	2 Jun 1998	15:02:24.640	157	150	741	598
4	45	Primary-1	50P-1	2 Jun 1998	15:04:27.140	155	152	760	617
5	46	Primary-2	50P-1	2 Jun 1998	15:04:29.310	155	151	764	621
6	47	Primary-Lockout	50P-1	2 Jun 1998	15:04:33.690	157	151	763	621
7	48	Primary-1	51N	2 Jun 1998	15:05:37.600	157	151	762	619
8	49	Primary-2	51N	2 Jun 1998	15:05:44.280	157	152	763	620
9	50	Primary-Lockout	51N	2 Jun 1998	15:05:53.180	156	152	761	618
10	51	Primary-Lockout	50P-1	2 Jun 1998	15:06:04.440	1218	152	241	404
11	52	Primary-Lockout	51N	2 Jun 1998	15:06:27.870	107	600	42	531

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Figure 8-7. Unreported Operations Records Window in WinPCD

Unreported Operations Records

Rec	Num	Message	Date	Time	Value
1	672	Operation Message #5	18 Apr 2000	18:51:37.260	0
2	673	Primary Set Active	18 Apr 2000	18:52:32.980	0
3	674	Operation Message #5	18 Apr 2000	18:52:44.090	0
4	675	Primary Set Active	19 Apr 2000	10:11:18.400	0
5	676	Operation Message #5	19 Apr 2000	10:11:29.520	0

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9 Communication

9.1 PCD2000 Communication Environment

The PCD2000 is equipped with an optical fiber optic port on the front panel for serial port communications. An optical communications cable can be connected from the front port or a standard null modem cable from the rear port to a personal computer running the WinPCD configuration software for data access and set up. Please contact your local ABB representative for information on these accessories.

In addition, two serial port modules are provided at the rear of the PCD2000, including a 9-pin RS-232C and a 3-wire RS-485connection. The rear RS-232C ports can interface with a modem using a straight through cable and a remotely connected computer. The RS-232C ports can also interface directly to a PC with the use of a null modem cable. The RS-232C ports are configured as data terminal equipment. Since non-isolated ports are susceptible to noise, this module, with its isolation, is recommended for connection to a SCADA system via modems, radios or other communication devices. In the event this module is installed, the non-isolated port on the CPU module will be disabled.

The PCD2000 supports various protocols. The command message structure and substructures for these protocols are available upon request. Contact the nearest ABB sales office or ABB at its Raleigh, NC technical support office and request the "Protocol Document" for the unit type (PCD2000 and the specific protocol of interest). The following protocols are available in the PCD2000 relay:

- Modbus® ASCII: Industry standard protocol available through the front panel optical port or communications module.
- Modbus® RTU: Industry standard protocol available through the communications module.
- DNP 3.0: An IEC60870-5 based protocol available through the communications module.

9.2 PCD2000 Communications Settings

Using the front panel HMI can change the communication settings for the PCD2000. When you use the local HMI, the communication ports are blocked from downloading settings but can still transmit data. Similarly, when a communications port is downloading settings, the HMI and other communication ports are blocked from changing settings.

Table 9-1. Communication Settings

HMI Abbreviation	WinPCD Name and Description
Unit Address	Unit Address This setting is the data-communications address of the PCD2000 unit. The value is an integer in the range 1 to 65,535. This value is used by the computer (or other digital device) communicating with the PCD2000 to know which PCD2000 it is communicating with.
FP Baud FP Frame	Front Panel Configuration Two values are specified for digital communication through the front panel data port. The baud rate: 300, 1200, 2400, 4800, 9600 (default), or 19200 baud; and the frame pattern: EVEN-7-1, ODD-7-1, NONE-8-1 (default), EVEN-8-1, ODD-8-1, NONE-8-2, and NONE-7-2. These much match the communications settings of the computer (or other digital device) communicating with the PCD2000.
RP Baud RP Frame	Rear Panel Configuration Two values are specified for digital communication through the front panel data port. The baud rate: 300, 1200, 2400, 4800, 9600 (default), or 19200 baud; and the frame pattern: EVEN-7-1, ODD-7-1, NONE-8-1 (default), EVEN-8-1, ODD-8-1, NONE-8-2, and NONE-7-2. These much match the communications settings of the computer (or other digital device) communicating with the PCD2000.
RP Protocol	Rear Panel Protocol This setting specifies which communications protocol to use for data communication through the rear data port that is communicating with the computer connected to the PCD2000. The available choices are: ASCII Modbus® (default), RTU Modbus®, and DNP 3.0.
Parameter 1 : Parameter 25	Rear Port Parameter 1 : Rear Port Parameter 25 This settings affect data communication using the DNP 3.0 protocol. Contact ABB Power T&D Company Inc. for more information.
Mode Par 1: : Mode Par 8:	Rear Port Param Mode 1 : Rear Port Param Mode 8 This settings affect data communication using the DNP 3.0 protocol. Contact ABB Power T&D Company Inc. for more information.

9.2.1 PCD2000 Communications Module Overview:

The PCD2000 provides two communication module options: Type 3 and Type 4. The module types are summarized as follows:

- Type 3: Isolated RS-232 and RS-485 communication ports with selectable RTS/CTS flow control.
- Type 4: Isolated RS-232 and RS-485 ports with RTS/CTS flow control and radial or looped fiber-optic communication port.

9.2.2 Type 3 and Type 4 Communication Module Description

The PCD2000 offers two communication module options, the Type 3 and Type 4 Communication modules. The Type 3 module has electrically isolated RS232 and RS485 communication ports. The Type 4 module also has the same RS-232 and RS-485 but with an additional fiber optic communication port. The only difference between the PCD 2000 Type 3 Communications module and the PCD 2000 Type 4 Communications module is the addition of a fiber optic interface port installed on the Type 4 Communications module.

The Type 3 and 4 Communications Modules provide three serial communication paths between the outside world and the PCD2000's CPU. Additionally, this module provides RS-232 RTS/CTS handshaking to assist with data flow control that may be needed when interfacing with radio receiver/transmitters. The RTS/CTS feature may be selected by the placement of jumper H302. The time in milliseconds that RTS remains asserted past the end of data transmission is selected by jumper H202. This feature is used to eliminate squelch problems associated with radio transmission and reception. The module will transmit data on all ports at once but can only receive but on one port at one time. When data is received then that data is retransmitted over all ports except for the port were the data was received. This is basically the way all data is handled by this module.

Type 3 and Type 4 Communication Modules provide either two (Type 3 Module) or three (Type 4 Module) serial communication ports that function as a communication bridge between the RS-232 (9 pin D shell connector), the RS-485 (green 8 pin terminal connector), or the fiber optic ST connectors (Type 4 only). When these modules are installed, several PCD2000's, or other devices, may be networked together using a multi-dropped RS-485 scheme (Type 3 or Type 4) or a looped fiber network scheme (Type 4 only).

The modules will communicate at 1200, 2400, 4800, 9600, and 19.2K baud with any character framing or protocol without setup prior to operation.

9.2.3 Communication Bridge Feature

As previously described, the Type 3 and Type 4 Communication modules have the unique ability to re-transmit or echo messages on all ports simultaneously with the restriction that only one port can be assigned to receive. When data is received, it is re-transmitted over all ports except for the port where the data was received. The only exception is when the jumper H303 has LOOPED FIBER selected. In this case all data received by the fiber optic RxD port is re-transmitted back through the TxD fiber optic port in addition to the RS-232 and RS-485 ports.

This re-transmission ability allows the Type 3 and Type 4 Modules to act as a communication bridge where conversion from one physical media (i.e., RS-232, RS-485 or fiber) to another can be achieved on-board. All data transmitted by the module is regenerated to correct for signal distortion introduced in the transmission medium.

Typical applications would include installations where a single point of remote connection via an RS-232 based radio would need to be networked over several installed PCD2000's. This can be accomplished by attaching the radio's RS-232 output to one PCD2000, then multi-dropping the remaining PCD2000s via a RS-485 or looped fiber network connection. In this case, the first PCD2000 attached to the radio would act as the Communication Bridge, converting the RS-232 to either RS-485 or fiber. Other combinations are possible including 1) fiber to either RS-232 or RS-485 or 2) RS-485 to fiber either or RS-232.

Figure 9-1. Type 3 Communications Module

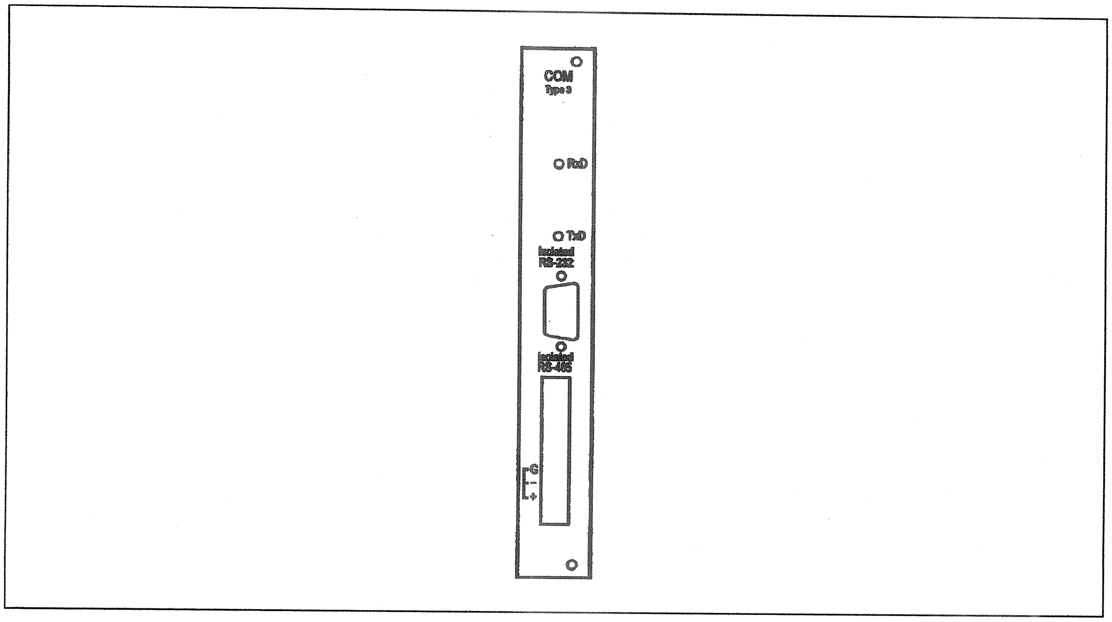
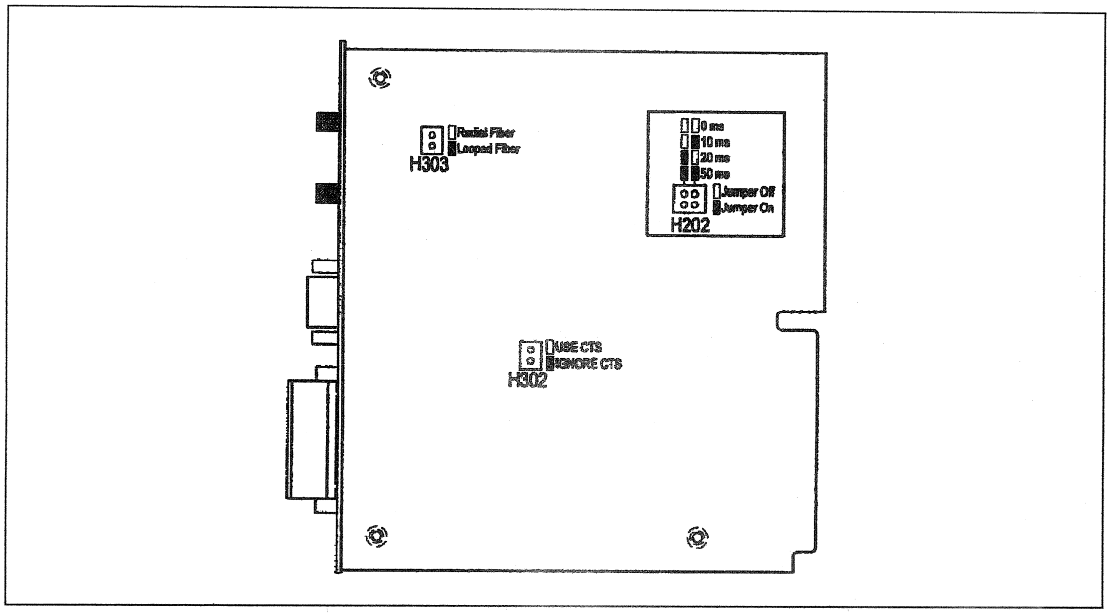


Figure 9-2. Type 4 Communications Module Jumper Locations



9.2.4 RS-232/RS-485 Pin Connections

The pin connections for the various communications ports are shown in Table 9-1 and 9-2.

Table 9-2. RS-485 Port Pin Connections

Pin	Description Number
G	RS-485 Common/VDC Return
-	RS-485 Minus
+	RS-485 Positive

9.2.4.1 RS-485 Port and Communications Card Internal Jumper Positioning

The RS-485 standard defines the properties of the electrical signal of the electronic bus interface that handles this communication. RS-485 differs from the RS-232C standard found on most devices. RS-485 has the advantage that makes it well suited for substation applications in a ring network where a maximum of 32 devices may be connected in a single RS-485 bus with a maximum distant of the communication wire length is 4,000 feet.

The RS-485 cable should be a shielded 3 conductor twisted cable. Using this kind of cable offers an inexpensive, easily available method for connecting field devices to the master device. The shield should be grounded at one end of the communications circuit, preferably the IED end to prevent induced interference that may result from circulating ground currents. Connect the field device's ground terminal directly to the equipment ground bus. Secure ground connections directly to the equipment ground bus and do not daisy chain them from one device ground to the next. Do not position signal cabling parallel to power conductors. Power conductors are defined as any cable or conductor carrying currents greater than 20 amperes. Make certain the polarity (+) and (-) is correct when connecting the RS-485 terminals on each device. Cables should be isolated from sources of electrical noise. Recommended cables are Alpha #58902; Belden #9729, #9842, #9829; and Carol #58902.

Table 9-3. RS-232 Port Pin Connections

Pin	Description Number
2	Receive Data - Relay receives data through this pin
3	Transmit Data - Relay transmits data through this pin
5	Signal Ground
7	Request To Send
8	Clear To Send

By contrast, the RS-232C standard supports one driver and receiver over a distance of 50 feet. However, RS-232C will also support an external modem or a radio transmitter remote from the substation increasing the communication distance to approximately 3.5 miles at transmission speeds as high as 20 KBPS. RS-232C has this advantage for remote communication to and from PCD2000 and VR-3S reclosers.

9.2.5 Enabling RTS/CTS Control

If your communications application requires RTS/CTS control, as in some radio applications, this can be enabled on the Com Type 3 and 4 Communications Module. To enable these features remove the module from the housing and locate a jumper labeled CTS (H302). Install the jumper across the two pins to disable RTS/CTS control, remove the jumper to enable RTS/CTS control.

Table 9-4. Communication Module Type 3 and Type 4 RTS/CTS Control, Jumper H302 Settings

RTS/CTS Control Jumper Settings	
Jumper Position	**RTS/CTS Control**
OFF	Disabled
ON	Enabled

The time in milliseconds jumper H202 selects that RTS remains asserted past the end of data transmission. This feature is used to eliminate squelch problems associated with radio transmission and reception. Delays can be programmed from 0 to 50 ms, refer to the following table for selection of desired delay times.

Table 9-5. Communication Module Type 3 and Type 4 RTS Drop Delay Time, Jumper H202 Settings

RTS Time Jumper Settings		
Jumper Position	**Jumper Position**	**RTS Drop Delay Time**
OFF	OFF	0 ms
OFF	ON	10 ms
ON	OFF	20 ms
ON	ON	50 ms

Note: If RTS/CTS is enabled and no CTS are applied, then message transmission for all remaining ports is disabled.

9.2.6 Fiber Optic Mode Control

As previously detailed, the Type 4 Communication module can be configured to operate in two basic fiber topologies: Radial or Looped. The mode of operation is selected via the H303 jumper labeled Radial Fiber or Looped Fiber.

Table 9-6. Communication Module Type 4 Fiber Optic Mode Control, Jumper H303 Settings

Fiber Optic Control Jumper Settings	
Jumper Position	**Mode**
OFF	Redial
ON	Looped

9.2.7 Radial Mode

When operating in this mode, incoming messages via the RxD fiber input are NOT re-transmitted to the TxD fiber output. This mode of operation should be considered the default mode for most installations. Also, this is the proper configuration mode for applications where the PCD2000 is acting as a communication bridge.

9.2.8 Looped Mode

In this mode the Type 4 Communication module will retransmit all data received by the fiber optic RxD input back through the TxD fiber optic output port in addition to the RS-232 TxD output and RS-485 ports. This mode of operation allows multiple PCD2000's to be networked in a single fiber loop without the need for external multiplexers or converters. It should be noted that since the incoming messages are re-generated, the number of units that can be physically looped is essentially unlimited, however, there is a small time delay introduced from unit-to-unit of approximately 10 ms. Connections should be made with ST type connectors.

