

Application guide—Miniature circuit breaker

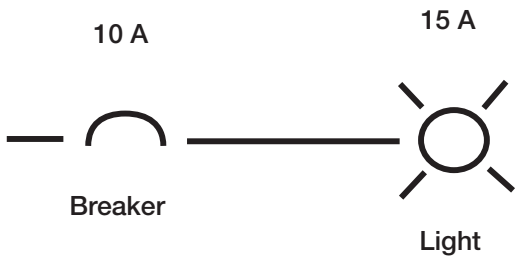
Introduction

The circuit breaker plays an important role in providing over-current protection and a disconnect means in electrical networks. Recent advancements in circuit breaker technology has increased breaker performance and protection.

Overload

An overload is a slow and small overcurrent situation that causes the ampacity and temperature of the circuit to gradually increase over time. This type of event is characterized by a slight increase in the load (ampacity) on the circuit and is interrupted by the thermal trip unit of the breaker.

Thermal Example

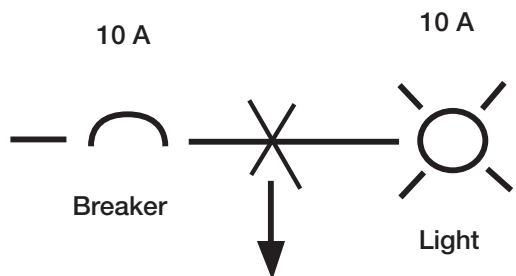


The light draws more than 10 amps for an extended period of time creating a thermal overload.

Short circuit

A short circuit is a rapid and intense overcurrent situation that causes the ampacity of the circuit to increase. This type of event is characterized by a dramatic increase in the load (ampacity) on the circuit and is interrupted by the magnetic trip unit of the breaker.

Magnetic Example

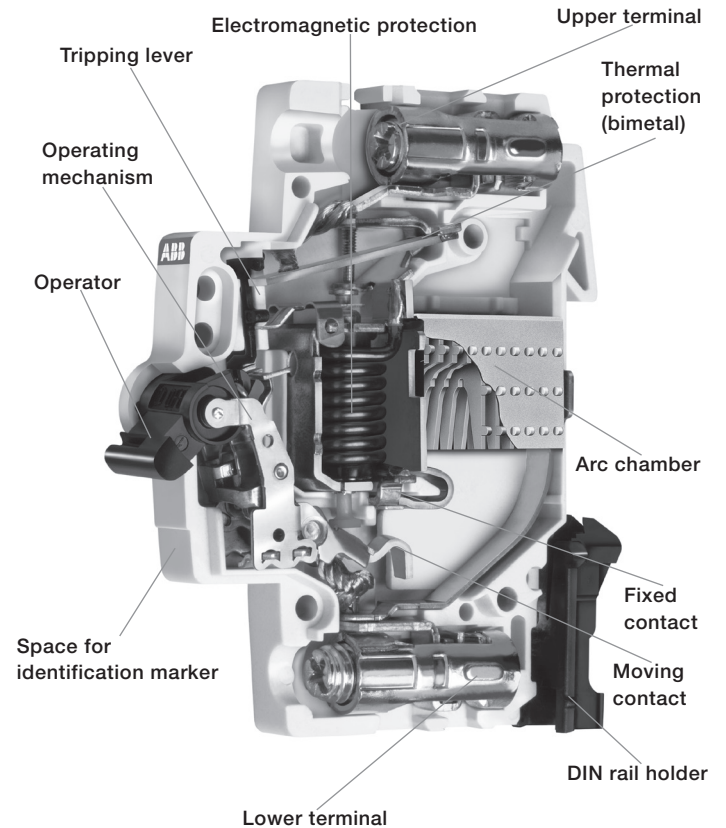


The wire connected between the light and breaker is cut and shorted to ground creating a short circuit.

Breaker definition

A breaker is a device designed to isolate a circuit during an overcurrent event without the use of a fusible element. A breaker is a resettable protective device that protects against two types of overcurrent situations: overload and short circuit.

