

Electronic Trip Circuit Breaker Basics

Circuit Breaker Application Guide

Class 0600

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by **Schneider** Electric

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Section 1—Electronic Trip Circuit Breakers

What is a Circuit Breaker?

A circuit breaker has two primary functions:

1. to provide a nonautomatic means to energize and de-energize the circuit
2. to open automatically to protect the circuit from damage due to an overcurrent condition.

In other words, a circuit breaker must be able to be switched on and off, and it must open automatically during an overcurrent condition.

In order to open automatically, circuit breakers are equipped with some type of tripping mechanism. Some circuit breakers employ electromechanical tripping mechanisms, some use hydromechanical tripping mechanisms, and some use electronic tripping mechanisms.

Square D brand electronic trip circuit breakers use the Micrologic™ tripping system, which includes current sensors, a microprocessor-based trip unit and a tripping solenoid.

Electronic trip molded case circuit breakers are designed to meet UL489, Underwriters Laboratories Standard for Safety for Molded Case Circuit Breakers and Circuit Breaker Enclosures.

Why Use Electronic Trip Circuit Breakers?

In most cases, the basic overcurrent protection provided by standard thermal-magnetic circuit breakers will meet the requirements of the electrical system design. In some cases, however, basic overcurrent protection might not be enough.

Electronic trip circuit breakers can provide the additional features needed in those cases. Reasons to use electronic trip circuit breakers include

- enhanced coordination capabilities
- integral ground-fault detection
- communication capabilities
- future growth potential

Enhanced Coordination Capabilities

In electrical systems where downtime could have critical consequences, electronic trip circuit breakers provide more versatility to achieve coordination. For instance, certain installations serving continuous processes may be required to continue operating during a fault condition because shutting the system down would be more costly than the damage done by the fault itself. Or, in critical care facilities, a loss of power could result in the loss of life.

These situations require that coordination be optimized at all costs. In order to maximize coordination, downstream branch devices should operate very fast (with no intentional delay) and main devices should delay operation so that the downstream devices have time to clear the fault.

Micrologic electronic trip circuit breakers can help optimize coordination:

- Withstand ratings give the designer a larger window of coordination potential. The withstand rating is the level of rms symmetrical current that a circuit breaker can carry with the contacts in the closed position for a certain period of time. At current levels above the withstand rating (and less than or equal to the interrupting rating), the circuit breaker will trip instantaneously. In other words, the withstand rating is the highest current level at which delay can be introduced to maintain coordination

with downstream devices. Withstand ratings are available only on full-function trip systems ordered with the adjustable short-time function.

- Inverse time delay characteristics allow for better coordination with fusible switches or thermal-magnetic circuit breakers downstream. Devices that respond to heat generated by current flow (such as fuses and thermal-magnetic circuit breakers) have inverse time tripping characteristics. This means that as current increases, the time that it takes the device to trip will decrease. In order to coordinate better with these types of downstream devices, Micrologic circuit breakers offer inverse time delay characteristics on the long-time, short-time and ground-fault functions.
- The ammeter/trip indicator displays the level of ground-fault leakage current associated with the circuit. The ground-fault pickup level on the circuit breaker may then be adjusted somewhat higher than the amount of leakage current displayed on the ammeter.

This assumes that ground-fault detection testing was done before the system was energized and no ground-fault problems were found. In retrofit situations the magnitude of leakage current may be significant due to the deteriorating effects of moisture, dirt, rodents, etc., over time. New installations will also show some magnitude of leakage current at start-up.

There are no hard and fast rules for selecting the proper level of ground-fault protection because the level of leakage current on each system is different. The system engineer should provide information on the proper levels of protection.

Integral Ground-Fault Detection

Electronic trip circuit breakers simplify the installation of equipment ground-fault detection into the electrical system.

Externally-mounted ground-fault detection systems require the specifying of five different parts:

- a circuit breaker,
- a ground-fault relay
- a ground-fault sensor
- a shunt trip for the circuit breaker
- a testing means

Additional wiring is also required to install the system.

Electronic trip circuit breakers include most of the detection equipment within the circuit breaker housing. The phase current sensors, summing toroid, pickup and delay adjustments, tripping solenoid, and a push-to-test feature are all enclosed within the molded case.

The only part not within the circuit breaker case is the optional neutral sensor required for a four-wire system. That means that ground-fault detection plus overcurrent protection is as easy as specifying and mounting one device (except four-wire systems which require an additional neutral sensor).