Figure 9-3. Typical Application - Type 3 or 4 Communication Module RS-485 Multi-Drop

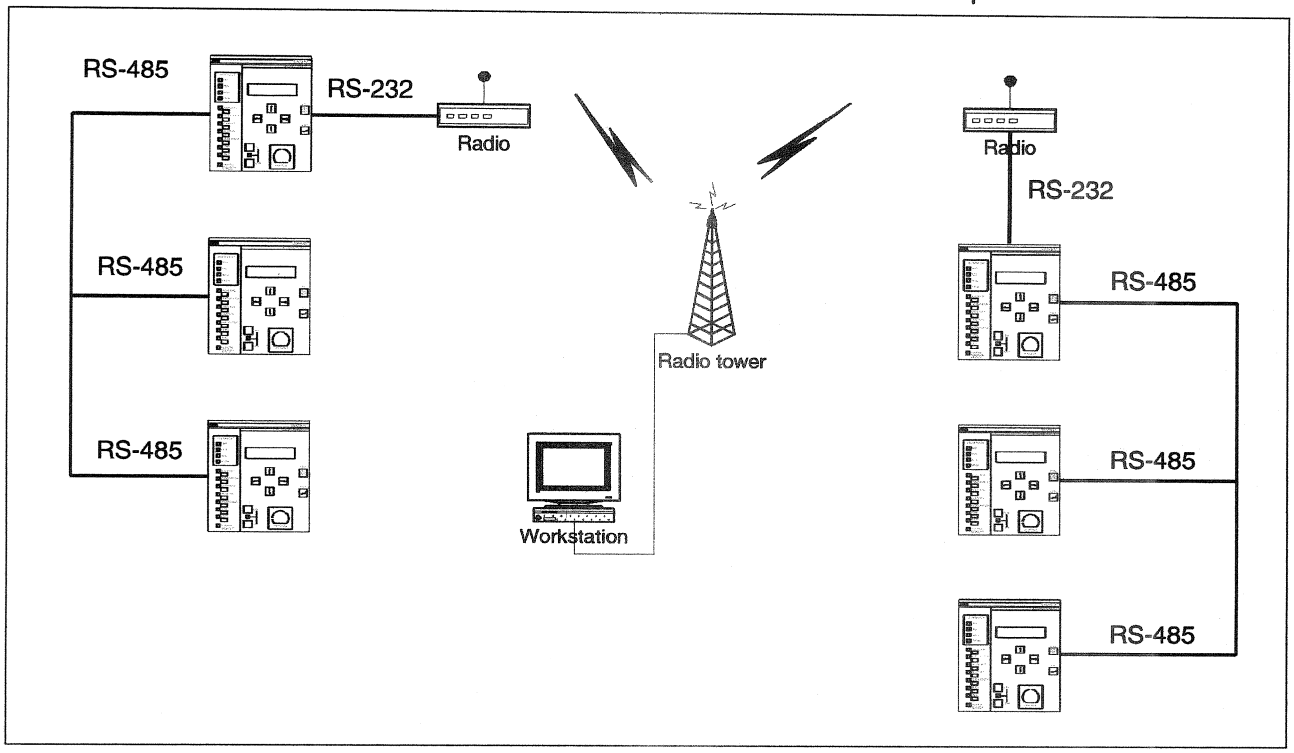


Figure 9-4. Typical Application - Type 4 Communication Module Radial Mode

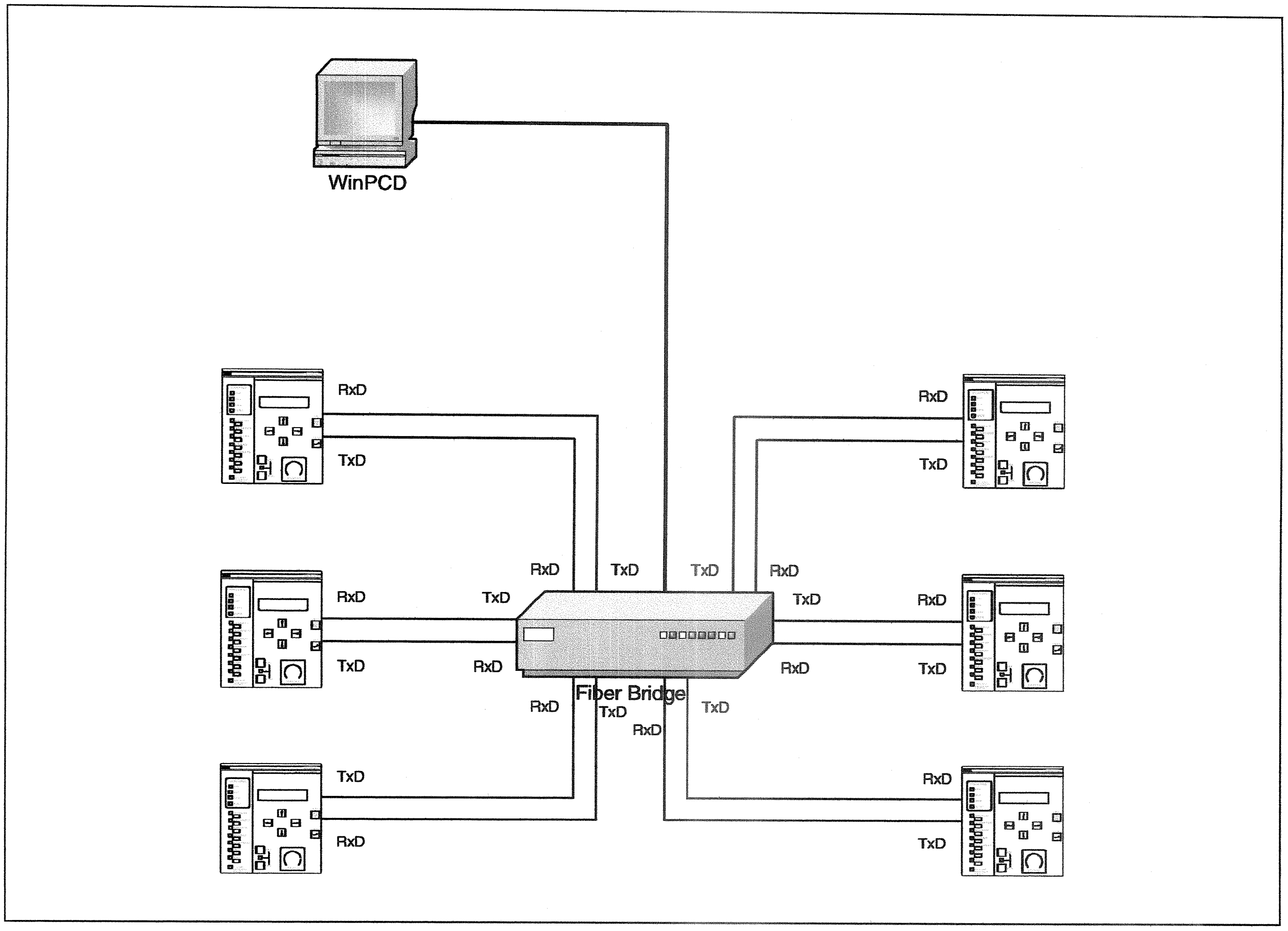


Figure 9-5. Typical Application - Type 4 Communication Module Loop Mode

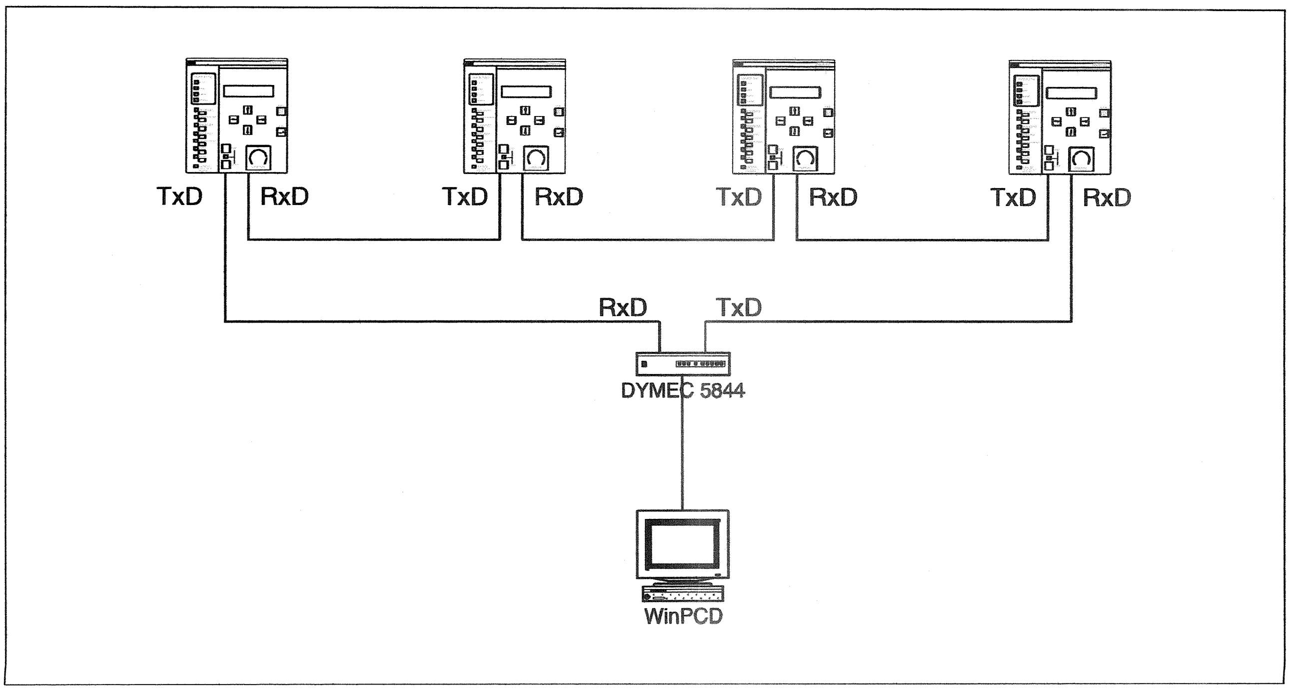
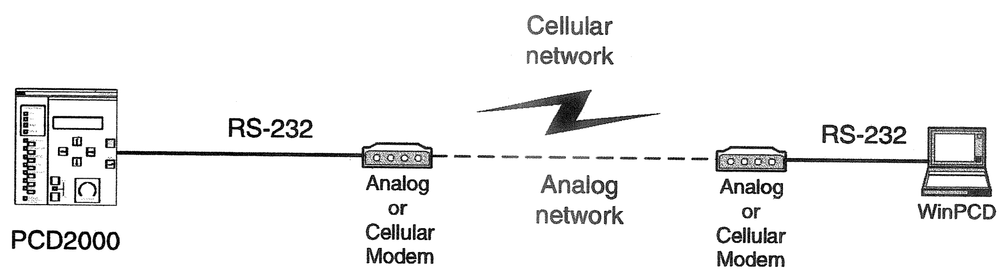


Figure 9-6. Typical Application - Analog Cellular Network



9.2.9 Connections to PCD2000

9.2.9.1 External Modem

There are many varieties of external modems available for electronic communication. Therefore, the recommended modem to use with PCD2000 is the US Robotics®, 56K Fax/Modem with the following configurations for Send and Receive:

Send Modem Dip-Switch Configuration:
Data Terminal Ready Override
Numeric result Codes
Display result codes
No echo, Offline commands
Auto answer off
Carrier detect override
Load factory defaults
Smart mode

Receive Modem Dip-Switch Configuration:
Data Terminal Ready Override
Numeric result Codes
Suppress result codes
No echo, Offline commands
Auto answer on first ring
Carrier detect override
Load factory defaults
Dumb mode

The use of the US Robotics® external modem connected to the isolated RS-232C communication port on the PCD2000 will guarantee reliable communication from the PCD2000 to the Master.

9.2.9.2 Using a Modem

When using an external modem connected to your PCD2000 or PC, a telephone system may require you to do more than enter a telephone number in the WinPCD program's Modem dialog box. For example, you may first be expected to dial "9" for an outside line at your office. If so, preface the telephone number you want to dial with the characters "9W", as in this string: 9W19195554567. In this example, the "9" gives you the outside line, and the "W" instructs the modem to wait for a second dial tone before continuing to dial. The following table lists the dial modifiers and their definitions recognized by most modems.

Table 9-7. Modem Dialing Modifiers

Dial Modifier	Description
0 - 9 - #ABCD	Specifies the letters, numbers, and symbols a modem uses when dialing.
T	Instructs the modem to dial using the Tone method.
P	Instructs the modem to dial using the Pulse method.
,	Pauses before continuing the dial string. The length of this pause is programmed into your modem; usually, it is 1 or 2 seconds. For longer pauses, enter multiple commas or reprogram your modem.
W	Waits for another dial tone.
@	Waits for silent answer from those modems that do not offer a tone when they answer.
!	Issues a hook flash, which is equivalent to pressing and quickly releasing the switch hook on your phone as you would to answer a call waiting.
R	Places your call in reverse mode (originates your call in answer mode), to call an originate-only modem. This character must be the last one in the dial string before the carriage return.
;	Returns the modem to the command state.
S = n	Dial the telephone number n stored in your modem. (Consult the modem's documentation where to store this number.)

9.3 Serial Communications Overview

Protocols define the pattern of bits and bytes within a communications data packet that contains the specific information to be transferred. Data communicated along the bus is in binary. The information is broken down into combinations of 1 and 0 or bits, whose exact combination and pattern are understood by both devices. For example, in binary-coded decimal (BCD) form, the numbers 2, 4, 8 and 0 are 0010, 0100, 1000, and 0000 respectively. Each number is represented by a combination of four bits 1s and 0s. Eight bits are commonly called a byte. A word can be made up of two or more bytes.

The value of this system is that 1 or 0 can be translated by the electronic circuitry as a high (1) or low (0) State, either ON or OFF. To send the above numbers (2, 4, 8, 0) along the bus to another unit, the binary bits representing each number are put onto the bus one bit at a time, in sequence. This system is known as serial data communication. Before transmission can occur, the receiving unit must first be instructed to receive data, and it must have a context for the values. For example, when the numbers 2, 4, 8 and 0 are received, the receiving device must understand what they mean. To make sense of this string of 1s and 0s transmitted must be organized as defined by the protocol definitions.

9.4 Definitions

Access - specific interaction between a subject and an object that is intended to result in the flow of information from one device to the other device.

Accumulator - an integer value that counts the number of pulses or transitions of a binary input.

Addressing - method to identify the source and recipients of all information transfers.

Agent - servers that are designed to work with compatible client stubs known as user agents which share the same server protocol. Agents are responsible for picking up and delivering messages between senders and receivers.

Alarm Processing - alarm analysis procedures to improve presentation of alarm data. It ranges from updating alarm lists and producing group alarms up to more intelligent evaluations.

Automatic Reclosing - automated closing of reclosers after the trip by a control device.

Automatic Switching sequences - automatic sequential operation of groups of power system devices to reduce operator workload and/or switching time and to avoid unsuccessful or unnecessary switching attempts.

Availability of Data - state in which data are where, when and how the user needs data.

BFI - breaker failure initiate.

Breaker - device that connects and disconnects energized power circuits with fault interrupting capability under normal operational conditions and is capable of interrupting short circuits. See Recloser.

Breaker Monitoring - automated procedure to measure breaker operating times and accumulated interrupting duty for maintenance scheduling or maintenance on request.

Broadcast - simultaneous transmission of data to all destinations on a communications network.

Client - an IED that requests information from a Server.

Client/Server Architecture - an architecture where one end system (client) requests another end system (server) to perform operation(s) and to send back the results.

Client/Server Concept - communication scheme where multiple objects (clients) can request specified information from one or more other objects (server). Usually data flows primarily from the server to the clients.

Communication Interface - connection of a communication ling with regard to the mechanical connection as well to the signal's physical and functional characteristics allowing exchange for physical and logical information among devices of the same or different functional levels in a hierarchical system.

ANSI or American National Standards Institute - Organization of American industry and business groups that develop trade and communications standards.

ANSI Character Set - This is a standard set of characters that include the alphabet, numbers, punctuation marks, and several other symbols. The characters in this set have 256 possible values (0 to 255) called ANSI values. Each value represents a different character. Values 0 to 127 are known as the ASCII character set.

Application Program - a program that runs on your computer (e.g. WinPCD).

Arrow Key - keyboard key used to navigate around your screen. Each key is marked with an arrow indicating the direction the cursor moves when you press the key. The four standard arrow keys are Up Arrow, Down Arrow, Left Arrow, and Right Arrow.

ASCII or American Standard Code for Information Interchange - predominant character set of present-day computers. Numeric values are assigned to letters, numbers, punctuation marks, and a few additional characters. Computers and computer programs use these numeric codes to represent characters and other information. Values 0 to 31 are assigned to control codes, such as backspace and carriage return, and are generally nonprinting characters. In some fonts, these characters represent graphical symbols. Values from 32 to 127 represent the numbers 0 to 9, common punctuation marks, and the upper- and lowercase letters of the alphabet. See also, ANSI; ANSI character.

ASCII File - File made up exclusively of ASCII characters.

Attribute - property of an object, such as a file or display device.

Baud Rate - number of times per second a signal change in a communications channel. Speed of data transmission in a modem or other device. The rate specifies the number of signal variations per second. It is commonly used as a synonym for bits-per-second, but this is inaccurate. While one signal change can represent one bit of data, in today's high-speed communications, one signal change usually encodes more than a single bit.

Bit - smallest data component of software. It is a binary switch that is turned to "0" or "1". Eight bits make a byte.

BPS or Bits Per Second - measure of the speed at which a device such as a modem can transfer data. Also known as data rate. See also, baud rate.

Buffer - portion of memory that temporarily holds data until it is transferred to its ultimate destination.

Bus - set of hardware lines that connects different parts of the device (e.g., CPU, UPS, input/output, communication ports, and memory) and over which data is transferred.

Byte - a sequence of eight bits. Usually a byte stores the data equivalent to a single character (letter, numeral, or other character). Systems or applications using the Unicode character set, however, require two bytes of data to represent a single character.

Cable - group of wires enclosed in a protective tube, usually organized to correspond to specific pins on 9- or 25-pin connectors located at each end. This group of wires is used to connect peripheral devices to each other or to other computers.

Cache - memory that temporarily holds data or program instructions to improve overall computer and network performance. Most caches copy data from a standard computer memory disk or RAM to another type of memory allowing faster data access by the CPU. Some caches can hold data awaiting storage, freeing the CPU for other tasks, and writing that data only when the CPU is otherwise idle.

CD-ROM or Compact Disk Read-Only Memory - CD-ROMs consist of polished metallic disks with a clear plastic surface coating. Data is stored as minute pits and lands that affect how the laser beam is reflected from the disk surface. CD-ROMs can store more information than floppy disks, but it takes longer to read data from CD-ROMs. CD-ROM drives include photodetectors containing the optical and electrical components necessary to read the data.

CD-ROM Drive - a device that uses a laser beam, mirrors, and a photodetector to read data from CD-ROMs. Because CD-ROMs are a read-only data storage medium, the CD-ROM drive can read data from, but not write data to, a CD-ROM.

Character - letter of the alphabet, a digit, or another computer symbol that is used in a string.

Click - to press and release the primary mouse button.

Client - a networked IED that requests information from another IED or server.

COM Port - serial port. COM port is derived from communication port.

CPU or Central Processing Unit - performs computations, executes instructions and transfers information between all parts of the device.

CTS - acronym for Clear to Send.

Data - contents of a file, numerical information that is processed by a CPU.

Data Rate - speed at which information moves between a computer and another location, measured in BPS.

Data Transfer - movement of information from one location to another. The speed of transfer is called the data rate or data transfer rate and is usually measured in BPS.

DCE - an acronym for data communication equipment that electrically modifies and transfers data from point to point, (e.g. line drivers, modems, and converters).

Default - preset value that is used unless a different value is entered or otherwise specified.

Device Driver - a program that allows a PC to communicate with a device, such as a modem.

Download - to transfer a file from one PC to another device through a modem or a network (for example, to transfer a file from a server to a client).

DTE - acronym for data terminal equipment that originates and transfers data (e.g. PCD2000, RTU, and PC).

DTR - acronym for Data Terminal Ready.

Encryption - act of securing files by making their data unreadable without a key or password. This process actually alters the data in the files.

Error Message - a message from the system identifying a problem that the CPU cannot fix itself, (e.g. PCD2000 self-check).

External Modem - a modem that does not reside inside a device rather it resides outside the device and connected via a communication port. External modems have communication sockets to connect a phone line or a radio transmitter.

Fault Isolating - minimizing the impact of a fault on a feeder network.

Fault Recording - procedures for collection, storage, and analysis of power system fault data.

Feeder Fault Isolation - automated procedure to operate feeder sectionalizing switches to bypass a faulted feeder section.

Feeder Monitoring - an automated process to display feeder breaker and connectivity status.

Feeder Switching - an automated procedure to manage feeder connectivity changes.

Handshaking - the ability to control data flow between various devices utilizing two types of handshaking, hardware or software.