ABB current limiting breaker

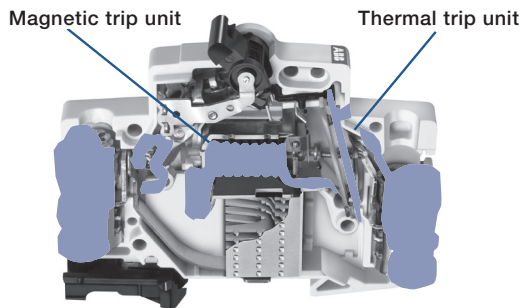


Circuit breaker construction

Thermal/Magnetic trip units definition

ABB Current Limiting Breakers use an electromechanical (Thermal/Magnetic) trip unit to open the breaker contacts during an overcurrent event. The thermal trip unit is temperature sensitive and the magnetic trip unit is current sensitive. Both units act independently and mechanically with the breaker's trip mechanism to open the breaker's contacts.

Current flow during operation



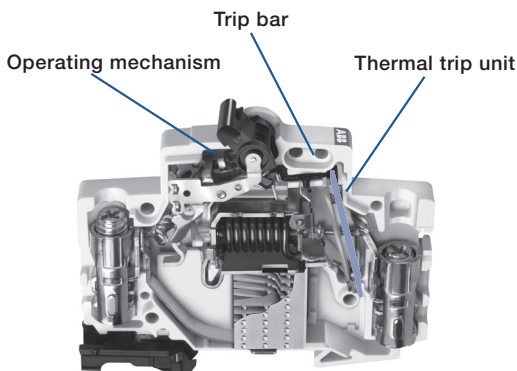
All highlighted components are energized during operation

Overload protection

The thermal trip unit protects against a continuous overload. The thermal unit is comprised of a bimetal element located behind the circuit breaker trip bar and is part of the breaker's current carrying path. When there is an overload, the increased current flow heats the bimetal causing it to bend. As the bimetal bends, it pulls the trip bar that opens the breaker's contacts.

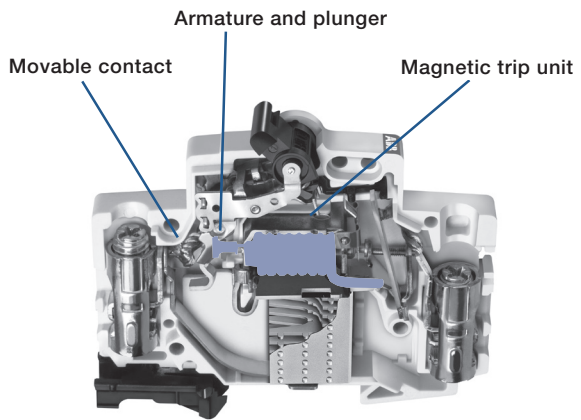
The time required for the bimetal to bend and trip the breaker varies inversely with the current. Because of this, the tripping time becomes quicker as current increases in magnitude.

Overload protection is applicable to any installation, conductor, or component that can be subjected to low-magnitude but long-time overcurrents. Low-magnitude, long-time overcurrents can be dangerous because they reduce the life of the electrical installation, conductor, and components. If left unchecked, fire could result.



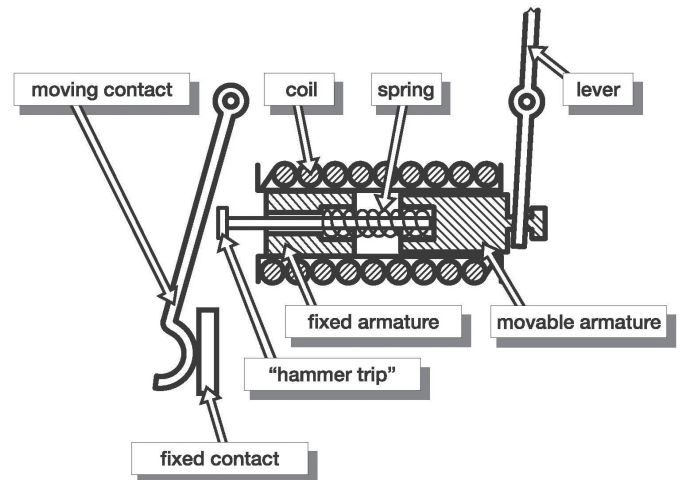
Magnetic trip units (short circuit protection)

The magnetic trip unit protects against a short circuit. The magnetic trip unit is comprised of an electromagnet and an armature.