Micrologic circuit breakers are available with two different ground-fault detection options:

- ground-fault protection for equipment
- ground-fault alarm

The ground-fault protection for equipment is available on circuit breakers with Micrologic ground-fault trip units, and will trip the circuit breaker in the event of a ground fault.

The ground-fault alarm option is available on circuit breakers with the Micrologic 5.0P trip system only. This function will allow a signal to be sent but will not trip due to a ground fault—maintaining system continuity.

Coordination Capabilities

Micrologic circuit breakers can coordinate with each other and with power monitoring systems.

Communication between circuit breakers at different levels in the system allows the downstream circuit breaker closest to the fault to ignore its preset delay time and trip without any intentional time delay on a short circuit or ground fault. This form of communication is known as zone-selective interlocking (ZSI).

Coordination assures that continuity of service is maximized during any type of overcurrent. However, coordination does not eliminate the stress on the system caused by the energy dissipated during a fault. ZSI actually reduces the stress on the system resulting from a fault while maximizing continuity of service.

Micrologic trip units are equipped with ZSI communication capabilities as a standard feature. For more information on ZSI, see Data Bulletin 0600DB0001, *Reducing Fault Stress With Zone-selective Interlocking*.

Communication between circuit breakers and the power monitoring system allows the user to monitor each circuit and record energy usage, power surges, normal operating modes, harmonic contribution, etc. In addition, Micrologic trip systems can communicate the following information:

- history of last trip
- trip unit pickup and delay levels
- impending trip conditions
- operating currents for each phase
- ground-fault leakage current associated with the circuit
- ground-fault alarm signal
- power and energy measurements

The ground-fault alarm signal allows a ground fault to be reported without interrupting power to the system. It is especially useful when continuity of service must be maintained at all costs and where the maintenance staff is trained to locate and correct any fault problems before an unplanned outage takes place.

Future Growth Potential

Many of the adjustable features that enhance coordination also provide means for increasing the ampere rating of an electronic trip circuit breaker to meet future growth needs. The adjustability of a Micrologic circuit breaker enables a designer to plan for future growth. A circuit breaker can be chosen based on projected growth, and by changing the long-time pickup, its ampacity can be reduced down to 20% of its maximum. When growth occurs, the ampacity may be increased up to the circuit breaker's maximum. The versatility of the adjustments on an electronic trip circuit breaker offers the designer a multitude of options to meet initial and future capacity requirements.

Another way to plan for future growth or to save space and minimize cost is to specify 100% rated electrical distribution equipment. A circuit breaker either carries a standard rating or a 100% rating. The standard rating is subject to NEC sizing rules which limit the application to 80% of the circuit breaker rating when continuous loads are involved.

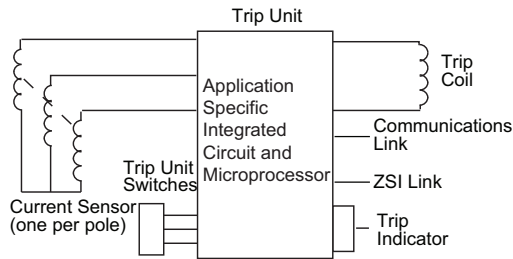
The National Electrical Code (NEC) recognizes overcurrent devices that are listed for operation at 100% of their rating for continuous loading. This means that the equipment has undergone additional testing to verify that it can handle

the additional heat rise associated with this level of operation. 100% rated circuit breakers are permitted to be loaded continuously at their full rating (as long as minimum enclosure requirements, venting configurations and wire insulation requirements have been met).

Section 2—Micrologic™ Trip Systems

General

Figure 1: Trip System



Square D brand electronic trip circuit breakers are equipped with Micrologic™ Trip Systems, which provide adjustable tripping functions and characteristics using true root-mean-square (rms) current sensing.

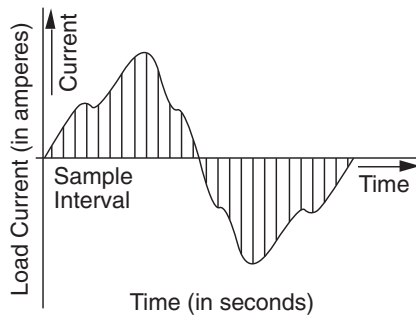
Micrologic trip systems use a set of current transformers (called CTs or sensors) to sense current, an electronic trip unit to evaluate the current, and a tripping solenoid to trip the circuit breaker.