HTML or HyperText Markup Language - language used to create Web pages. HTML allows the author to control the appearance of a Web page, and to set up links to other locations in the document or on the Internet. Web browsers read HTML and convert it into readable text and graphics. Using a browser, click the hyperlinks to jump to the specified location.

Hyperlink or Hypertext Link - text or a graphic in an online document that can be clicked to display a different location, or execute some functions. Links can open new windows, reference different documents, or refer to a target within the same document. Links are usually distinguished by underlines or different colors. When you click the link, the target reference is displayed. For example, click here to see the glossary contents.

Hypertext - text containing hyperlinks, hypertext is the basis of the web.

IED - acronym for Intelligent Electronic Device which is a programmable monitoring, control, protection and data processing device with at least one serial communication interface.

Initialize - in communications, to get the software and modem ready to communicate at the start of a session.

Interoperability - two IEDs are interoperable when able to exchange information needed for their on-line operation. This is normally achieved by using open standard protocols.

Interrupt - signal sent by a hardware device or by software that causes the CPU to stop what it is doing and execute special instructions.

IP or Internet Protocol - set of standards used in networks that allows PCs to trade information.

IRQ or Interrupt Request - hardware line used by networked devices to send interrupts to the CPU. Each hardware device is assigned its own IRQ. Two devices cannot share the same IRQ, or they will not work properly.

Kilobyte - defined as 1024 bytes.

LAN or Local Area Network - group of PCs and IEDs located in a limited area and connected together so that each IED can interact with other IEDs on the network. A LAN usually includes a central computer called a server, that stores commonly needed programs and data.

Login - to identify yourself to a computer after connecting to it over a communications line. The procedure of connecting to another computer. During this procedure, the remote computer usually requests your user name and a password. On a computer with multiple users, the login provides a means of identifying authorized users.

Logoff - to end a session with a computer accessed over a communications line.

Loop - program code that is repeated until a specific condition is met.

Master - the remote client that requests information or a control operation from an RTU.

Master/Slave Architecture - communication management scheme called polling where one IED (Master) requests a specified IED (Slave) to deliver specified information. Masters not Slaves may issue unsolicited data or commands.

Megabyte - defined as 1024 K or 1,048,576 bytes.

Memory - hardware that allows for the storage of data and provides for the retrieval of stored data. Generally, the term memory refers to random access memory (RAM), which is used to run applications and temporarily store data during program execution.

Modem - a communication device enabling a PC or IEDs to transmit and receive information over a standard telephone line or cellular telephone network. A modem translates (modulates) digital data to an analog signal for transmission and then back to digital (demodulates) at the other end.

Multicast - a simultaneous message of data transmitted to a defined group of destinations on a network.

Network - group of computers and associated IEDs that are connected by communication lines or other means. Networks allow users to share data and peripheral devices to exchange data.

Parallel Port - port connected to a computer that transfers data on more than one wire.

Parity - an extra bit added to a byte to reveal errors in storage or transmission. This parameter must be the same between two modems for them to properly communicate.

Password - private identification code. Passwords are often required for access to online services and networks. You can also protect IEDs with passwords so that unauthorized user cannot open them.

Plug-and-Play - an industry standard that allows IEDs to be automatically configured by a common protocol. Plug and Play eliminates the need for manually changing jumpers and other hardware settings when installing hardware, and for restarting an IED or PC after making a hardware change (for example, after inserting a radio transmitter).

Port - the portion of a computer or a hardware device through which data passes to get in to or out of the computer or device. PCs connect to IEDs and modems through ports.

Protocol - set of standard rules that enable computers to exchange data with one another with as few errors as possible. When information is transferred over a network or modem, all devices use the same protocol. There are many protocols used in communications. For example you might hear of TCP/IP in networks, and Modbus® ASCII, Modbus® RTU and DNP 3.0 in the world of substation automation.

Queue - buffer or list that holds commands waiting to be executed.

RAM or Random Access Memory - main memory of a CPU. The memory is considered random access because the memory locations might be accessed directly by address rather than sequentially. The CPU must load application programs and the data they need into RAM before they can perform any processing. RAM is often supplemented by virtual memory, which increases the number of applications that can be run simultaneously. RAM memory is volatile.

Remote - a PC or IED that is accessed through via a communication network through a modem.

Report By Exception - a mode of operation in which a RTU or IED reports information that has changed since data was transmitted previously.

ROM or Read-Only Memory - memory that can be read from but not written to, it usually contains programs or instructions. A common type of read-only memory is a CD-ROM.

RTS - acronym for Request to Send.

RTU - acronym for Remote Terminal Unit.

RxD - receive signal, an input for one IED and an output for another IED or client/server.

Sequence of Events (SOE) - an ordered time stamped log of the state changes of binary inputs, outputs and elements used to recreate or analyze the behavior of a feeder network over a period of time.

SCADA - acronym for Supervisory control and Data Acquisition.

Scan Group - RTU/SCADA term for a data set.

Security - immunity of network resources to accidental or intentional unauthorized access. Three levels are defined 1) High where access is limited to predefined and validated clients, 2) Medium where access is granted to any client meeting simple criteria, and 3) Low where access usually read only is granted to any client.

Serial Communication - standard method of communicating between two devices over a modem. Both devices must use the same data rate, parity, and control information.

Serial Port - a computer's input/output connection for serial communication. It is attached to the serial interface and is usually an RS-232-C type connector. The standard serial ports are called COM Ports.

Server - computer that provides some service for other devices connected to it through a network. The most common example is a file server, which has a local disk and services request from remote clients to read and write files on that disk. Often, a computer is used as a server only and does not have anyone using applications on it.

Static Noise - signal distortion due to electrical field radiated by a voltage source or natural electric disturbances in the atmosphere. Shielding to ground of the communication circuit is necessary to encompass the transmitting and receiving ends of the IED to eliminate the static noise coupled onto the communication signal(s).

Straight Line Topology - communication bus that is daisy chained between each IED connecting the supervisory device to another IED which in turn connects to another IED and so on.

TCP/IP or Transmission Control Protocol over Internet Protocol - standard protocols used over networks and the Internet.

Time Stamping - message contains a field that tells the age of the information that it carries.

Total Internal Reflection - the total reflection that occurs when light strikes an interface at angles of incidence with respect to the normal greater than the critical angle.

Transient Eliminator - a lightning conductor or surge protection module.

TxD - transmit signal, an output for one IED and an input for another IED or client/server.

Unit ID - a unique identification number assigned to each device on a communication network used to send and receive information between SCADA and field devices

Unsolicited Message - message transmitted in response to a locally occurring event rather than an explicit remote request.

Upload - in communications, the process of transferring a file to another device by means of a modem or network.

UPS or Uninterruptible Power Source - backup power used in the event of electrical power failure. UPS systems usually have enough battery power so you can shut down your CPU properly. Unlike a surge protector that filters power surges, your CPU keeps running when plugged into an UPS, even if there is no electrical power.

Velocity of Propagation - the speed of an electrical signal down a length of cable compared to speed in free space expressed as a percent. It is the reciprocal of the square root of the dielectric constant of the cable insulation.

WAN or Wide Area Network - network, usually constructed with serial lines, extending over distances greater than one kilometer.

WYSIWYG - acronym for "What You See Is What You Get". This information prints just as it appears on the screen.

32-bit application - application that works with information 32 bits at a time. These applications generally provide better performance and memory management than 16-bit applications.

10 Maintenance & Testing

Because of its continuous self-testing, the PCD2000 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.

10.1 High-Potential Tests

High-potential tests are not recommended. If a control wire insulation test is required, completely withdraw the PCD2000 from its case and perform only a DC high-potential test.

10.2 Withdrawing the PCD2000 from Its Case

The PCD2000 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). Follow the steps and procedures detailed in Section 1 of this instruction book.

10.3 System Verification Tests

Besides continuously monitoring a Self-Check output contact, perform routine hardware tests to verify that the PCD2000 is functioning properly. Run these tests via the HMI or via the communications port and WinPCD.

The tests are to:

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 PCD2000 settings are correct by using the Show Settings Menu.
6. Check the Fault and Operation Records for proper sequential operation.

10.4 Testing the PCD2000

When the PCD2000 is in service, its functions depend on the state of the recloser monitored through the 52a and 52b contacts. Therefore, to fully test the system, apply a test circuit that simulates a recloser operation.

If it is not possible to use test equipment that simulates a recloser operation, place the PCD2000 in the Functional Test Mode. This mode allows testing of the programmed overcurrent functions and reclose sequence (when the test current is removed) without simulating the operation of the 52a and 52b contacts.

If you do not place the unit in Functional Test Mode and do not connect the 52a and 52b contacts during testing, the PCD2000 will go into the Breaker Failure state (and Lockout) on the first test trip. The PCD2000 stays in the Functional Test Mode for fifteen minutes or until you exit whichever occurs first. Use the "C" key on the HMI to reset the recloser when it is in Lockout in the Test Mode. In the Test Mode the fault sequence is written only to the Operations Record.

The tests described below confirm the PCD2000's protective capabilities and metering accuracy. Test only those elements that will be enabled when the PCD2000 is placed into service. Testing the enabled functions ensures that the PCD2000 settings are correct for the desired application. Check the Fault and Operations Records after each test to confirm proper sequential operation of the PCD2000 logic.

Note: The following test procedures are written from the perspective of using the HMI. If you choose to use WinPCD then refer to Section 4 for reference to select the correct dialog window to change settings and run the test.

Use a single-phase current test set to confirm continuity through the four current input sensors and the proper operation/settings of 51P, 51N, 50P-1, 50N-1, 50P-2, 50N-2, 50P-3, 50N-3 and 46 functions. Test the phase functions by injecting current into the I_A and I_B input sensors. Test the neutral (ground) elements by injecting current into the I_C and I_N input sensors. Test the 46 element by injecting current into a single-phase input since $I_2 = \frac{1}{3} I_A$ when $I_B = I_C = 0$.

It is recommended to use a three-phase current and voltage test set to test the proper operation and setting of the 67P and 67N protective functions, the fault locator and the accuracy of watts, VARs and power factor metering. Use a single-phase voltage test set to confirm the proper operation and settings of the 27, 59, 79V and 81 elements.

Warning: Follow all safety procedures of the test equipment whenever testing the PCD2000.

Table 10-1 and Table 10-2 show the factory default settings on which the tests are based.

Table 10-1. Factory Defaults for Testing Primary Settings

Function	Setting
51P Curve	Extremely Inverse
51P Pickup	6.0
51P Time Dial	5.0
50P-1 Curve	Standard
50P-1 Pickup	3.0
50P-2 Select	Disable
50P-3 Select	Disable
46 Curve	Disable
51N Curve	Extremely Inverse
51N Pickup A	6.0
51N Time Dial	5.0
50N-1 Select	Standard
50N-1 Pickup	3.0
50N-2 Select	Disable
50N-3 Select	Disable
79 Reset Time	10
79-1 Select 50P-1, 51N, and 50N-1	Enable
79-1 Open Time	LOCK
79 Cutout Time	Disable
Cold Load Time	Disable
2Phase 50P	Disable
67P Select	Disable
67N Select	Disable
81 Select	Disable
27 Select	Disable
79V Select	Disable
59 Select	Disable
32 P-2 Select	Disable
32 N-2 Select	Disable

Table 10-2. Factory Defaults for Testing Configuration Settings

Function	Setting
Phase CT ratio	100
Neutral CT ratio	100
VT Ratio	100
VT Connection	120 wye
Positive Sequence X/Mi.	0.001
Positive Sequence R/Mi.	0.001
Zero Sequence X/Mi.	0.001
Zero Sequence R/Mi.	0.001
Line Length Miles	20
Trip Fail Time 18	18
Close Fail Time 18	18
Phase Rotation ABC	ABC
Protection Mode	Fund
Reset Mode	Instant
ALT1	Enable
ALT2	Enable
Zone Sequence Coordination	Disable
Target Mode	Last
Local Edit (Remote Edit)	Enable
Meter Mode (WHr Display)	kWHr
LCD Light	On
Unit ID (ID)	PCD2000
Demand Meter Constant	15
LCD Contrast	16
PCD2000 Password	[_ _ _ _] 4 underscore
Test Password	[_ _ _ _] 4 underscore
Cold Load Time Mode	Seconds
Standard Unit	Standard
CT Ratio (SEF)	1

Programmable inputs IN1 (52a), IN2 (52b) and IN3 (43a) must be wired to Enable their respective functions and programmed via the Input Mapping screen. Programmable output OUT 2 (Close) must be wired to Enable the respective function and programmed via the output mapping screen.

10.5 Functional Test Mode (Password Protected)

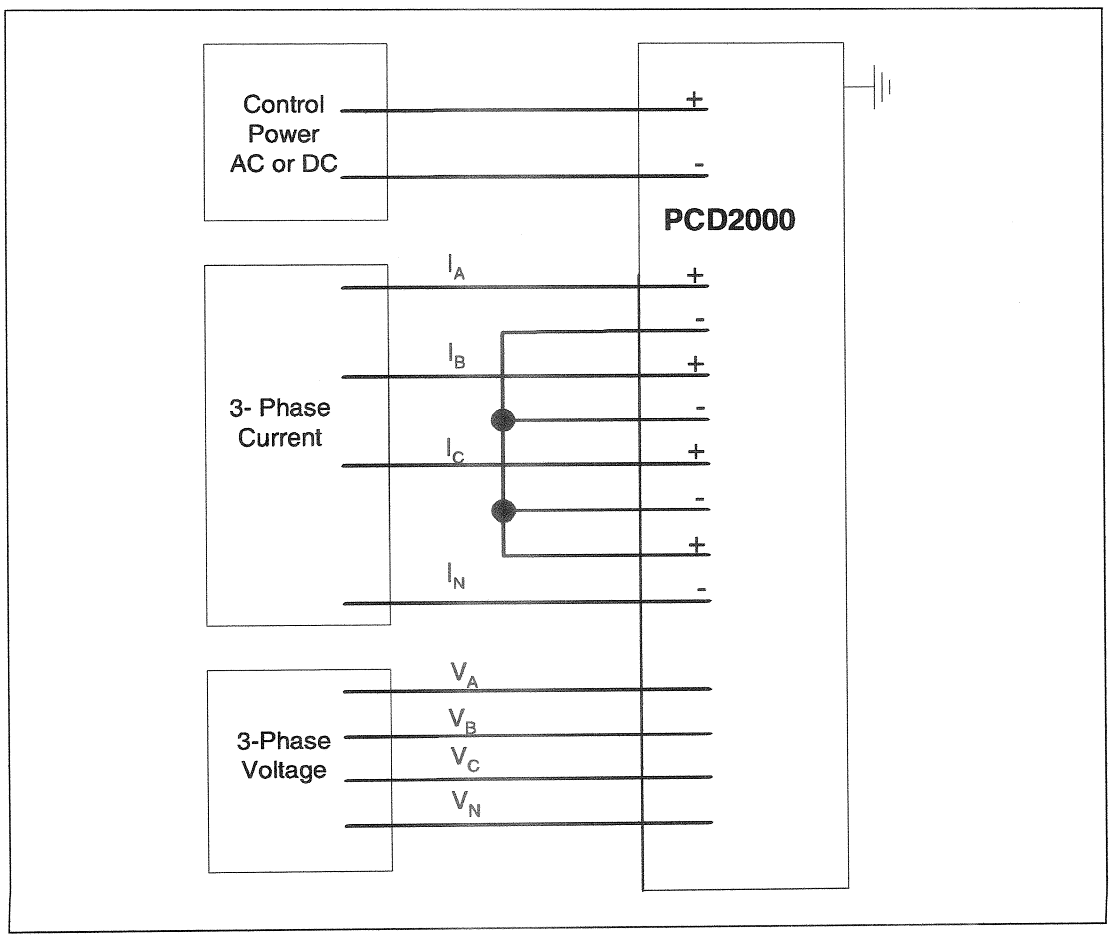
Use the Functional Test Mode to test programmed overcurrent functions and the reclose sequence (upon removal of test current) without simulating operation of the 52a and 52b contact inputs. The PCD2000 stays in Functional Test Mode for fifteen minutes or until you exit, whichever occurs first. Use the [C] key on the HMI to reset the recloser when it is in Lockout in the Test Mode. The HMI display shows the time remaining in the Functional Test Mode (except when the Trip Coil Monitor function has been enabled). The test sequences are written only into the Operations Record.

10.6 Verify Self-Checking Test Via HMI

Follow these steps to verify the pass/fail status of each self-check element on the PCD2000:

1. Connect the proper control power to the unit. Wait for initialization to be complete.
2. The green STATUS LED should be lit and the red RECLOSER OUT LED should also be lit if the recloser is disabled by the active settings table.
3. From the HMI, press "E" to get the Main Menu.
4. Scroll down to "TEST" and press "E."

Figure 10-1. Typical Test Circuit



10 MAINTENACE & TEST

5. The first choice is "Self Test," so press "E." All elements under the "Self Test" should read "pass."
6. Press "C" to return to the meter display.

10.7 Phase Angle Conventions

For tests that follow, refer to Figure 4-1 for phase angle and metering conventions used in the PCD2000. In general, all angles are degrees leading or positive going counter-clockwise rotation.

10.8 Metering Test

Apply 3-phase voltages and currents as shown in Figure 10-1. The values for these are:

Current	Voltage
$I_A = 3.0\ A \angle 0°$	$V_{A\text{-}N} = 120.0\ V \angle 0°$
$I_B = 3.0\ A \angle 240°$	$V_{B\text{-}N} = 120.0\ V \angle 240°$
$I_C = 3.0\ A \angle 120°$	$V_{C\text{-}N} = 120.0\ V \angle 120°$

From the HMI main menu, press "E" twice to gain access to the metering menu.

Press "E" on the "Load" choice. The following should be within the ranges listed:

Current	Voltage	Power
$I_A = 300.0\ A \angle 0°$	$kV_{A\text{-}N} = 12.0\ V \angle 0°$	kW-A = 3600
$I_B = 300.0\ A \angle 240°$	$kV_{B\text{-}N} = 12.0\ V \angle 240°$	KW-B = 3600
$I_C = 300.0\ A \angle 120°$	$kV_{C\text{-}N} = 12.0\ V \angle 120°$	kW-C = 3600
$I_N = 0.0$		kW-3P = 10800
I0 = 0	$kV_1 = 12.00 \angle 0°$	kVAR-A = 0
$I_1 = 300 \angle 0°$	$kV_2 = 0 \angle 0°$	kVAR-B = 0
$I_2 = 0 \angle 0°$		kVAR-C = 0
Freq = 60.00		kVAR-3P = 0
		PF = 1.00 Lagging or Leading

Connect the PCD2000 as shown in Figure 10-1. Apply 3.0 A to C-Phase and the Neutral. Read the current from the metering menu as above. The currents I_C and I_N should be 300.0A.

10.9 Pickup—Time Overcurrent

Follow these steps to check the time overcurrent of the pickup current.