Components of a magnetic trip unit

When there is a short circuit, a high magnitude of current passes through the coils creating a magnetic field that attracts the movable armature towards the fixed armature. The hammer trip is pushed against the movable contact and the contacts are opened. The opening of the breaker's contacts during a short circuit is complete in .5 milli-seconds.

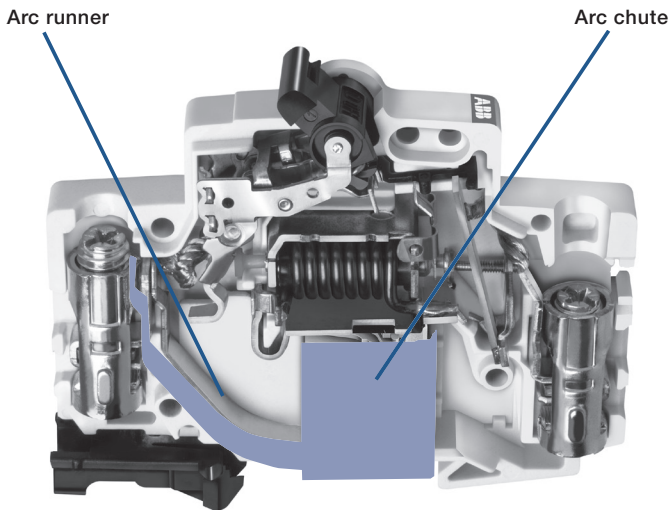


Circuit breaker construction

Arc runners/arc chutes

The arc runner guides the electric arc away from the open contacts into the arc chute where it is extinguished.

During an overload or short circuit event, the contacts of the breaker separate, and an electrical arc is formed between the contacts through air. The arc is moved into the arc chute by "running" the arc down the interior of the breaker along the arc runner. When the arc reaches the arc chute, it is broken into small segmented arcs. The segmented arcs split the overall energy level into segments less than 25 V. Each 25 V segment does not have a high enough energy level to maintain an arc and all energy is naturally dissipated.



Breaker curves

Thermal trip unit (region one)

The first sloping region of the breaker curve is a graphical representation of the tripping characteristics of the thermal trip unit. This portion of the curve is sloped due to the nature of the thermal trip unit. The trip unit bends to trip the breaker's trip bar in conjunction with a rise in amperage (temperature) over time. As the current on the circuit increases, the temperature rises, the faster the thermal element will trip.

Example using the curve below: If you had a 10 A breaker and the circuit was producing 30 amps of current, the breaker would trip between two seconds and one minute. In this example, you would find the circuit current on the bottom of the graph (multiples of rated current). The first line is 10 amps (10 amp breaker x a multiple of one), the second line is 20 amps (10 amp breaker x multiple of two), and the third line is 30 amps (10 amp breaker x multiple of three). Next, you would trace the vertical 30 A line up until it intersects the red portion of the breaker thermal curve. If you follow the horizontal lines on both sides of the red curve to the left, you will see that the breaker can trip as fast as two seconds and no slower than one minute.

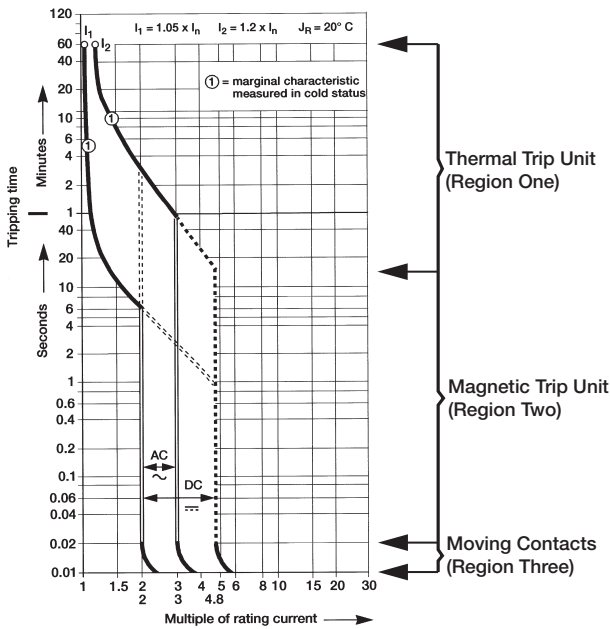
Magnetic trip unit (region two)