Micrologic trip units allow the user to set the proper overcurrent or ground current protection required in the electrical system. If current exceeds the set value for longer than its set time delay, the trip system automatically opens the circuit breaker. All Micrologic protective functions are fully fault powered, no external power source is required.

Circuit breakers are shipped with the long-time pickup set at rated current and all other trip unit adjustments set at their lowest settings. Actual settings required for a specific application must be determined by a qualified consultant or plant engineer. A coordination study is recommended to provide coordination between all overcurrent protective devices in the distribution system.

RMS Sensing

Figure 2: Trip System Current Sensing



The sensing system on an electronic trip circuit breaker responds to the flow of current through the circuit breaker. Electronic trip circuit breakers are limited to ac systems because the electronic trip system uses current transformers to sense the current.

The Micrologic trip system samples the current waveform many times per cycle to assure true rms measurements to the 31st harmonic.

True rms sensing accurately measures the magnitude of a non-sinusoidal waveform. Therefore, the heating effects of harmonically distorted waveforms are accurately evaluated.

Electronic trip circuit breakers with Micrologic trip systems can be used on 50/60 Hz systems with alternating current (ac) to direct current (dc), dc to ac, and ac to ac converters. This includes applications that use silicon-controlled rectifiers (SCRs) and adjustable frequency controls.

Micrologic Trip Systems

The type of Micrologic trip systems depends on the circuit breaker:

Table 1: Micrologic Trip Units




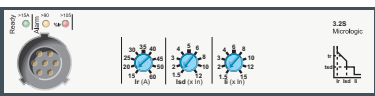

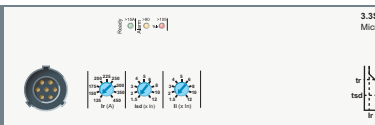
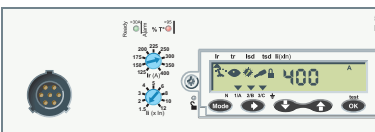
Micrologic Trip Unit		Circuit Breaker
	Micrologic 3.0 / 5.0	Masterpact NT, NW PowerPact P-, R-frame
	Micrologic 3.0A / 5.0A / 6.0A	Masterpact NT, NW PowerPact P-, R-frame
	Micrologic 5.0P / 6.0P Micrologic 5.0H / 6.0H	Masterpact NT, NW PowerPact P-, R-frame
	Micrologic 3.2 / 3.2S	PowerPact H-, J-frame
	Micrologic 5.2A / 6.2A Micrologic 5.2E / 6.2E	PowerPact H-, J-frame
	Micrologic 3.3 / 3.3S	PowerPact L-frame
	Micrologic 5.3A / 6.3A Micrologic 5.3E / 6.3E	PowerPact L-frame

Table 2: Micrologic Trip Units

x—Standard Feature o—Available Option

Features	PowerPact H-, J-, and L-Frame Circuit Breakers						PowerPact P and R Circuit Breakers Masterpact NT and MW Circuit Breakers								
	Standard		Ammeter		Energy		Standard		Ammeter			Power		Harmonic	
	3.2/ 3.3	3.2S/ 3.3S	5.2A/ 5.3A	6.2A/ 6.3A	5.2E/ 5.3E	6.2E/ 6.3E	3.0	5.0	3.0A	5.0A	6.0A	5.0P	6.0P	5.0H	6.0H
LI	x						x		x						
LSI ¹		x	x		x			x		x		x		x	
LSIG / Ground-Fault Trip ²				x		x					x		x		x
Ground-Fault Alarm/No Trip ^{2,3}												x		x	
Ground-Fault Alarm/Trip ²				x		x							x		x
Current Setting Directly in Amperes	x	x	x	x	x	x									
Adjustable Rating Plugs							x	x	x	x	x	x	x	x	x
True RMS Sensing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
UL Listed	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Thermal Imaging	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
LED for Long-time Pickup	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
LED for Trip Indication	x	x	x	x	x	x			x	x	x	x	x	x	x
LED for Green "Ready"	x	x	x	x	x	x									
Up to 12 Alarms Used Together			x	x	x	x									
Digital Ammeter			x	x	x	x			x	x	x	x	x	x	x
Zone-selective Interlocking ⁴			x	x	x	x			x	x	x	x	x	x	x
Communications	o	o	o	o	o	o			o	o	o	x	x	x	x
LCD Display			x	x	x	x			x	x	x	x	x	x	x
Front Display Module FDM121			o	o	o	o									
Advanced User Interface			x	x	x	x						x	x	x	x
Neutral Protection ²			x	x	x	x						x	x	x	x
Contact Wear Indication ⁵			x	x	x	x						x	x	x	x
Incremental Fine Tuning of Settings			x	x	x	x						x	x	x	x
Load Profile ^{5,6}			x	x	x	x									
Power Measurement					x	x						x	x	x	x
Power Quality Measurements					x	x								x	x
Phase Loading Bar Graph									x	x	x	x	x	x	x