1. Connect the PCD2000 as shown in Figure 10-1.
2. Apply 5.5 A, gradually increasing the current until the PICKUP LED just lights. This should be within ±3% of the pickup (see Table 10-1) or ±0.18 A (±18.0 A primary). This confirms the continuity and accuracy of phases A and B.
3. Decrease the input current to 0 and reset targets, if necessary, by pressing the target-reset push button.
4. Connect the PCD2000 as shown in Figure 10-1. Repeat Step 2 to confirm the continuity and accuracy of phase C and Neutral.

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5. To confirm the ground pickup, lower the 51N setting to 5.0 A by:
   a. Access the settings menu pressing "E" on the HMI.
   b. Scroll to "Settings."
   c. Hit "E" and scroll to "Change Settings."
   d. Hit "E" again to access "Prim Settings."
   e. Enter the password (four spaces for factory default) and press "E."
   f. Scroll to "51N Pickup A" and Press "E."
   g. Press the left arrow key until 5.0 is displayed; hit "E" to accept this value.
   h. Press "C" twice to get out of setting change.
   i. Press right or left arrow key to respond "YES" to the "Save Settings" prompt. Press "E."
   j. Press "C" until the metering values are displayed.
6. Apply 4.5 A to the PCD2000 as shown in Figure 10-1. Gradually increase the current until the PICKUP LED just lights. This should be within ±3% of the pickup (5 A). This confirms the ground pickup.
7. Decrease the input current to 0.0 A and reset targets, if necessary, by pressing the target-reset push button.
8. Repeat step 5 above to reset the 51N pickup to 6.0 amps.

10.10 Pickup—Instantaneous Overcurrent

Follow these steps to test the instantaneous overcurrent of the pickup current:

1. To test the 50P-1 phase instantaneous unit:
   a. Connect the PCD2000 as shown in Figure 10-1.
   b. Apply approximately 85% of the instantaneous pickup current (18 A from Table 10-1) to the PCD2000 or 15.3 A.
   c. Gradually increase the current until the INSTANTANEOUS LED lights. This should be ±7% of the setting or
   d. ±1.26 A (±126 A primary). This confirms phases A & B. Targets that should be lit are A, B and INSTANTANEOUS.
   e. Decrease the input current to 0 and reset targets by pressing the target reset push button.
2. To test the 50N-1 ground instantaneous unit:
   a. Disable the 50P-1 function via the "Change Settings", "Primary Settings" menus.
   b. Connect the PCD2000 as shown in Figure 10-1.
   c. Apply approximately 85% of the instantaneous pickup current (18 A from Table 10-1) to the PCD2000 or 15.3 A.
   d. Gradually increase the current until the INSTANTANEOUS LED lights. This should be ±7% (from Table 10-1)
   e. of the setting or ±1.26 A (±126 A primary). Targets N and INSTANTANEOUS should be lit.
   f. Decrease the input current to 0 and reset targets by pressing "C" on the HMI.

3. To test the 50P-2 phase instantaneous unit:
   a. Enable the 50P-2 function and disable the 50N-1 function via the "Change Settings", "Primary Settings"
   b. menus.
   c. Connect the PCD2000 as shown in Figure 10-1.
   d. Apply approximately 85% of the instantaneous pickup current (18 A from Table 10-1) to the PCD2000 or 15.3 A.
   e. Gradually increase the current until the INSTANTANEOUS LED lights. This should be ±7% of the setting ±1.26 A (±126 A primary).
   f. Targets C and INSTANTANEOUS should be lit.
   g. Decrease the input current to 0 and reset targets by pressing "C" on the HMI.
4. To test the 50N-2 ground instantaneous unit
   a. Enable the 50N-2 function and disable the 50P-2 function via the "Change Settings", "Primary Settings" menus.
   b. Connect the PCD2000 as shown in Figure 10-1.
   c. Apply approximately 85% of the instantaneous pickup current (18 A from Table 10-1) to the PCD2000 or 15.3 A.
   d. Gradually increase the current until the INSTANTANEOUS LED lights. This should be ±7% of the setting or ±1.26 A (±126 A primary).
   e. Targets N and INSTANTANEOUS should be lit.
   f. Decrease the input current to 0 and reset targets by pressing "C" on the HMI.
5. To test the 50P-3 phase instantaneous unit:
   a. Enable the 50P-3 function and disable the 50N-2 function via the "Change Settings", "Primary Settings" menus.
   b. Connect the PCD2000 as shown in Figure 10-1.
   c. Apply approximately 85% of the instantaneous pickup current (18 A from Table 15) to the PCD2000 or 15.3 A.
   d. Gradually increase the current until the INSTANTANEOUS LED lights. This should be ±7% of the setting or ±1.26 A (±126 A primary).
   e. Targets C and INSTANTANEOUS should be lit.
   f. Decrease the input current to 0 and reset targets by pressing "C" on the HMI.
6. To test the 50N-3 ground instantaneous unit:
   a. Enable the 50N-3 function and disable the 50P-3 function via the "Change Settings", "Primary Settings" menus.
   b. Connect the PCD2000 as shown in Figure 10-1.
   c. Apply approximately 85% of the instantaneous pickup current (18 A from Table 10-1) to the PCD2000 or 15.3 A.
   d. Gradually increase the current until the INSTANTANEOUS LED lights. This should be ±7% of the setting or
   e. ±1.26 A (±126 A primary). Targets N and INSTANTANEOUS should be lit.
   f. Decrease the input current to 0 and reset targets by pressing "C" on the HMI.

7. To test the 2-Phase 50P Trip function:
   a. Enable the 50P-2 and 2-Phase 50P function via the "Change Settings", "Primary Settings" menus.
   b. Connect the test set as shown in Figure 10-1.
   c. Apply approximately 85% of the instantaneous pickup current (18 A from Table 10-2) to the PCD2000 or 15.3 A.
   d. Gradually increase the current until the 50P-2 PCD2000 trips. This should be ±7% of the setting or ±1.26 A (±126
   e. A primary). This confirms phases A & B. Targets A, B and INSTANTANEOUS should be lit.
   f. Decrease the input current to 0 and reset targets by pressing "C" on the HMI.
   g. Connect the test set as shown in Figure 10-1, repeat tests c), d) and e). This should confirm that the PCD2000 does not trip and no INST targets light.
8. Disable the 50P-2 and the 2-Phase 50P functions via the "Change Settings", "Primary Settings" menus.
9. Connect the PCD2000 as shown in Figure 10-1 and map GRD to an available input (ex: IN4) with logic "C", in the programmable inputs screen. (This will disable the GRD function.)
10. Apply the fault as in step 2 and confirm that the PCD2000 will not trip on 50N-1.

10.11 Timing Tests

Follow these steps to test the timing of the PCD2000:

1. Connect the PCD2000 as shown in Figure 10-1.
2. Apply a fault current of 12.0 A to the PCD2000. This current is 2 times the default pickup current of 6.0 A. The PCD2000 should trip between 14.5 and 16.7 seconds (derived from the Extremely Inverse curve, Figure 1-4, by using the default values in Table 10-1).
3. Apply a fault current of 24.0 A to the PCD2000 (4 times the default pickup current). The PCD2000 should trip between 3.0 and 3.5 seconds.
4. Apply a fault current of 36.0 A to the PCD2000 (6 times the default pickup current). The PCD2000 should trip between 1.4 and 1.6 seconds.

10.12 Directional Testing

Follow these steps to test the directional functions:

1. To test the 67P protective function, enable the directional functions:
   a. Press the "E" key.
   b. Scroll to "Settings" and press "E."
   c. Scroll to "Change Settings" and press "E."
   d. Scroll to "Prim Settings" and press "E."
   e. Enter password (four underscores for default) and press "E."
   f. Scroll down to "67P" and press "E."

g. Hit right arrow key to change to "Enable" and press "E."

h. Press "C" twice.

i. Press right arrow key to "Yes" and press "E" to save settings.

j. The factory default settings are as follows:
67P Curve Extremely Inverse
67P Pickup 1.0
67P Time Dial 5.0
Torque Angle 0°

k. Apply the following test values to the circuit, as shown in Figure 10-1:
$I_A = 5.0\ A\ \angle 0°$
$I_B = 0.0\ A$
$I_C = 0.0\ A$
$I_N = 5.0\ A\ \angle 0°$
$V_{A\text{-}N} = 10.0\ V\ \angle 0°$
$V_{B\text{-}N} = 120.0\ V\ \angle 240°$
$V_{C\text{-}N} = 120.0\ V\ \angle 120°$

l. The PCD2000 should trip on 67P directional overcurrent between 2.00 and 2.35 seconds (from the Extremely Inverse curve, Figure X-4), indicated by a phase target (e.g., A-phase) with no other targets lit.

m. Check the fault records to confirm the 67P trip.

n. Reset the targets by pressing "C" on the HMI.

o. Change the I_A and I_N angles to 180° and reapply the current.

p. The PCD2000 should not trip on the 67P directional overcurrent.

2. To test the 67N, disable the 67P function and enable the 67N function.

a. Press the "E" key.

b. Scroll to "Settings" and press "E."

c. Scroll to "Change Settings" and press "E."

d. Scroll to "Prim Settings" and press "E."

e. Enter the password (four spaces for default) and press "E."

f. Scroll down to "67N" and press "E."

g. Hit right arrow key to change to "Enable" and press "E."

h. Press "C" twice.

i. Press right arrow key to "Yes" and press "E" to save settings.

j. The factory default settings are as follows:
67P Curve Extremely Inverse
67P Pickup 1.0
67P Time Dial 1.0
Torque Angle 0°

k. Apply the following test values to the circuit as shown in Figure 10-1:
$I_A = 5.0\ A\ \angle 180°$
$I_B = 0.0\ A$
$I_C = 0.0\ A$
$I_N = 5.0\ A\ \angle 180°$
$V_{A\text{-}N} = 10.0\ V\ \angle 0°$

$V_{B\text{-}N}$ = 120.0 V ∠240°
$V_{C\text{-}N}$ = 120.0 V ∠120°

l. The PCD2000 should trip on 67N directional overcurrent between 0.28 and 0.32 seconds (from the Extremely Inverse curve, Figure 1-4), indicated by the N LED lit and no other targets lit.

m. Verify the fault records to confirm the 67N trip.

n. Reset the targets by pressing "C" on the HMI.

o. Change the I_A and I_N angles to 0° and reapply the current.

p. The PCD2000 should not trip on 67N directional overcurrent.

10.13 Negative Sequence Testing

Follow these steps to test the 46 function:

1. Disable all instantaneous elements (50P-1, 50P-2, 50P-3).
2. Raise the 51P Pickup setting to 12.0 A to prevent a 51P operation during this test.
3. Set the 46 function according to the following values, similar to how the 67P and 67N were enabled:
   46 Curve: Extremely Inverse
   46 Pickup: 3.5A
   46 Time Dial: 5.0
4. Apply the following currents as shown in Figure 10-1:
   I_A = 12.0 A ∠0°
   I_B = 12.0 A ∠180°
   I_C = 0.0 A

This phase-to-phase fault simulation will produce a two per unit negative-sequence current, 6.9A I_2 (12.0A x 58% = 6.9A), in the PCD2000.

5. In this case, I_2 is determined in the PCD2000s as follows:

$I_2 = 1/3\,(I_A + a^2 I_B + aI_C)$

where:

$a = 1\ \angle 120°$

$a_2 = 1\ \angle -120°$

since $I_C = 0$, then

$I_2 = 1/3\,(I_A + (1\ \angle -120°)\, I_B)$

$= 1/3\,(12.0\ \angle 0° + (1\ \angle -120°)\,(12.0\ \angle 180°))$

$= 1/3\,(12.0\ \angle 0° + 12.0\ \angle 60°)$

$= 1/3\,(20.7\ \angle 30°)$

$\therefore I_2 = 6.9\ \angle 30°$

therefore, we are at approximately 2x pickup.

6. The PCD2000 should trip between 14.3 and 16.3 seconds (from the Extremely Inverse curve) and only the NEGATIVE SEQUENCE LED should light.

10.14 Reclosing Sequence Test

Follow these steps to test the reclosing sequence:

1. Change the Primary Settings.
   a. Press the "E" key.
   b. Scroll to "Settings" and press "E."
   c. Scroll to "Change Settings" and press "E."
   d. Scroll to "Prim Settings" and press "E."
   e. Enter the password (four spaces for default) and press "E."
   f. Scroll down to each of the following and change the value as necessary by using the right arrow key. Verify or change the following PRIMARY settings for this test:

50P-1 Curve	Standard
50P-1 Pickup	1.0
2-Phase 50P	Disable
79 Reset Time	10 seconds
79-1 Select	50P-1, 51N, 50N-1 Enabled
79-2 Select	50P-1, 51N, 50N-1 Enabled
79-2 Open Time	10 seconds
79-3 Select	50P-1, 51N, 50N-1 Enabled
79-3 Open Time	15 seconds
79-4 Select	50P-1, 51N, 50N-1 Enabled
79-4 Open Time	15 seconds
79-5 Select	50P-1, 51N, 50N-1 Enabled
79-5 Open Time	LOCK
Trip Fail Time	18 cycles

   g. Press "E" when the value you want is displayed.
   h. Press "C" twice.
   i. Press the right arrow key to "Yes" and press "E" to save settings.
2. Set the PCD2000 to Functional Test Mode. This eliminates the need for a breaker.
   a. Press the "E" key to access the main menu.
   b. Scroll to "Test" and press "E."
   c. Scroll to "Func. Test Mode" and press "E."
   d. Enter the password (four spaces for default) and press "E."
   e. Press right arrow key to "Yes" and press "E."
   f. The PCD2000 will remain in the Functional Test Mode for 15 minutes, unless reset.
3. Test the Recloser Lockout function.
   a. Connect the PCD2000 as shown in Figure 10-1.

b. Apply a fault current of 12 A to the PCD2000. Once the PCD2000 has tripped, it remains open according to the settings in Step 1f; then the PCD2000 should reclose. Be sure the current is removed within the "Trip Fail Time" setting in the configuration settings.

c. Before the reset time of the PCD2000 has expired, apply a subsequent fault current. The PCD2000 will trip and reclose.

d. Continue to apply the fault until Recloser Lockout occurs. This should be on the fourth trip.

10.15 Frequency Tests

1. To enable the 81 function through the menus:

   a. Press the "E" key.

   b. Scroll to "Settings" and press "E."

   c. Scroll to "Change Settings" and press "E."

   d. Scroll to "Prim Settings" and press "E."

   e. Enter the password (four spaces for default) and press "E."

   f. Scroll down to 81 Disable and press "E."

   g. Press the right arrow key until "81S Enable" appears and press "E."

   h. Press "C." Note that additional settings for 81 have been added.

   i. Scroll to the following values and press "E."

   j. Change the value as necessary by pressing the right arrow key.

   k. When the value you want is displayed, press "E."

81 Select	81-1
81S-1 Pickup	60.02 Hz
81S-1 T. Delay	0.10 seconds
81V Block	40 volts

   l. After changing the values for 81, press "C" again.

   m. Use the right arrow key to select "Yes" and press "E" to save the new settings.

2. Program an output contact by using WinPCD to detect the underfrequency trip conditions.

3. Verify the underfrequency condition by applying the following voltages to the PCD2000 at 60 Hertz.
   $V_{A\text{-}N} = 120.0\ V\ \angle 0°$
   $V_{B\text{-}N} = 120.0\ V\ \angle 240°$
   $V_{C\text{-}N} = 120.0\ V\ \angle 120°$

4. The PCD2000 should trip for an underfrequency condition and light the FREQUENCY target LED on the front panel of the PCD2000.

5. Reset the frequency target by pressing "C" on the HMI.

6. Change the settings as follows:

81 Select	81-1
81S-1 Pickup	59.95 Hz
81S-1 T. Delay	0.10 seconds

7. Apply the same voltages as in Step 4. The PCD2000 should not trip for an underfrequency condition.

10.16 Loss of Control Power and Self-Check Alarm Contact Test

Follow these steps to test the loss of control power and the self-check alarm contact:

1. With control power applied to the PCD2000, check the self-check alarm contact and the STATUS LED.
2. Normal status indicated by a green LED.
3. Interrupt the control power to the PCD2000. The self-check contacts should return to their normal state.
4. Reapply control power and check the PCD2000 to see that all settings were properly retained.

11 Single-Phase Tripping

The PCD2000 single-phase tripping and reclosing option is advantageous for use on many electric utility distribution systems, including commercial, rural, and residential loads. It provides a control capability function of the recloser to trip and/or lockout whenever there is a fault on one-phase, two-phases or three-phases. This feature allows an electric utility to prevent unnecessary three-phase interruptions and outages of their distribution network where a majority of outages can be attributed to single-phase transient type faults thereby improving the overall power system reliability and quantity of power delivered to customers on the distribution feeder.

Single-phase tripping and reclosing is currently available for use only with the VR-3S recloser.

11.1 Overview of the Features in Single-Phase Tripping

As an example of single-phase operation of a PCD2000 with a VR-3S recloser, imagine that a VR-3S recloser is protecting a rural three-phase line. Suppose that a fault occurs on A-phase, where the fault is permanent and there is no fuse between the recloser and the fault. A conventional three-phase recloser will trip for two instantaneous operations followed by two time-delayed operations. The single-phase fault on A-phase will cause all customers downstream to experience three interruptions of power and an outage until the fault is repaired, cleared, and the recloser restored to normal operation. The PCD2000 with single-phase tripping can operate the VR-3S recloser for the same single-phase fault on A-phase as a single-pole trip, reclose and lockout. This provides a significant advantage to 67% of the customers downstream of the fault since their power is interrupted. The operation of single-phase operation will trip for two instantaneous operations, two time-delayed operation and lockout on the A-phase pole. Since the fault is a permanent single-phase-to-ground fault (e.g. A-N) the load connected to A-phase will experience an outage but the other two phases (e.g. B-phase and C-phase) will not experience any interruption of power and will stay energized.

The single phase tripping option is designed to be extremely flexible in order to meet the most demanding requirements. Listed below are brief descriptions of the features for single-phase and three-phase tripping operation:

Three global modes are selectable from the PCD2000 front panel: 1) Three-phase tripping, 2) Single-phase tripping OPUP and 3) Single-phase tripping OOAP.

In **three-phase tripping mode**, the PCD2000 operates in the same manner as a unit without the single-phase tripping option. Single-phase tripping is disabled. Three-phase tripping is enabled.

In **single-phase tripping mode**, the phase that detects fault current (e.g., current above the pickup threshold level) will initiate the VR-3S respective pole to trip open. There are two modes of operation for single-phase tripping: **OPUP** (Only Picked Up Phases) and **OOAP** (One Or All Phases)

Note: In single-phase tripping, the phase fault current must be greater than the 51P element pickup for the single-phase trip to occur. If the fault current is above the 51N or 50N setting, but below the 51P and 50P setting, a three-phase trip will occur.