This region of the breaker curve is the instantaneous trip unit. ABB's miniature circuit breaker's instantaneous trip unit interrupts a short circuit in 2.3 to 2.5 milliseconds. Because of this, the curve has no slope and is graphically represented as a vertical straight line.

See curve example. If you had a 10 amp breaker, the magnetic trip element would interrupt a short circuit between 10 and 30 amps (10 amp breaker x multiple of two and three) in 2.3 to 2.5 milliseconds.

Breaker contacts (region three)

This region of the curve is the time required for the contacts of the breaker to begin to separate. The contacts will open in less than .5 milliseconds and is graphically represented by the bottom vertical portion of the curve.



Circuit breaker current limitation

Current limiting definitions

All ABB miniature circuit breakers are UL tested and certified as current limiting protective devices. Current limiting circuit breakers provide a higher level of circuit protection than typical zero point external breakers.

UL AC 60 Hz cycle

UL defines an AC cycle as the potential energy of the wave form traveling from zero-to-positive amplitude, positive-to-zero amplitude, zero-to-negative amplitude, negative-to-zero amplitude 60 times in one second. One cycle is completed every 16.6 milliseconds.

UL breaker current limiting

UL defines breaker current limitation as a breaker that interrupts and isolates a fault in less than $\frac{1}{2}$ of an AC cycle. $\frac{1}{2}$ a cycle is completed in 8.3 milliseconds.

NEC240.2 current limiting

A device that, when interrupting current in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.

IEC 60947-2 current limiting circuit breaker

A circuit breaker with sufficiently short trip time to prevent the short-circuit current from reaching the peak value which would otherwise be reached.

ABB current limiting breakers

ABB current limiting breakers can interrupt and isolate a fault in $\frac{1}{8}$ of an AC cycle. The breaker fault interruption is completed in 2.3 to 2.5 milliseconds.

Zero point extinguishing breakers

A typical zero point extinguishing breaker interrupts a fault and does not isolate the energy. The breaker allows an arc to be present between the open contacts until the AC wave form crosses zero. When the wave form crosses zero, the potential energy is zero and the arc (fault) naturally extinguishes. The arc could be present for up to 8.3 milliseconds.

Current limiting breakers and electrical networks

Current Limitation

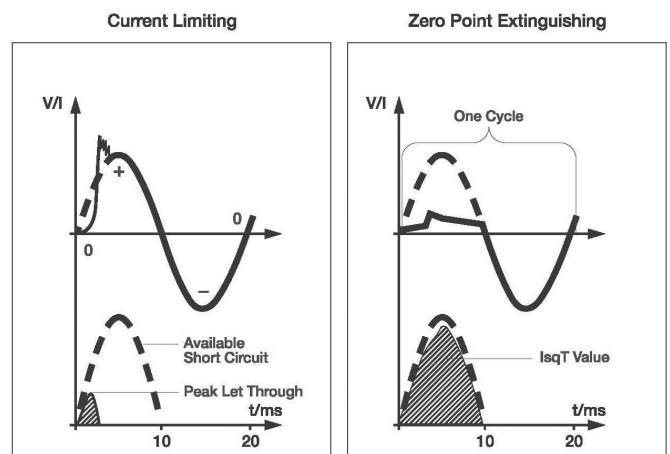
When a short-circuit condition occurs, the “ideal” current limiting circuit breaker opens before the current waveform can reach its full potential magnitude which occurs at $\frac{1}{4}$ cycle (4.17ms). ABB’s current limiting breakers can interrupt a fault in about $\frac{1}{2}$ cycle or 2.3 ms to 2.5 ms. ABB’s current limiting breakers interrupt a short circuit in less than $\frac{1}{8}$ cycle and limit the amount of current that can reach a circuit. Limiting the available current on the circuit provides additional protection against network, breaker, or bus damage and prevents the tripping of upstream breakers (selective coordination).