¹ The LSI with 3.2S/3.3S trip units have fixed short time and long time delays.

² Requires neutral current transformer on the three-phase four-wire loads

³ Requires M2C or M6C Programmable Contact Module.

⁴ ZSI for H/J frames is only IN. For other circuit breakers ZSI is IN and OUT.

⁵ Indication available using the communication system only

⁶ % of hours in 4 current ranges: 0–49%, 50–79%, 80–89%, and >90% In.

Trip Characteristics

Micrologic trip units provide a full range of adjustable tripping characteristics that constantly monitor the line currents. If the line current exceeds the trip settings longer than the delay settings, the trip unit signals the circuit breaker to trip.

Table 3: Trip Unit Adjustable Tripping Characteristics

3.0/3.2/3.2S/3.3/3.3S/5.0	3.0A/5.0A/6.0A/5.0P/6.0P/5.0H/6.0H 5.2A/5.3A/6.2A/6.3A/5.2E/5.3E/6.2E/5.3E
Long-time pickup	Long-time pickup
Long-time delay	Long-time delay
Short-time pickup	Short-time pickup
Short-time delay (I ² t IN only)	Short-time delay (I ² t IN and I ² t OUT)
Instantaneous pickup	Instantaneous pickup
Ground-fault pickup	Ground-fault pickup
Ground-fault delay (I ² t IN only)	Ground-fault delay (I ² t IN and I ² t OUT)
	Ground-fault alarm

Trip settings are used to obtain a coordinated system in which a downstream circuit breaker will trip before an upstream circuit breaker.

Properly adjusting the Micrologic trip settings will result in a circuit breaker trip curve that falls above and to the right of the downstream circuit breaker trip curve. Under overcurrent conditions, the downstream circuit breaker will trip first.

Schneider Electric recommends that a system coordination study be done to find the proper trip unit settings to optimize coordination with other devices.

Trip Unit Functions

Adjusting the trip unit functions will change the trip characteristics of the circuit breaker.

Long-Time Trip Function

LONG-TIME PICKUP — set value (multiplied by the ampere rating) sets the maximum current level which the circuit breaker will carry continuously. If the current exceeds this value for longer than the set delay time, the circuit breaker will trip.

LONG-TIME DELAY — sets length of time that the circuit breaker will carry a sustained overload before tripping. Delay bands are labeled in seconds of overcurrent at six times the ampere rating.

Long-time delay is an inverse time characteristic in that the tripping time decreases as the current increases.

INDICATOR — the trip unit includes an indicator that will flash when the current reaches 90% of the LONG-TIME PICKUP setting and will be lit continuously when the current is above 100% of the pickup setting.

Short-time Trip Function

SHORT-TIME PICKUP — set value (multiplied by the ampere rating) sets the short circuit current level at which the circuit breaker will trip after the set SHORT-TIME DELAY.

SHORT-TIME DELAY — sets length of time the circuit breaker will carry a short circuit within the short-time pickup range. Delay bands are labeled in seconds of short-circuit current at 10 times the ampere rating. The short-time delay can be set to I²t On and I²t OFF settings.

Instantaneous Trip Function

INSTANTANEOUS PICKUP — set value (multiplied by the ampere rating) sets the short-circuit current level at which the circuit breaker will trip with no intentional time delay.

The instantaneous function will override the short-time function if the INSTANTANEOUS PICKUP is adjusted at the same or lower setting than the SHORT-TIME PICKUP.