11.1.1 OPUP Mode - Only Picked Up Phases

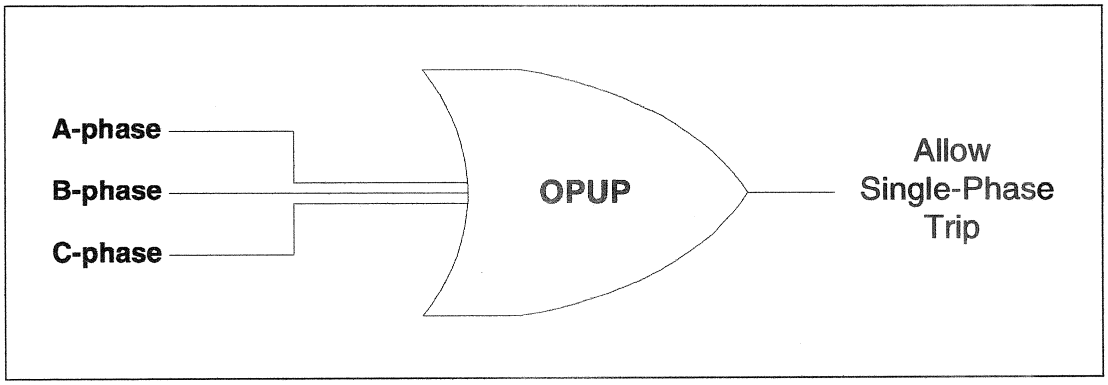
If **OPUP** is selected, any respective phase that detects fault current by the PCD2000 is actuated to open the respective pole of the VR-3S. The option for OPUP also allows each pole on the VR-3S to open independently if the PCD2000 detects fault current on any other two phases.

The 79-X reclose functions should be set to operate for both phase and/or neutral protective functions. The protective element listed in the "Function Enabled" column should be set to "Single Phase Enable" for all of the 79-X functions.

For example, suppose that a fault is detected on phase B. The PCD2000 will sense this pickup and initiate a binary output signal from the PCD2000 to the VR-3S, the VR-3S will trip open phase B and await timing from the PCD2000 for subsequent reclose or lockout. Now suppose that during the pickup and subsequent trip of phase B, the PCD2000 senses another fault on phase A. The PCD2000 will detect that fault and initiate a binary output signal from the PCD2000 to the VR-3S for pole A, the VR-3S will trip open phase A, and then await timing from the PCD2000 for reclose or lockout. Comparable sequences may occur and operation of the PCD2000 will continue to operate for phase C or any combination of phase(s) caused by excessive load or fault current.

Note: The fault on A will reset the open interval time on B if B has not yet reclosed.

Figure 11-1. OPUP Mode Logic



11.1.2 OOAP Mode - One Or All Phases

In this mode, if a single-phase fault is detected or picked up on one pole, a single-phase trip will occur as in the case of **OPUP** mode. However, if a combination of two or three phases pickup or detect a fault, then the PCD2000 will initiate a binary trip output to the VR-3S for all three poles to trip.

The 79-X reclose functions should be set to operate for both phase and/or neutral protective functions. The protective element listed in the "Function Enabled" column should be set to "Single Phase Enable" for the initial 79-X functions, and thus the last 79-X should be set to "Single Phase Lockout".

If the 79-1 function is set to "3-Phase Lockout" for a specified protective element, then reclosing does not occur and all the poles on the VR-3S are locked out after the first trip.

For example, consider a situation where the distribution load has motors connected onto the distribution line. If a single-phase fault occurred on any phase of the line, the PCD2000 should initiate a trip of all three phases, OOAP, to prevent the three-phase motors from single phasing. A three-phase motor may continue to run with the loss of a single-phase, but it will overheat. And a stopped three-phase motor that is attempting to start with the loss of a single-phase will cause overheating in the motor. For this application a distribution line with three-phase motors should implement OOAP on single-phase faults.

Each of the four phase overcurrent protection elements, one slow (51P), and three fast (50P-1, 50P-2 & 50P-3) can be individually configured to trip for either single-phase or three-phase faults.

Each step of the reclose cycle can be individually configured to single-phase or three-phase trip and/or lockout. Common examples are:

- The recloser is set to trip on a single-phase fault in single-phase fashion, but lockout in three-phase fashion (OOAP). A fault is detected and the recloser trips open on one phase and will lockout on all three phases if the fault detected is a permanent fault.
- The recloser is set to trip on a single-phase fault (OOAP). A two-phase fault is detected and the recloser trips open on all three-phases and will lockout on all three phases if the fault detected is a permanent fault.

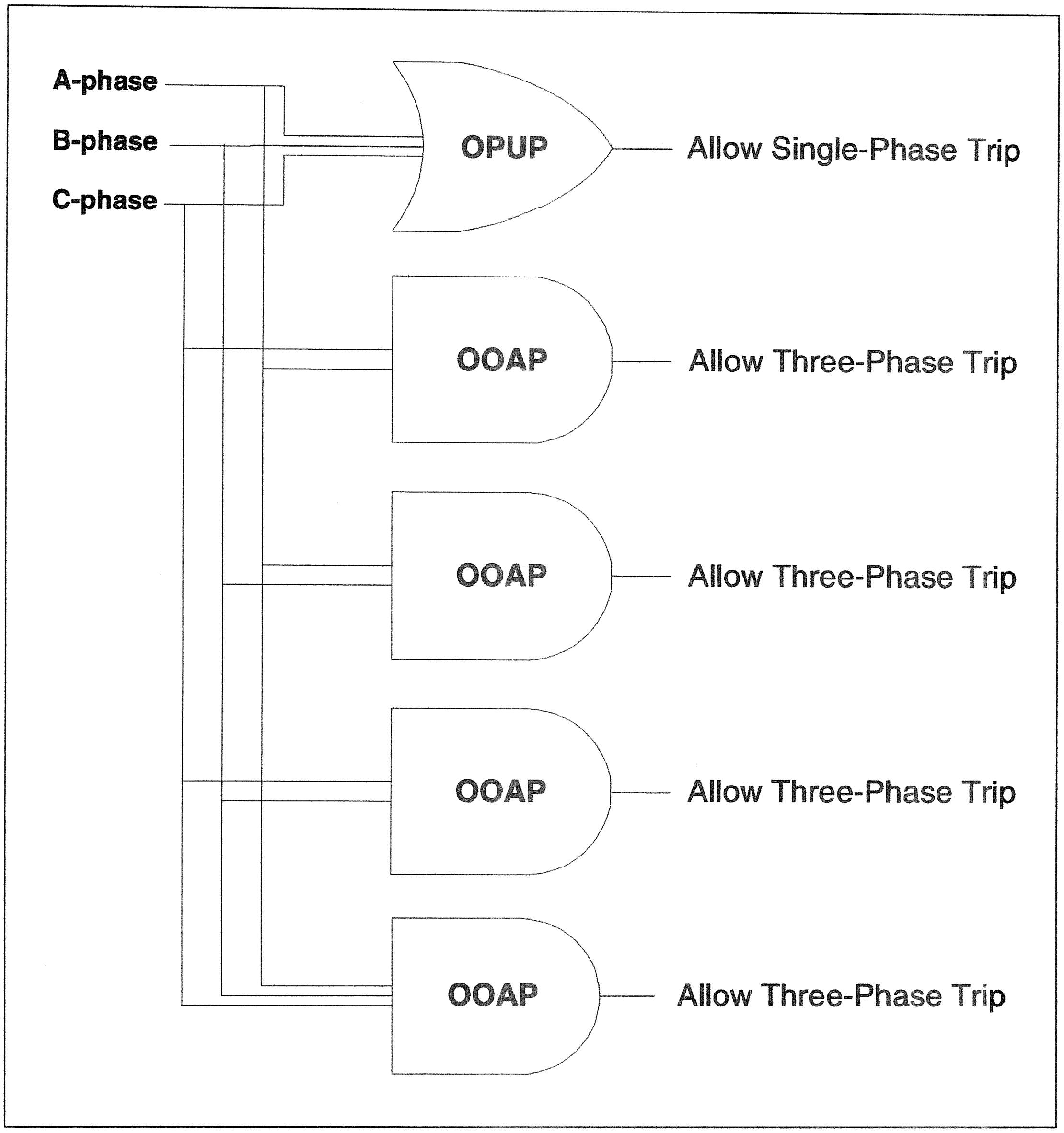
Operation counts are recorded on a per phase basis.

Each open phase will be shown on the HMI as "OPEN"

The recloser can be manually opened either single-phase or three-phase through the HMI.

The Primary and Alternate protection groups, Alt1 and Alt2, can be set up independently and switched to allow quick reconfiguration between single-phase and three-phase tripping.

Figure 11-2. OOAP Mode Logic



11.2 Settings

The intent of this section is to outline the operation settings required by the user in support of the single-phase operation. More detail is included in the Front Panel HMI and Communication Protocol sections.

11.2.1 Catalog Number Control

Single Phase mode of operation occurs with the appropriate catalog numbers as defined in the example below. The enabling digit is where the twelfth digit or second software option selector set to one:

XRXX-XXXX-XX-X1XX

If this digit is zero all settings access to single phase control will be blocked via the intelligent settings mechanism.

11.2.2 New Settings Parameters

Additional setting fields have been added to the following menus as follows:

11.2.2.1 Configuration Setting

Menu Item	Selections	Location	Visibility
Recloser Mode	3Ph 1PH	Top of Menu	Always

11.2.2.2 Primary and Alternate Setting-Group Settings

Menu Item	Selections	Location	Visibility
Single Phase Trip Mode	Disabled OPUP OOAP	Immediately before 79-1 selection	Only if single phase is enabled in Config menu
Single Phase Lockout Mode	Gnd Suppres Mod Phase	Immediately after Single Phase Trip Mode	Only if single phase is enabled in Config menu and if OPUP or OOAP is selected above.
79-X Selections	Enable 1PH Enable 3PH Lockout 1PH Lockout 3PH Alarm Disable	No change from present location	Single phase items only visible if single phase is enabled in Config. Menu

Note: The 51P element cannot be set to be disabled for any recloser stage.

11.2.3 Permitted Intervals of Changes

There are times where it is not desired to allow a change of settings request to be immediately honored particularly with the complexity of the new single-phase mechanism. These times are mostly related to the state machine when it is actively traversing system states. The following rules govern when requests for setting changes are allowed:

- All poles closed and no protective elements picked up
- All poles opened and locked out

Changes in setting groups cannot be allowed to occur when any protective element is in the picked up state or the recloser is active, e.g., transitioning between close and open states, open interval timer decrementing, or reset timer decrementing. If a setting change is requested during any of these conditions it is marked as pending and when the pickup or recloser activity has ended and the change request is still valid then the setting group change can take place.

11.3 Logical Input / Output

11.3.1 New IO Points

Many new logical IO points have been added to support the functionality of the Single-Phase Tripping logic. Most of these points are a triplication of points used for three-phase tripping.

Note: Several of the IO points must be programmed in a particular way (the default) for single-phase tripping and reclosing to function properly (see Section 6.6).

52aA	(Input)	Phase A 52a contact input
52aB	(Input)	Phase B 52a contact input
52aC	(Input)	Phase C 52a contact input
52bA	(Input)	Phase A 52b contact input
52bB	(Input)	Phase B 52b contact input
52bC	(Input)	Phase C 52b contact input
TRIPA	(Input)	Initiate Phase A trip
TRIPB	(Input)	Initiate Phase B trip
TRIPC	(Input)	Initiate Phase C trip
CLOSEA	(Input)	Initiate Phase A close
CLOSEB	(Input)	Initiate Phase B close
CLOSEC	(Input)	Initiate Phase C close
CLOSEA	(Output)	Phase A close
CLOSEB	(Output)	Phase B close
CLOSEC	(Output)	Phase C close
FAILA	(Output)	Phase A trip failure
FAILB	(Output)	Phase A trip failure
FAILC	(Output)	Phase A trip failure
LOCKA	(Output)	Phase A lockout alarm
LOCKB	(Output)	Phase B lockout alarm
LOCKC	(Output)	Phase C lockout alarm

11.3.2 Removed I/O Points

The following logical inputs and outputs are not available on units ordered with the single-phase tripping option.

EXTBFI	(Input)	External Breaker Failure Initiate
BFI	(Input)	Breaker Failure Initiate
BFT	(Output)	Breaker Fail Trip
BFT*	(Output)	Breaker Fail Trip Seal-in
Re-Trip	(Output)	Breaker Failure Re-trip
Re-Trip*	(Output)	Breaker Failure Re-trip Seal-in

11.3.3 Modified I/O Points

11.3.3.1 Logical I/O defined only for 3-phase operation

79S	(Input)	Single shot reclose initiate
79M	(Input)	Multi-shot reclose initiate
TCM	(Input)	Trip Coil Monitor
ARCI	(Input)	Automatic Reclose Inhibit
TARC	(Input)	Trip and Automatic Reclose

11.4 Event Logging and Counters

Extensions to the event logging and counters have been added due to the multiplicity of functional units required by single phase tripping. For the most part this is simply a triplication of existing types, e.g., 51P Trip becomes 51PA Trip, 51PB Trip, and 51PC Trip. However, certain new types will be needed because of the unique functionality of a single-phase tripping operation.

11.4.1 Fault Record

Similar to the operation record per phase logging of faulted protective elements must also occur. There is, however, no value field available in which to record phase information. Therefore, a pole mask field is assigned with the high byte of the Fault Type Element field in the Modbus® protocol (this high byte is currently unused). If the fault occurs when the unit is operating in three phase mode this field will contain zeroes but, if a single phase event occurs the appropriate bit in the mask will be set indicating which phase the fault occurred on. This should not create any compatibility problem with the previous structure of PCD2000 devices.

In addition, since fault records are logged at very specific points in time all multiple phase events are logged within the same record.

11.4.2 Counters

Extensions to the recloser counters have been made, essentially adding per phase versions of the following items:

Type	Description
Total Phase A Operations	Total number of pole open operations on phase A
Total Phase A Recloses	Total number of reclose operations on phase A
Ph A Stage 1 Recloses	Successful phase A reclose operations on the first step
Ph A Stage 2 Recloses	Successful phase A reclose operations on the second step
Ph A Stage 3 Recloses	Successful phase A reclose operations on the third step
Ph A Stage 4 Recloses	Successful phase A reclose operations on the fourth step
Total Phase B Operations	Total number of pole open operations on phase B
Total Phase B Recloses	Total number of reclose operations on phase B
Ph B Stage 1 Recloses	Successful phase B reclose operations on the first step
Ph B Stage 2 Recloses	Successful phase B reclose operations on the second step
Ph B Stage 3 Recloses	Successful phase B reclose operations on the third step
Ph B Stage 4 Recloses	Successful phase B reclose operations on the fourth step
Total Phase C Operations	Total number of pole open operations on phase C
Total Phase C Recloses	Total number of reclose operations on phase C
Ph C Stage 1 Recloses	Successful phase C reclose operations on the first step
Ph C Stage 2 Recloses	Successful phase C reclose operations on the second step
Ph C Stage 3 Recloses	Successful phase C reclose operations on the third step
Ph C Stage 4 Recloses	Successful phase C reclose operations on the fourth step

The original counters will operate as before when the unit is in the Three Phase mode of operation.

Note: The above counters are additions, not replacements of, the existing counters.

11.5 Front Panel HMI

11.5.1 Control Functions

11.5.1.1 Front Panel Trip and Close

The front panel trip and close controls will drive all poles to the selected position trip or close regardless of what operational mode the unit is in single-phase or three- phase. Three phase breaker failure logic shall apply, i.e., if two poles are closed and a front panel trip is issued and only one of the closed poles opens, then the breaker fail mechanism will attempt to drive the remaining closed pole open failed open mode.

11.5.1.2 Trip and Close via the Operations Menu

Three-phase trip and close operation is available in the operations menu and will operate similar to section 8.1.1 above. In addition, single pole trip and close items are also added to this menu to allow operation on a pole by pole basis. When issuing trip and close operations in this manner the single-phase breaker fail scheme applies.

11.5.2 Breaker State LED

The front panel Breaker State LED indicates Red when all three recloser poles are closed as determined by the 52A/52B logical inputs. Similarly, when all poles are opened the LED indicates green. A flashing Red/Green LED indicates a Breaker Fail State. When in the single phase tripping mode of operation and the poles are inconsistent but, a Breaker Failure has not been detected then the LED is turned OFF. To determine pole status from the background meter screen 'OPEN' or 'LOCKOUT' replaces the current value field, if the respective pole(s) reflect these states. For example, if pole 'A' is open and pole 'B' is locked out the LCD will look like the following illustration:

A Open	C Lockout
Ib: 647	In: 647

In addition, if one or two (but not all) poles are locked out the Lockout LED flashes at a once per second rate. If all poles are locked out the LED will be on continuously.

Screen 1 indicates the status of the individual poles as 'OPEN', 'CLOSED', or 'LOCKOUT'. The fault currents are not displayed on this screen. Instead, Screen 2 will indicate the maximum fault current, the protective element faulted, and the phases involved. An example follows in which phase 'A' is locked out (from a previous fault), phase 'B' operates on a phase to ground fault and subsequently recloses, and phase 'C' was open due to a previous manual operation on that phase closed:

Screen 1:

A Lockout	C Opened
B Closed	

Screen 2:

Max. Fault:	647 A
51P (BN)	

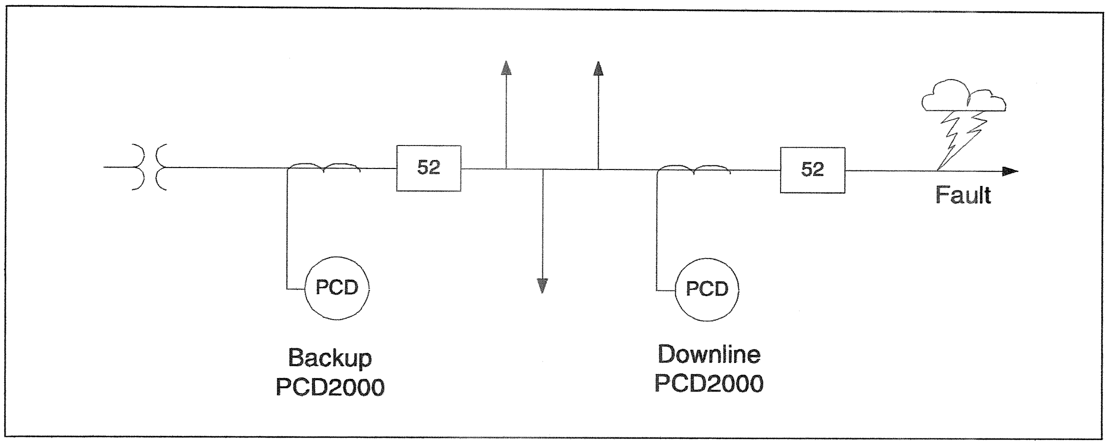
PCD2000 Application Note 1

AN1 Zone Sequence Coordination

Introduction

In power systems, protection schemes include series combinations of reclosers on medium voltage overhead distribution radial feeder lines. The series combination consists of one or several down-line recloser(s) and a backup substation recloser. This is shown in Figure AN1-1. The down-line and backup reclosers would be set for a typical operating sequence involving two fast or overcurrent trips. The trip times are coordinated so that the substation breaker does not normally operate for faults beyond the down-line device.