I^2t

The true destructive nature of a short circuit is measured by the time it is available combined with the peak value of the short circuit. The I^2t (Amps Squared over Time) value represents the amount of energy available on a network during a short circuit and is represented by the shaded area on the graph below.

During a short circuit, both magnetic forces and thermal energy combine to damage devices on the electrical network. The level of thermal energy and magnetic forces are directly proportional to the square of the current. The magnetic forces vary as a square of the peak current available and the thermal energy varies as a square of the RMS (root mean square) current available.

ABB’s current limiting breakers will limit the let-through energy to a fraction ($\frac{1}{100}$) of the value that is available from the network. By comparison, a zero crossing breaker would let through approximately 100 times as much destructive energy as the current limiting circuit breaker [$(100,000A / 10,000A)^2 = 100X$]. ABB’s current limiting breakers limit the short circuit current to a relatively small magnitude in an extremely short time, which dramatically limits a short circuit’s destructive energy.



Circuit breaker current limitation

Current limiting and zero crossing breakers

During the initial stages of a short circuit, a breaker's contacts open to interrupt the circuit. After the contacts open, an arc forms in the air between the contacts on both the current limiting and zero crossing breaker contacts. What distinguishes a current limiting breaker from a zero crossing breaker is what each breaker does after an arc is formed between the open contacts.

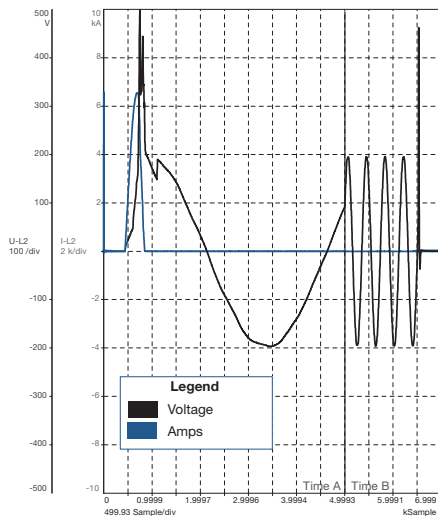
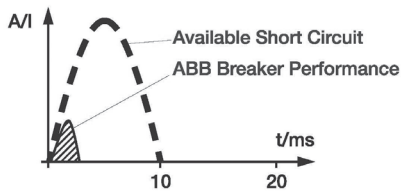
A current limiting breaker "runs" the arc down the breaker arc runner into an arc chute that extinguishes the arc.

A zero crossing breaker does not attempt to extinguish the arc. The breaker is designed to withstand the energy of the arc long enough for the waveform to cross zero. When the wave form crosses zero the potential energy is zero and the arc naturally extinguishes itself.

ABB's current limiting breakers interrupt the arc energy in 2.3 ms to 2.5 ms ($\frac{1}{8}$ cycle) and a zero crossing breaker allows the arc to be present for up to 8.3 ms ($\frac{1}{2}$ cycle). A zero crossing breaker will let through 100 times as much energy as an ABB current limiting breaker.