Ground-Fault Trip Function

GROUND-FAULT PICKUP — set value (multiplied by the sensor size) sets the current level at which the circuit breaker will trip after the set GROUND-FAULT DELAY.

GROUND-FAULT DELAY Switch — sets the length of time the circuit breaker will carry ground-fault current which exceeds the GROUND-FAULT PICKUP level before tripping. Delay bands can be adjusted to I²t ON and I²t OFF settings.

I²t OUT delay is a fixed time characteristic in that the delay time does not change.

Ground-fault Alarm Function

GROUND-FAULT ALARM — set value (multiplied by the sensor size) sets the current level at which the circuit breaker will signal that a ground fault is present.

Section 3—A Look at Coordination

Coordination

When designing an electrical distribution system, coordination must be considered.

Coordination is the process of localizing the protection against an overcurrent condition to restrict an outage to only affected equipment. Only the upstream device closest to the fault trips, leaving the rest of the system intact to continue supplying power to unaffected areas. Coordination does not exist when more than one device opens simultaneously during an overcurrent condition.

The degree of coordination required is dependent on the load. For less critical loads, such as commercial lighting, lack of coordination may only be a nuisance. For hospital applications, manufacturing processes and other critical loads, coordination may be required.

In order to maximize coordination, downstream branch devices should operate very fast (with little or no intentional delay) and main devices should delay operation so that the downstream devices can clear the fault.

Coordination is limited by the instantaneous trip characteristics of the upstream device. When the magnitude of the overcurrent exceeds the instantaneous pickup point of the upstream device, it will trip with no intentional delay and coordination is lost.

Electronic trip devices from Square D, such as Micrologic™ circuit breakers and GC-200 ground-fault relays, have adjustable pickup and delay settings to maximize coordination with other overcurrent protective devices in the system.

For more information on selectivity, see:

- *Short Circuit Selective Coordination for Low Voltage Circuit Breakers*
Data bulletin 00100DB501
- *Enhancing Short Circuit Selective Coordination with Low Voltage Circuit Breakers*
Data bulletin 0100DB0403
- *Overcurrent Protection*
Data bulletin 0600DB0301
- *Reducing Fault Stress with Zone-selective Interlocking*
Data bulletin 0600DB0001

Coordination Under Ground-Fault Conditions

The National Electrical Code (NEC) requires that equipment ground-fault protection be provided at service entrance disconnecting means rated for 1000 amperes or more on solidly grounded wye systems between 150 volt-to-ground and 600 volts phase-to-phase (NEC 215-10 includes ground-fault protection requirements for feeders). In order to meet the minimum requirements set forth in the NEC, it is acceptable to provide ground-fault protection only at a single point in the electrical system — at the main circuit breaker.

What happens if a ground fault occurs farther down in the system, at the branch circuit level for instance? If the only device capable of detecting a ground fault is the service entrance main, a ground fault anywhere in the system will trip the main device. Coordination is lost because the main circuit breaker tripped and shut down the entire system!

It is estimated that over 80% of all overcurrents are low-level overloads and ground faults. Odds are very high that the situation described above will happen in the real world. In order to prevent a blackout condition, multiple

levels of ground-fault protection are recommended. That is, equipment ground-fault protection should be provided at each level of distribution (main, feeder, branch, etc.) to maximize system continuity. By supplying multiple levels of ground fault protection, it is possible to isolate ground faults to feeders and branch circuits or to any portion of the system with ground-fault protection.

Zone-Selective Interlocking

Coordination assures that continuity of service is maximized during any type of overcurrent. However, coordination does not eliminate the stress on the system caused by the energy generated during a fault. Zone-selective interlocking (ZSI) actually reduces the stress on the system resulting from a fault while maximizing continuity of service.

Without ZSI, a coordinated system results in the circuit breaker closest to the fault clearing the fault, but with an intentional delay.

With ZSI, the device closest to the fault will ignore its preset short-time and/or ground-fault delays and clear the fault with no intentional delay.

Eliminating intentional delay with ZSI results in faster tripping times without sacrificing coordination. This limits fault stress by reducing the amount of let-through energy the system is subjected to during an overcurrent.

Circuit breakers that are not coordinated (due to improper settings) will not be coordinated simply by using ZSI. For more information on ZSI, see data bulletin 0600DB0001, *Reducing Fault Stress with Zone-Selective Interlocking*.

**Electronic Trip Circuit Breaker Basics
Instruction Bulletin**

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