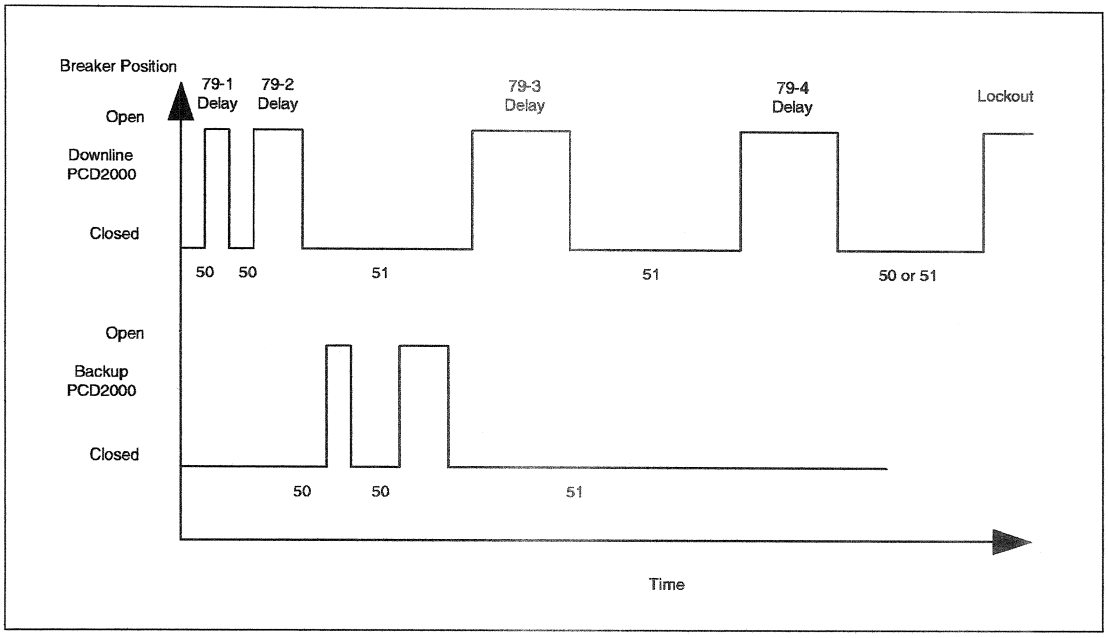
Figure AN1-1. Series Combination of Substation and Down-line Reclosers



Application

If the fault F1 in Figure AN1-1 were a permanent fault and the backup and down-line reclosers were set as described above, the down-line device would trip twice instantaneously and reclose and then begin to time out according to its time overcurrent setting. The backup recloser, however, sensing the same fault current, (series system) but having not tripped due to coordination, will now trip twice on its instantaneous trips since their times are faster than the down-line device's time overcurrent trip; times. The sequence of operations is shown in Figure AN1-2. These undesirable operations of the backup recloser not only interrupts power to more customers than required but also adds unnecessary wear on the mechanisms and contacts. Zone Sequence coordination (ZSC) is a coordination method that prevents undesirable trips of a backup recloser for a fault beyond a down-line recloser. The PCD2000 provides the ZSC function in its standard software. The backup PCD2000 senses the down-line device's interruption of the fault by entering and quickly exiting the 50/50N pickup state without issuing a trip and then advances to the next trip in the reclosing sequence. With the ZSC function enabled in the backup recloser described in Figure AN1-1, the down-line device alone will trip for fault F1 while the backup advances its recloser steps to remain coordinated. The correct operations are shown in Figure AN1-3.

Figure AN1-2. Down-line and Backup Recloser Operations without Zone Sequence Coordination



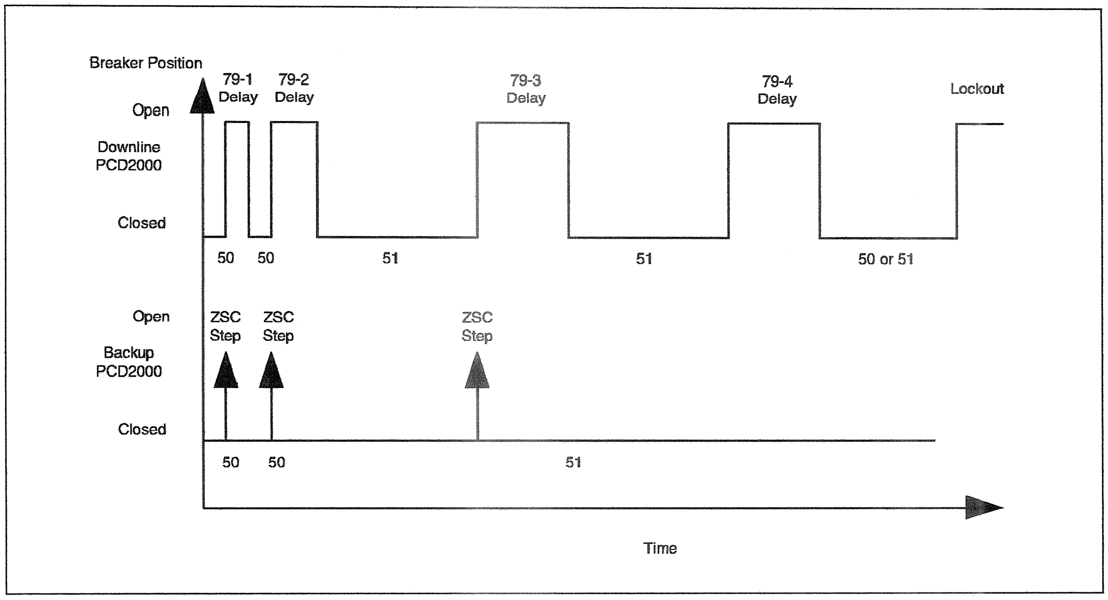
ZSC in the PCD2000

You can activate the ZSC feature by running the PCD2000 Operations software "External Communications Program (WinPCD)." Select **Change Settings** from the main menu and then select **Programmable Inputs**. Get the data from the PCD2000 and assign ZSC to one of the programmable inputs. Now you can remotely enable or disable the ZSC function via its programmed input terminals. With the relay's rated voltage applied to the ZSC terminals, the function is enabled. Conversely, without rated voltage applied to the ZSC terminals, the function is disabled. The status of the ZSC input terminals can be viewed by selecting **Test** in the main menu and then selecting Contact Inputs. The contact input status can be viewed with WinPCD and the man-machine interface LCD display. All Zone Sequence Coordination steps are stored in the Operations Record logs.

To ensure correct Zone Sequence Coordination operation, the protection engineer must adhere to the following criteria when setting the relays. Assume the backup PCD2000 is RELAY #1 and the down-line PCD2000 is RELAY #2.

1. RELAY #1 must be set for a longer instantaneous time than RELAY #2. The recommended minimum coordination margin is.1 seconds.
2. RELAY #1 time overcurrent settings must be programmed for a longer delay than those of RELAY #2.
3. The 79 reset time of RELAY #1 must be programmed greater than the largest open interval time of RELAY #2.

Figure AN1-3. Down-line and Backup Recloser Operations with Zone Sequence Coordination



PCD2000 Application Note 2

AN2 Coordination of Automatic Circuit Reclosers with Fuses

Many power utilities around the world use fuses on their lateral lines. It is important to ensure that Automatic Circuit Reclosers are appropriately programmed to coordinate in a predefined manner to ensure that distribution systems respond to line faults in accordance with expectations.

When using Automatic Circuit Reclosers in conjunction with fuses, they are generally set up in one of two modes, Fuse Saving or Fuse Clearing. The objective of these modes is as follows.

Fuse Savings: To have the Automatic Circuit Recloser operate a couple of operations faster than a fuse, trying to clear a momentary fault; if the fault is still present the Automatic Circuit Recloser operates more slowly than the fuse, enabling the fuse to clear.

Fuse Clearing: The Automatic Circuit Recloser is setup so that for a fault beyond any fuse in series, it shall be cleared by the fuse without causing the recloser to operate.

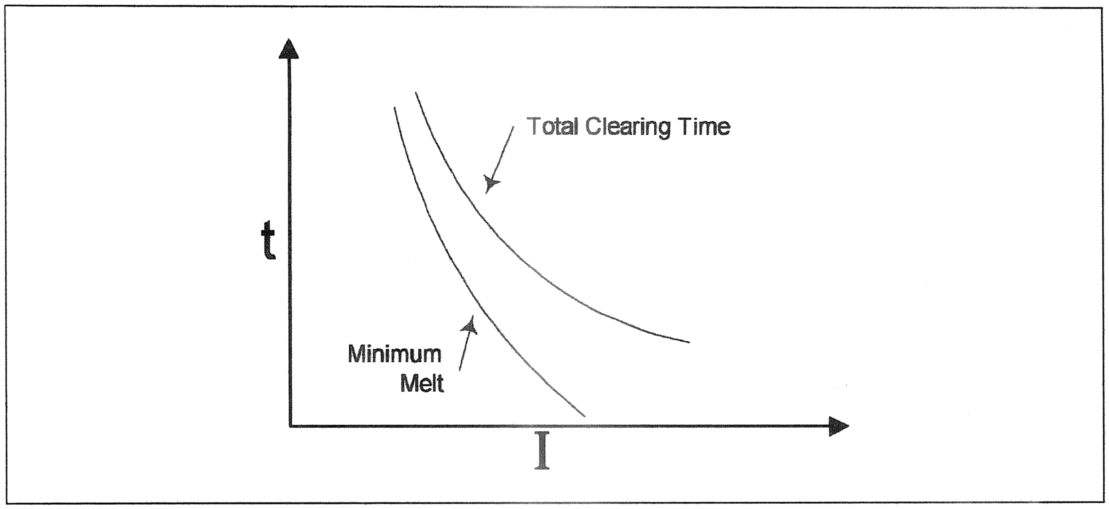
In order to implement these protection modes, it is necessary to consider the characteristics of the fuse. Fuses can be divided into two category types, current limiting and expulsion. Both of these fuse types have very different operational characteristics.

Current Limiting: As its name suggests, current limiting fuse are designed to limit through current. The time current characteristic is very steep. A current limiting fuse for part of its characteristic can operate in sub-half-cycle time. As a generalization current limiting fuses have very good performance when subjected to high magnitude faults, performance on low magnitude faults is poor. Because of this fuse types internal construction, they are susceptible to damage from the passing of lightning induced transients.

Expulsion: An expulsion fuse ultimately clears a fault by drawing an arc which extinguishes when the current goes through zero crossing (i.e. every half cycle). The published timing characteristics are achieved by a conducting metal filament which heats and melts with a known characteristic. When the filament melts, the end contacts of the fuse are able to separate, drawing an arc. The zero crossing of the current waveform then causes the arc to be extinguished. Expulsion fuses generally have very good performance on low magnitude faults. Their response time on high magnitude faults is limited by the need for a zero current crossing to turn off.

On overhead electricity distribution lines, it is most common to coordinate with expulsion fuses, or an expulsion and current limiting fuse series configuration.

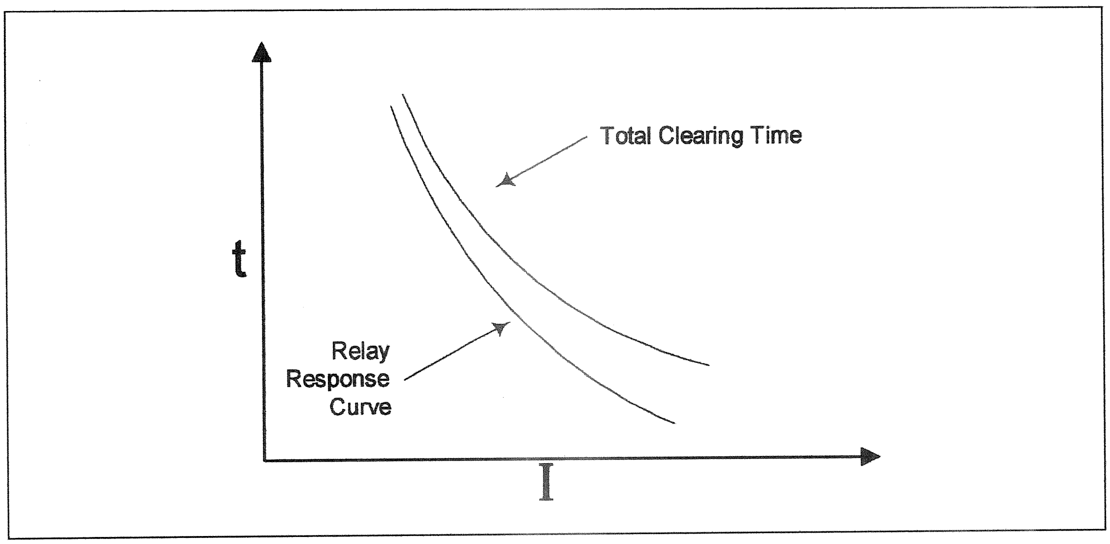
Fuses have two published characteristics, Minimum Melting Time and Total Clearing Time. These characteristics for an expulsion fuse can be plotted as follows:



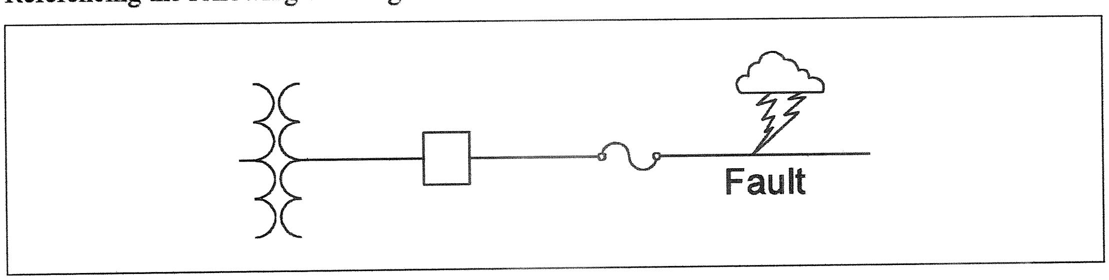
Minimum Melting Time: This curve is the time current relationship for a fuse, at which the fuse element has just melted.

Total Clearing Time: This curve is the time current relationship for which the fuse will clear a fault current, effectively isolating the length of power line beyond it.

For an electronically controlled Automatic Circuit Recloser similar curves are also used. The first is the Relay Response Curve and the second the Total Clearing Time. The Total Clearing Time is equal to the relay response time, plus the operating time of the recloser switching mechanism.



Referencing the following line diagram:



For a fuse clearing strategy, it is important that the total clearing time of the fuse is faster than the relay response time of the recloser.

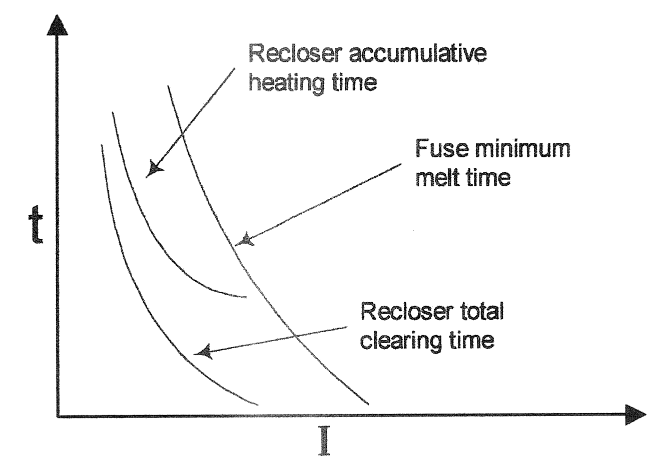
The coordination of Recloser and fuse becomes more involved when a fuse saving strategy is employed.

Simplistically for an Automatic Circuit Recloser, it is desirable for the fast operations that the reclosers' total clearing time is faster than the Minimum Melting Time of the fuse. For the Time-Delayed operation, the relay response time needs to be slower than the total clearing time of the fuse. The complication to this scheme comes when you consider that an Automatic Circuit Recloser is typically set for two fast and two time delayed operations. A fuse is a thermal device and its elements respond to an accumulative heat build up. Because the reclose time is sufficiently quick that the fuse doesn't completely cool down between recloser operations, coordination needs to be made between the recloser's accumulative heating curve and the fuse minimum melting time. Ideally, the recloser's accumulative heating curve takes into account the partial cooling between recloser trip operations. To produce this curve, two variables need to be known: The ability of the fuse to dissipate heat and the open time of the Automatic Circuit recloser.

Both of these variables are difficult to maintain as the Automatic Circuit Reclosers open time is often revised over the lifetime of its installation. The ability of a fuse to dissipate heat can vary from manufacture to manufacture, and is affected as well by its maintenance level. Installation point and the rating of the element also play a part.

It should be noted that the fast curve coordination is usually performed on the neutral (ground) curve of the recloser. The minimum operating current for phase protection needs to be set sufficiently high to carry line current, preventing it being an effective coordination curve.

For the two fast operations, an accumulative heating curve, assuming no between operations cooling can be constructed. The time for double the total clearing time is plotted as the accumulated heat curve. For consistent operation, the accumulated heat curve of the reclosers fast operations needs to be faster than the minimum melting time of the fuse link.



When it is difficult to coordinate the accumulative heating curve with the fuses Minimum Melting Time, then some allowance can be made for heat dissipation during the reclosers open time, the tighter the coordination, the longer the period that should be made between reclosures.

For fuse saving; it is the function of the time delay curve to cause the fuse to operate. Therefore, the only coordination that needs to be made is between the fuses total clearing time and the recloser's time delayed operating curve.

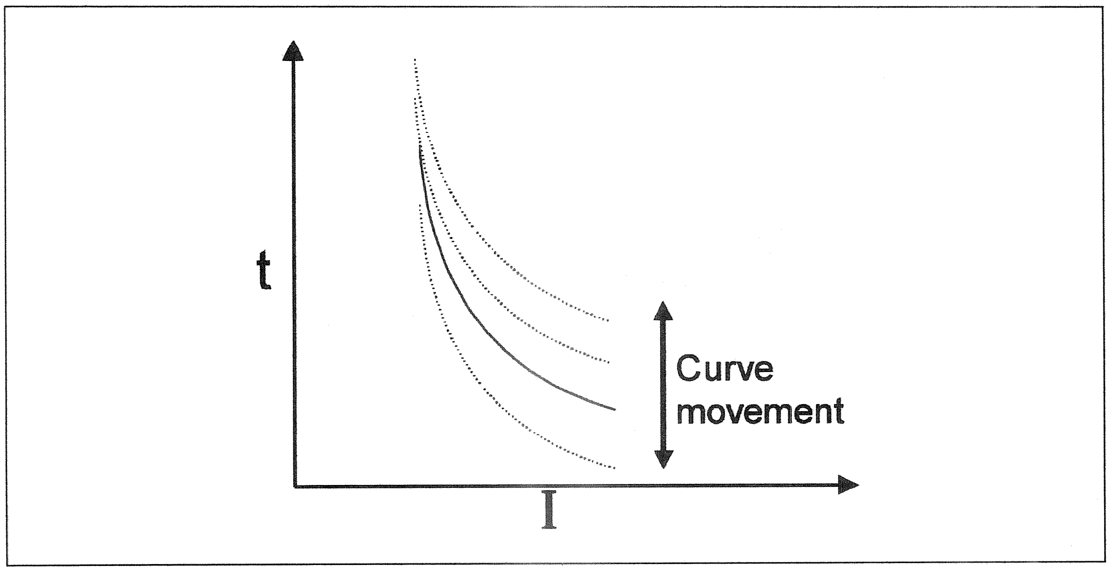
The practice of two time delay operations has its foundation with hydraulic reclosers where good coordination wasn't always achievable; and it is possible that the fuse may not have fully cleared by the time the recloser operates.