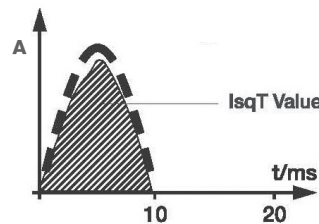
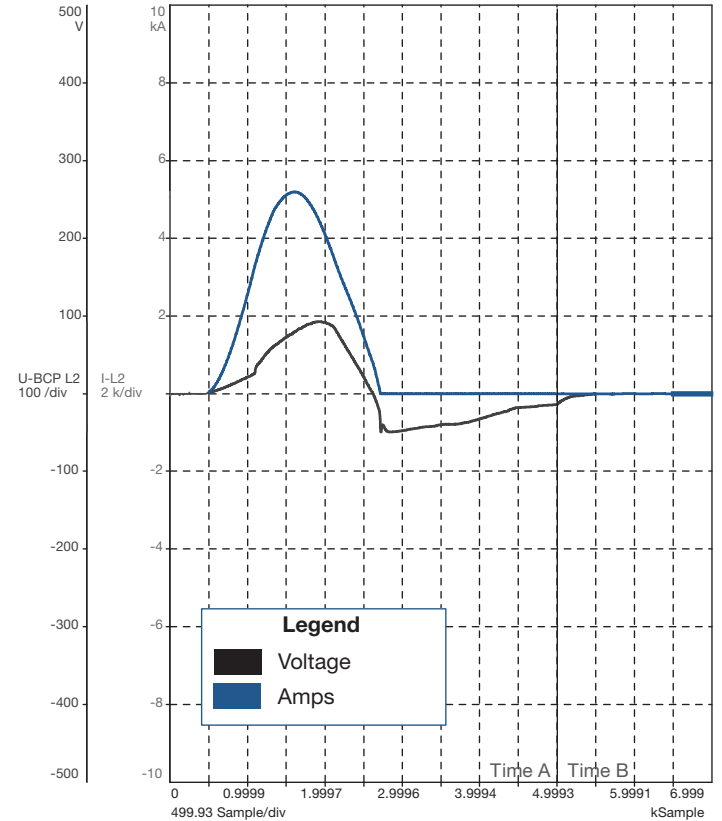
Current limiting example

The lab test report below details a 20 A S200 series current limiting breaker interrupting a 28 kA fault in 1.7 milliseconds. The total "I Square T" value is 32.0 kA.



Zero crossing example

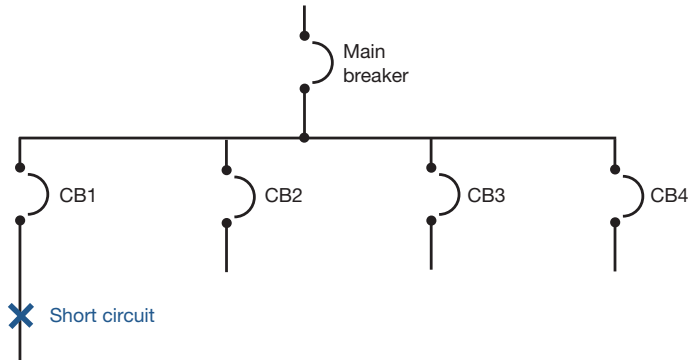
The test report below details a 20 A zero point extinguishing breaker interrupting a 9 kA fault in 9 milliseconds. The total "I Square T" value is 104.0 kA.



Selective coordination and series ratings

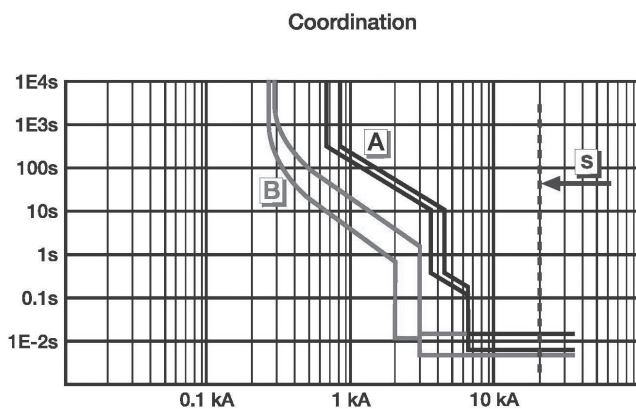
Definition of selective coordination

Coordination between the operating characteristics of two or more overcurrent protection devices, so that when an over-current within established limits occurs, the device designated to operate within those limits trips whereas the other devices does not trip.