In order to get Automatic Circuit Reclosers to coordinate with fuses, several curve modifiers are available.

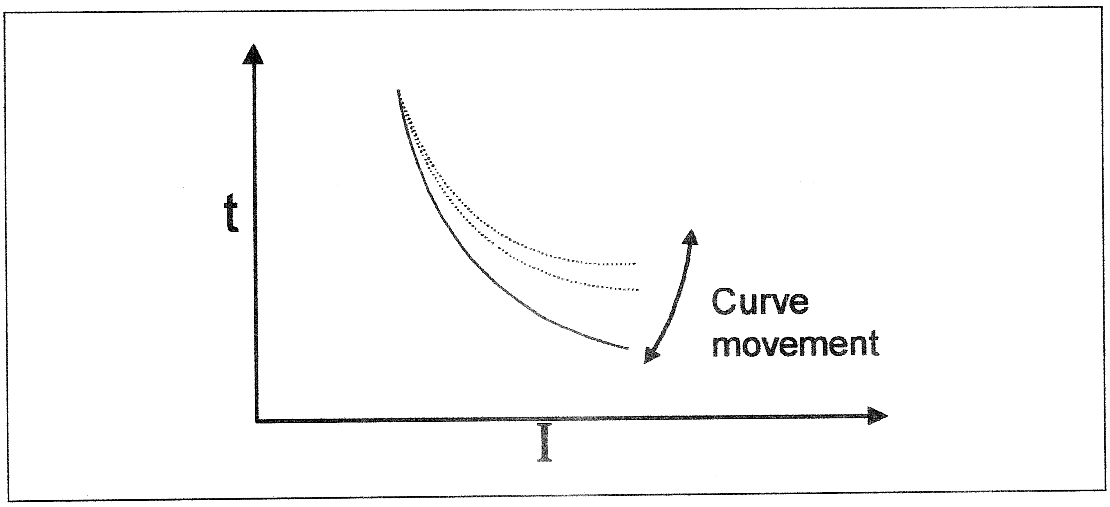
- Time dials (Curve Multipliers)
- Time curve adders
- Minimum response time

The affect on a curve by application of these modifiers can be illustrated as follows.

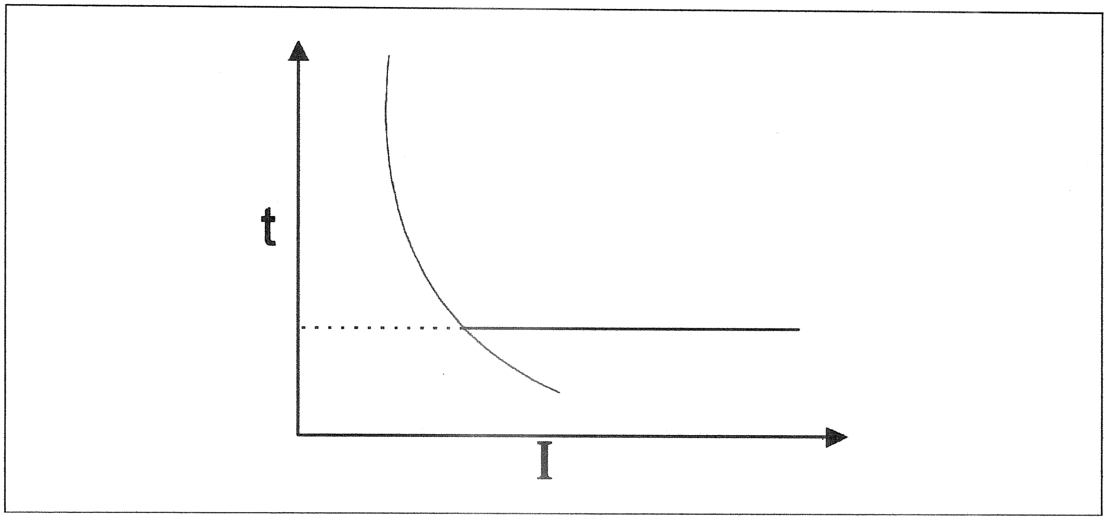
The affect of a **Time Dial** is to shift the operating curve in the vertical plane on the time current curve (TCC), as shown below. It should be remembered that the TCC has logarithmic axis. The time dial modifier multiplies every operating time point by its value.



The affect of a **Time Curve Adder** is to lift the faster response times that are associated with higher currents, as shown below. The time curve adder modifier adds a constant time offset to the time current curve.

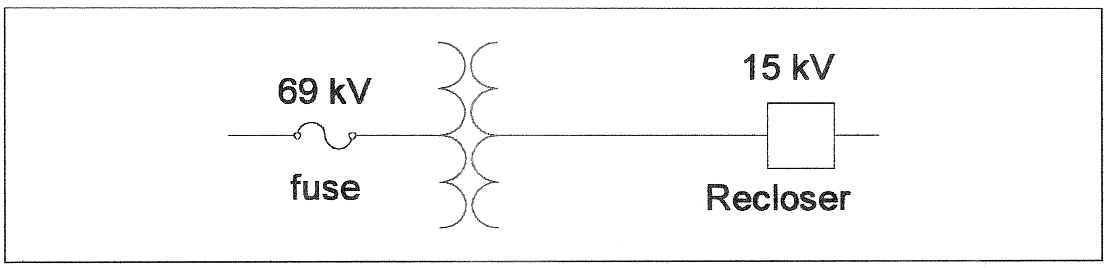


The affect of **Minimum Response Time** is to establish a time value at which no matter how fast the unmodified fuse curve says to respond, the trip signal shall only be issued at this time or greater, as shown below.



It is common practice to use these modifiers together on a single curve in order to achieve the desired response characteristic. The application priority of each modifier needs to be discussed. For a time current curve, the affect of the time dial is applied first and then the adder. These two modifiers do not affect the minimum response time.

So far, we have discussed coordination with fuses closer to the final customer then the recloser. When the recloser is closer to the delivery point then the fuse needs to be considered. This would be the case in small distribution substations where fuses are used on the high side of the substation transformer.



For this example, the Automatic Circuit Recloser needs to be able to go to lockout for all down stream faults before the high side fuses operate.

In order to perform this coordination, several pieces of information need to be accumulated:

- Fault current magnitude at the recloser location.
- The fuse size installed on the high side. If no size is specified, the minimum and maximum size that coordinates back to the terminal station needs to be known.
- Maximum load current through the Automatic Circuit Recloser. Note maximum load current on an individual distribution feeder may occur when it is used to back feed adjacent feeders.

The high side fuses are normally of the expulsion type for coordination to be possible.

The first step is to transfer the characteristic of the high side fuses' minimum melt curve to the characteristic it would be seen to have at the operating voltage of the Automatic Recloser. Should this fuse be one of a possible range of sizes, transpose the minimum melt curve of the fastest and the slowest fuse to the distribution voltage.

The transposed minimum melt curve can then be truncated at the maximum value of fault current possible at the point where the Automatic Circuit Recloser is installed.

The Automatic Circuit Reclosers protection elements are then set to operate faster than the high side fuse. Again, an accumulated heat curve needs to be constructed for the Automatic Circuit Recloser. Unlike the example where fuses are down line of the recloser, the accumulated heat curve, for this application, has to be constructed for all operations up to lock out. When no allowance is made for between operation cooling, the coordination between high side fuse and the recloser can be almost impossible. Two techniques are current practice to work around this issue.

1. Allow sufficient time between successive recloser operations that allow the fuse to cool.
2. Use high set instantaneous operations straight to lock out (ANSI 50P-3 protection) for higher magnitude faults.

A combination of these two techniques is possible. For a two fast, two time delayed operation sequence, the coordination may be established for the accumulated heating curve of the two fast operations. The second reclosing time could be set long enough to allow the fuse link to cool and the high set instantaneous set for lock out on the third and fourth curve sets.

When protection cannot be established by the use of modifiers, the possibility always exists to custom plot user defined curves.

While it is possible to perform recloser fuse coordination by plotting points on TCC tracing sheets, the use of specialized computer software makes the process much easier and more rapid. The use of these programs also one to easily investigate the fine tuning possibilities for curve sets.

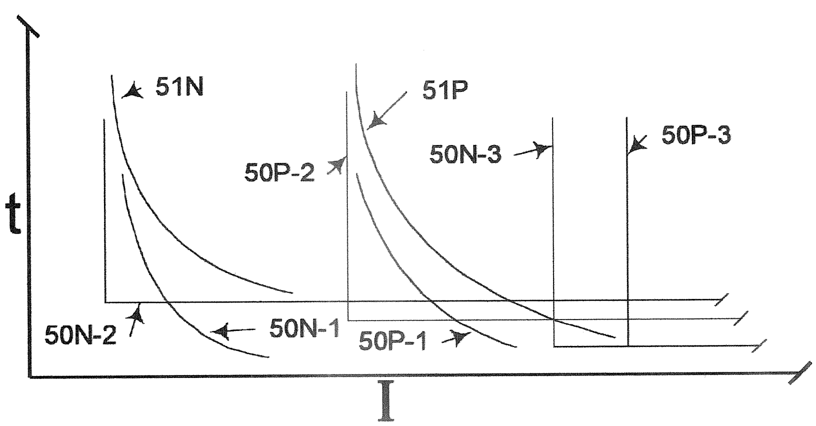
PCD2000 Application Note 3

AN3 Coordinating Multiple Automatic Circuit Reclosers in Series

It is frequently desirable to use Automatic Circuit Reclosers in series to extend effective protection reach, to form transition points for protection philosophies and to isolate sections of line from the effects of faults further along the feeder.

When Automatic Circuit Reclosers are deployed in series, the coordination between reclosers needs to be considered. This is especially true when the popular concept of a protection scheme based on a mixture of fast and time delayed tripping operations is employed.

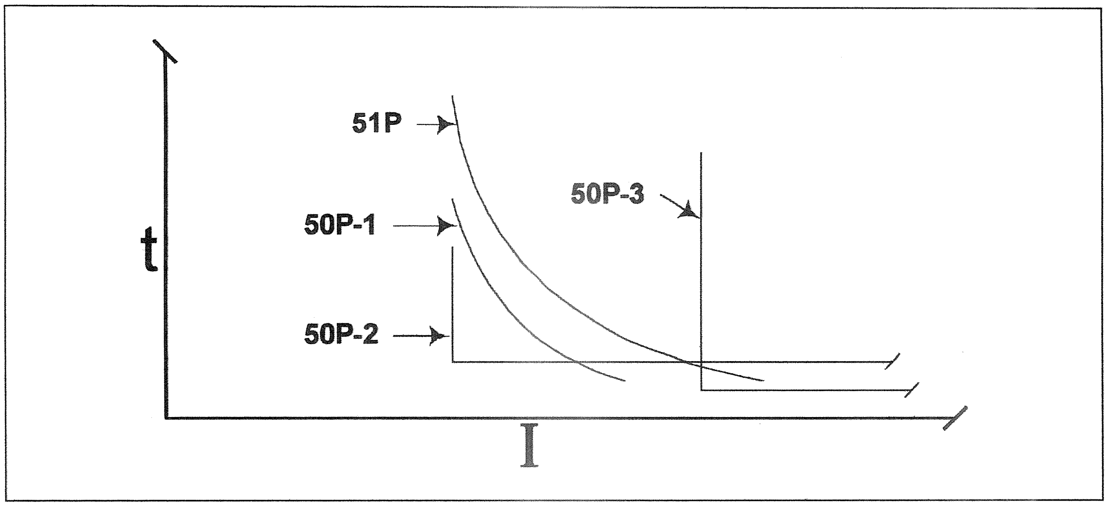
By referencing a typical construct of protection curve elements, the complexity that can be encountered in coordinating multiple ACR devices in series becomes more apparent.



The protection curves illustrated are a representation of the over-current elements only, and further protection elements may also be employed to fulfill particular functions.

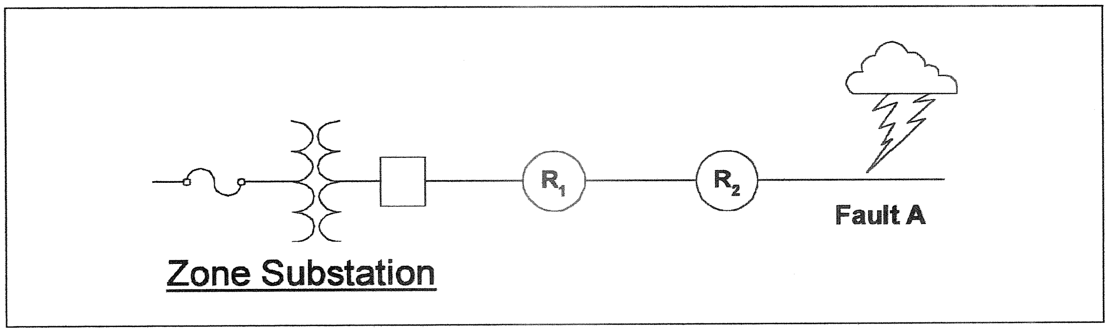
The 50 series nomenclature used in this paper is that defined by ANSI for over-current protection. For the purposes of discussing the coordination of multiple reclosers in series, this paper shall concentrate on the Phase Over-Current elements:

- 51P (Slow curve),
- 50P-1 (Fast curve),
- 50P-2 (Low set instantaneous)
- 50P-3 (High set instantaneous)



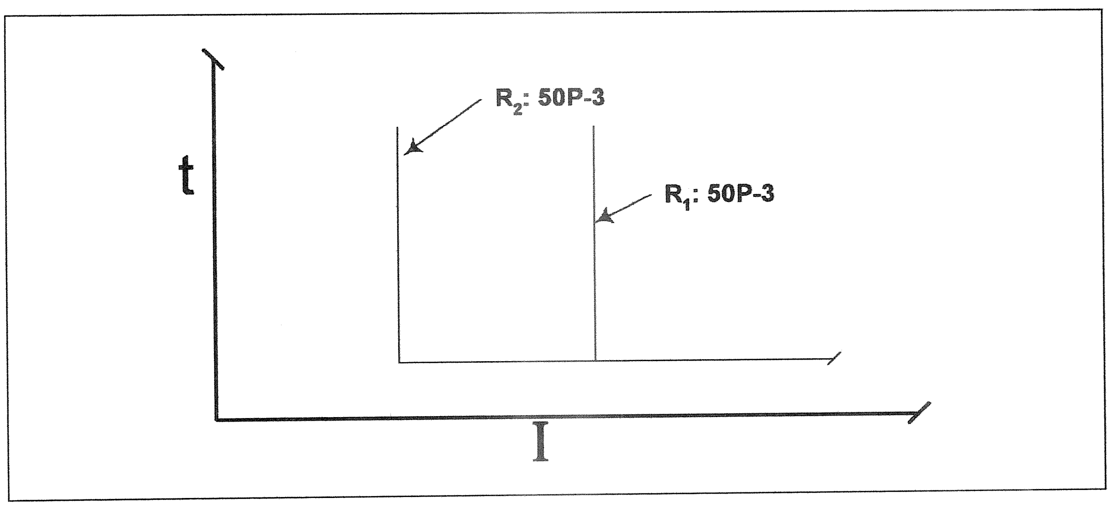
The principles illustrated for these curves apply equally to the neutral current (ground) fault elements.

Consider the following series arrangement of ACR's.



For a fault at location A, then it is desirable that recloser R2 handle the isolation of the fault without causing recloser R1 to operate.

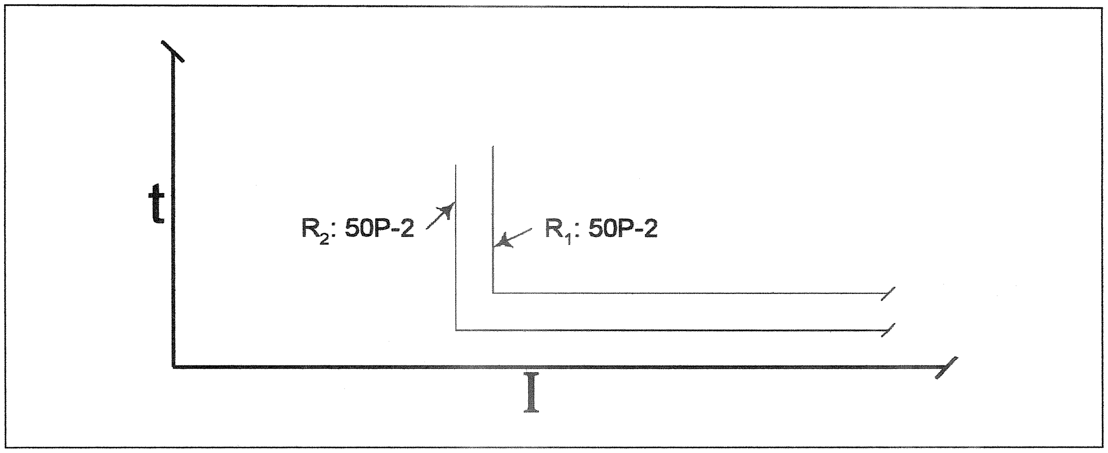
If both of these reclosers have their phase over-current protection elements enabled, then the coordination between these elements can be broken down as follows.



Consider the high-set instantaneous protection 50P-3. For both reclosers, the protection elements shall operate at the same time. A conservative coordination technique is to calculate the phase fault value at the Recloser R2 location, then set the minimum operating value for the 50P-3 element of Recloser R1 at this current value. Some protection practices will set it to the fault value less a percentage value (typically 10%). For feeders with very high fault values at the location of recloser R1, this may not always be possible to achieve, and for faults of a magnitude between the set minimum operating current and the fault level at the location of R2, tripping of both reclosers will occur.

The function of the protection 50P-2 can now be considered. The role of the 50P-2 is to establish a maximum response time for phase over-current protection. Its minimum operating value is set as a multiple of the minimum phase over-current 51P value, this value is typically in the range 0.5 to 20.

For the example:

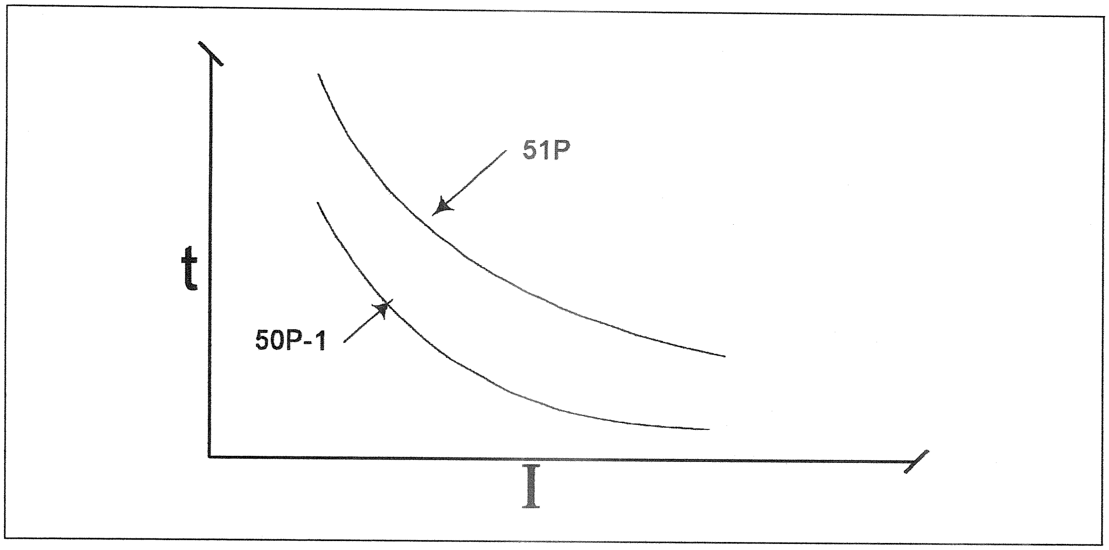


Coordination between the two devices is achieved by two variables, minimum operating current and definite time response.

For:

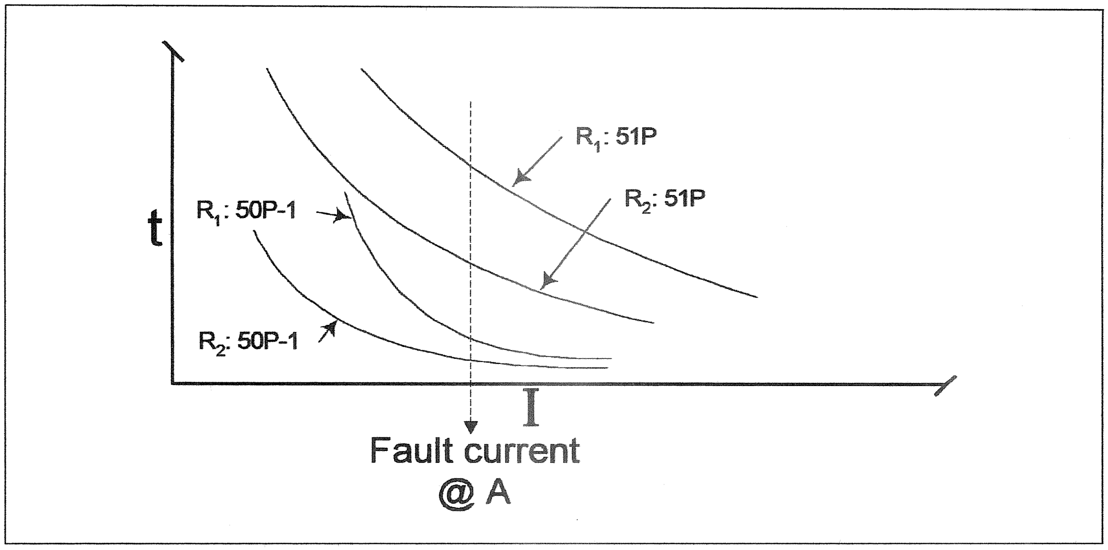
- **Minimum Operating Current:** The value set for recloser R2 needs to be lower than the R1 setting by a suitable margin to allow for any error differences between the values of current both devices read.
- **Definite Time:** The definite time value for recloser R1 needs to be greater than the value set for Recloser R2 plus the total closing time of the recloser. A conservative practice is to also allow an additional minimum time difference equal to a half cycle allowing the possibility for vacuum bottle restrike.

Protection elements 51P and 50P-1 need to be considered as a pair.



Coordination between Recloser 1-51P and Recloser 2-51P elements, as well as the reclosers respective 50P-1 elements are achieved in the same manner as described for the 50P-2 element using both current magnitude and time. It is important to ensure that the minimum difference between the operating time of the respective curves is achieved for the value of the phase fault current calculated at the location of Recloser 2 and for all values lesser in magnitude.

Consider how these curves can overlap for two reclosers in series.



A frequent operating sequence for Automatic Circuit Reclosers is two fast, two time delayed. The 50P-1 is setup as the fast curve and the 51P is the time delayed. Assume both reclosers are setup through the operation to lockout for a fault at location A, then the operating sequences would be as follows:

1. TripR2 on 50P-1
2. Reclose
3. TripR2 on 50P-1
4. Reclose
5. TripR1 on 50P-1
6. Reclose

7. TripR1 on 50P-1
8. Reclose
9. TripR2 on 51P
10. Reclose
11. Lockout R2 on 51P

This operating sequence has the undesirable affect of tripping the recloser R1, increasing the number of customers momentarily interrupted by the fault. In order to combat this affect, most modem Automatic Circuit Reclosers have a Zone Sequence Coordination (ZSC) feature.

The Zone Sequence Coordination feature increments the Automatic Circuit Reclosers trip counter whenever a fault element pickup is cleared before its protection elements generates a trip command. It should be noted that it will increment up to, but not generate the lockout trip.

Should the Automatic Recloser R1 be equipped with and have enabled Zone Sequence Coordination, then the operating sequence for a fault at location A would be:

1. TripR2 on 50P-1
2. Recloser
3. TripR2 on 50P-1
4. Recloser
5. TripR2 on 51P-1
6. Recloser
7. Lockout R2 on 51P

For the Automatic Reclosers in this example the same coordination issues need to be satisfied for the neutral (ground) fault time current curves.

It should be noted that when the recloser R2 doesn't have neutral (ground) fault time current elements that correspond with the recloser R1, settings, then it is necessary coordinate the phase over-current settings of recloser R2 with the neutral (ground) time current curves of the recloser R1. This would typically be the case if R2 is a hydraulic timing type recloser. As a general note, the accuracy of neutral current readings is generally less than for phase over-current, since the accumulative errors of three current transformers have to be taken into account. Thus, greater timing margins are advisable for neutral to neutral curve coordination than would be used for phase to phase. Additionally, the timing of hydraulic reclosers drift with temperatures, wear and level of maintenance. Their timing accuracy is not as well defined as that achievable with electronic controllers.

A cautionary note should be made regarding comparing time curves. The curves for electronic controls are typically relay times (minimum response) and the operating time of the interruption mechanism needs to be added to generate a total clearing time curve. For hydraulic reclosers and some analog electronic controlled reclosers, the published time current curves are for total clearing time. This needs to be taken into consideration when comparing coordination curves, or upgrading hydraulic reclosers with electronically controlled ones.

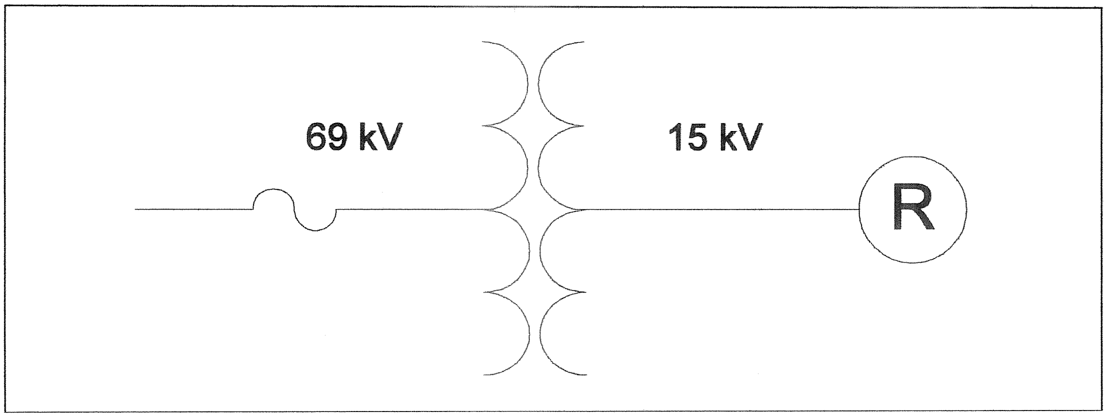
So far, the coordination between two reclosers in series has been discussed. For three or more reclosing devices, coordination is first considered for the recloser closer to the substation; then a check with the other Automatic Recloser(s) it associates with. It is often frequently necessary to iterate setting values in order to achieve full coordination. For greater than three reclosers in series, this can be extremely difficult and frequently not achievable without making compromises in terms of usable protection elements and the possibility of co-tripping. As a general rule of thumb, the coordination of greater than three reclosers in series is to be discouraged; however, it isn't impossible. In order to provide an increased number of automatically isolated protection zones, the use of Automatic Sectionalizers that count the number of recloser operations could be considered.

The concepts discussed are a generalized guide, modified and different practices are followed in many places around the world. They generally take into account local constraints and field practices. Whatever your local practices, the use of multiple Automatic Reclosers in series can achieve incremental performance increases in distribution feeder availability and quality of supply to power utility customers, while generating operational savings to the utilities own bottom-line.

PCD2000 Application Note 4

AN4 Using a PCD2000 as Feeder Protection on a Primary Fused Substation

For smaller sized substations, it is common practice to fuse the transmission side of the transformer rather than incur the capital cost of installing a breaker. On the distribution side, the fault and line currents are usually sufficiently low that automatic circuit reclosers can be used for feeder protection.

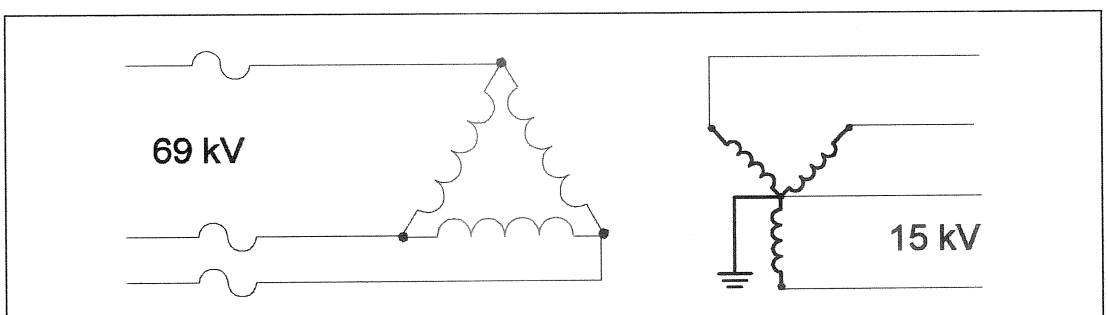


If one phase fuse operates, the transformer can be in a position of having only two phases energized.

The downstream protection device can be used for:

- Primary side blown fuse indication.
- Disconnecting the feeder load from the transformer when a fuse operates.
- Reducing the probability of a fuse operating as a result of accumulated heating.

This article is written with reference to delta-wye connected transformers. If wye-wye transformers are installed, the same practice will work, but the settings could be slightly different. Please contact ABB for recommendations.



If one of the high side fuses operate on a substation, it is desirable to detect it immediately.

Single-phase protection can be achieved by the collective use of single and three-phase undervoltage elements,27-1P and 27-3P,in the PCD2000 control of the VR-3S recloser.

When a phase is lost on the delta side primary, the voltage on two phases of the secondary side star winding fall to approximately half of their normal voltage.

This half voltage can be detected using the undervoltage protection element.

For this protection scenario, it is often desirable not to trip the recloser if an undervoltage condition exists on all three phases. A three-phase undervoltage would most likely be due to other system conditions rather than a blown high side fuse, such as three-phase switching on the transmission line side or voltage pull down due to a heavy fault.

In the PCD2000,the undervoltage protection element (27)needs to be set for every protection group used (Main,Alt1,Alt2).The three-phase (27-3P)and single-phase (27-1P)functions both use the same undervoltage 27 setting. The undervoltage setting has two variables, voltage and time. When using the 27 element in this way, the voltage needs to be set sufficiently high to detect a half voltage as a fault, while being low enough that line faults will not be seen as an undervoltage. It is suggested that a voltage setting of approximately 70%of nominal line voltage can be used to meet this criteria.

Having set the undervoltage variables, it is still necessary to enable the protection. This is achieved by mapping the variables into the programmable outputs so that a feedback shall be made when a 27-1P (single-phase undervoltage) but not a 27-3P (three-phase undervoltage) protection element operates. This feedback is then mapped to the open input in the programmable input map.

The question of how quickly to trip is subject to many opinions. However, as a guide when practicing a two-second clearing protection philosophy, a greater time such as three seconds would significantly contribute to a reduction in the possibility of tripping due to bus voltage pull down during a fault.

When the instrument transformers that supply voltage signals to the recloser are fused, concern is often expressed about causing a false trip as a result of an instrument transformer fuse operation. The protection element for a blown fuse alarm (BFUA) can be used in conjunction with the 27-3P to prevent the recloser tripping. The BFUA becomes active when any phase secondary voltage drops below 7 volts and 51P (phase overcurrent) or 51N (neutral overcurrent)pickup condition doesn't exist.

The resulting logic is therefore: **Trip if 27-1P and not (27-3P or BFUA)**

We have discussed so far protection in the event of a single-phase condition. There are, however, many protection features in the PCD2000 control of the VR-3S to reduce the possibility of the substation fuse operating in the first place. For a fused substation, the automatic circuit recloser needs to be able to go to lockout for all downstream faults before the high side fuse operates on accumulated heating from the reclosing cycle.

In order to perform this coordination, several pieces of information need to be accumulated:

- Fault current magnitude at the recloser location.
- The fuse size installed on the high side. If no size is specified, the minimum and maximum size that coordinates back to the terminal station needs to be known.
- Maximum load current through the automatic circuit recloser. Note, the maximum load current on an individual distribution feeder may occur when it is used to backfeed adjacent feeders.

The high side fuses are normally of the expulsion type in order for coordination to be possible.

The first step is to transfer the characteristic of the high side fuses ' minimum melt curve to the characteristic it would have at distribution normal voltage. Should this fuse be one of a possible range of sizes, transpose the minimum melt curve of the fastest and the slowest fuse to the distribution voltage.

The transposed minimum melt curve can then be truncated at the maximum value of fault current possible at the point where the automatic circuit recloser is installed.

The automatic circuit recloser 's protection elements are then set to operate faster than the high side fuse. An accumulated heat curve needs to be constructed for the automatic circuit recloser. Unlike when fuses are down line of the recloser, the accumulated heat curve for this application has to be constructed for all operations to lock out. When no allowance is made for between operation cooling, the coordination between high side fuse and the recloser can be almost impossible. Two techniques are used in current practice to work around this issue.

1. Allow sufficient time between successive recloser operations that allow the fuse to cool.
2. Use high set instantaneous operations straight to lockout (ANSI 50P-3 protection) for higher magnitude faults.

A combination of these two techniques is possible. For a two fast, two time-delayed operation sequence, the coordination may be established for the accumulated heating curve of the two fast operations. The second reclose time could be set long enough to allow the fuse link to cool and the high set instantaneous set for lockout on the third and fourth curve sets.

When protection cannot be established by the use of modifiers, the possibility always exists to custom plot user definable curves.

The use of undervoltage protection and suitable overcurrent protection in the PCD2000 control of the VR-3S recloser will improve the overall protection performance of the fused substation and protect the utility assets.

PCD2000 Application Note 5

AN5 Breaker Failure Settings on Oil-Filled Retrofits & Coordination with Downstream Hydraulic Reclosers

Applying the PCD2000 on Oil-Filled Reclosers

When applying a PCD2000 on oil filled reclosers, certain considerations must be made to assure proper performance of the system. When compared with magnetic actuation of the VR-3S, high voltage solenoids and motor mechanisms require a longer time to complete an open or close operation and to send the position status back to the control.

Thus, particular importance must be given the Trip Failure setting and the Close Failure setting in the Configuration Settings menu of the PCD2000, as well as the programmed Open Times (or "dead time") in the reclose sequence that are part of the Primary, Alternate 1 and Alternate 2 Settings. The PCD2000 uses these settings to determine whether there is a breaker problem and when to reclose in a fault sequence.

The first open time can be set to 0.1 on a PCD2000 control, however in a Form 4C control the minimum reclose time should be set to 0.6 seconds. From experience, a minimum open time of 0.6 seconds is also recommended in the PCD2000 for application with these oil reclosers to allow the unit time to successfully trip. Therefore, it is recommended that regardless of the operating unit program, at least 0.5 seconds of Open Time is needed to ensure that arcing on a temporary fault has a chance to extinguish and dissipate before the circuit is re-energized.

This setting is found in the Primary, Alternate 1 and Alternate 2 protection groups in the 79 Open Time selection.

Trip Failure Time & Close Failure Time

There are two other important settings: Trip Failure Time and Close Failure Time. These must be set at a minimum level above the actual trip and close time of the recloser, and the trip failure time must be set less than the shortest reclose time selected. The following table contains the recommended settings for different types of reclosers.

Table AN5-1. Minimum Reclose Time, Trip Failure, and Close Failure Settings for Retrofit Applications

Recloser	Recommended Minimum Reclose Time	Recommended Trip Failure Setting	Recommended Close Failure Setting
Non-ABB Retrofits	0.6 sec	30 cycles	24 cycles
ESV Retrofits	0.5 sec*	24 cycles	24 cycles
VR-3S Reclosers	0.5 sec	18 cycles	18 cycles
* ESV retrofits must have at least 8 second reclose times after the second trip to allow for motor charging.			

This setting is found in the Configuration menu under Trip failure Mode and Close Failure Mode.

Breaker Failure Mode

One final setting is Breaker Failure Mode that is also in the Configuration Settings menu. This setting has two options, Open and Original. Should the control determine a problem in the operating unit, the Open setting will allow the PCD2000 control to attempt two additional trip operations to open the unit. Original mode will allow the unit to return to the state, which it was in before a problem was detected. Hence, if the unit was closed and the control detected a problem in the operating unit, it would allow the unit to remain in the closed position with no additional trip attempts. This is only to be used if there is backup protection for the range of faults that could be seen on this section of line.

The normal setting for the Breaker Failure Mode is "Open."

Additionally, consideration should be made with regard to applying any microprocessor-controlled recloser on systems, which previously used plug type curves. The microprocessor control is more exacting in its response time, and there is no variation with the resistor used in a plug and mechanical relays.

Applying the PCD2000 on Systems with Downstream Hydraulic Reclosers

In addition to the breaker failure settings, consideration should be made with regard to applying any microprocessor-controlled recloser on systems that employ downstream hydraulic reclosers. The tripping time on these type reclosers can fluctuate with temperature, condition of the oil, and with the age of the recloser. The PCD2000 microprocessor control is not affected by these factors, and as such there can be coordination variations between the PCD2000 controlled recloser and hydraulic reclosers. To adjust for this, some things can be done to assure proper coordination. If an "A" (101) curve is used on the PCD2000 control, consider changing to a slightly slower curve such as an "N" (104) or an "R" (105) curve. Alternatively, a minimum response time can be selected to slow up the curve.

Looking at the difference between the hydraulic and the curve response time in the PCD2000, one rule of thumb is to allow a 12-cycle separation between the respective fast and slow curves of the two devices.

Note: It is highly recommended that only experienced personnel familiar with the entire application must do the modification of curves. Modification of protection curves on the PCD2000 from the replaced control and coordination with any upstream devices is the responsibility of the user.

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