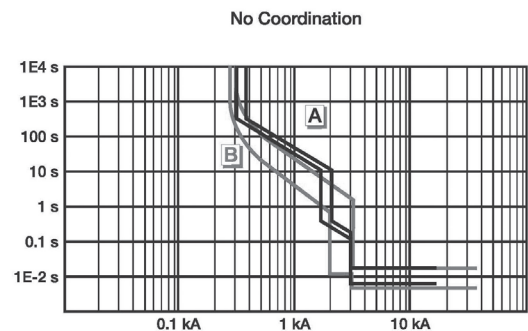
Example of breaker coordination

When an over-current event occurs at the branch breaker level (CB1), and the event is within the operating characteristics of the breaker, then the branch breaker should interrupt the circuit (open) and the main breaker should remain closed and energized. The chart below gives a graphical representation of a down stream branch breaker (B curve) and a main breaker (A curve) with coordination. The separation between the curves allows the branch breaker to react to the fault and the main breaker remains closed and energized.



Example of no breaker coordination

Selective breaker coordination is not achieved when there is an overload event at the branch breaker level (MCB1) and both the branch breaker and main breaker interrupt the circuit (open). When there is no breaker coordination, several circuits lose power that should remain operational during and after the overload event. The chart below gives a graphical representation of a down stream branch breaker (B curve) and a main breaker (A curve) without coordination. There is no separation between the curves. The branch breaker will react to a fault and the main breaker will open and de-energize all circuits down stream.



Problems in coordination occur when the branch breaker allows the “I Square T” value of the short circuit to rise to a level that is in the operating range of the upstream main breaker. Proper breaker coordination is easier to achieve with the use of current limiting breakers at the branch level.

Selective coordination and current limiting breakers

Recent improvements in ABB circuit breaker technology has pushed the performance of breakers to the same level as fuses. The reaction time and tripping characteristics of current limiting breakers are now on par with fuses. This allows ABB to provide a high level of coordination between branch breakers and the main. A current limiting branch breaker will limit the “I Square T” value well below the level of the operating range of the upstream main breaker. ABB’s current limiting branch breakers can coordinate between the main breaker up to 35 kA.

Selective coordination and zero crossing breakers

Zero crossing breakers do not limit the “I Square T” value. They wait for the wave form to cross zero and allow a high level of let-through energy to pass through the system. The “I Square T” value of a zero crossing breaker is high enough that the main breaker will likely trip during a short circuit. With zero crossing breakers it is extremely difficult to coordinate between branch and main breakers. A typical zero crossing breaker’s coordination level is below 10 kA. There are a few manufacturers that have achieved coordination between a branch zero crossing breaker and the main by slowing the performance (protection) of the main breaker.

Selective coordination and series ratings

Selective coordination

Selective coordination is achieved when there is a short circuit on a branch circuit breaker, the branch breaker opens and isolates the fault, and the main breaker remains closed. The rating is usually a value above the “stand alone” interrupting rating of the branch breaker and the “stand alone” rating of the main breaker.

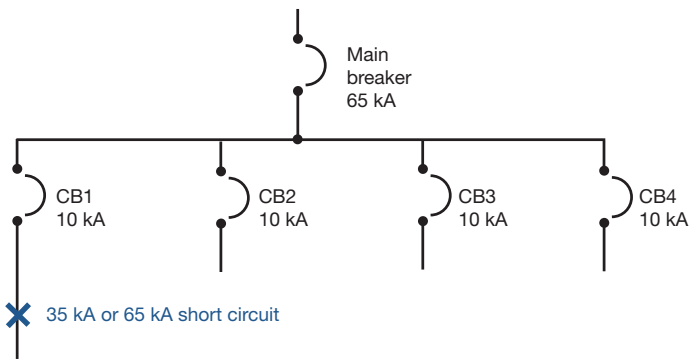
Example:

65 kA rated main breaker

10 kA rated branch breaker

Coordination between the two breakers up to 35 kA

There can be a short circuit on the branch breaker up to 35 kA where the branch will open (CB1) and the main breaker will remain closed. Although the branch has a 10 kA “stand alone” rating, both the breakers work together to limit the available short circuit to allow the branch (CB1) to isolate the fault.



Series ratings

Series ratings are different from coordination ratings. Unlike coordination ratings where the branch opens and the main remains closed, a series rated combination is one where both the branch and main breakers open and work together to isolate the fault.

The series rating combination of two breakers is equal to the “stand alone” interrupting value of the main breaker. This is a result of the main breaker let-through value being lower than the “stand alone” interrupting value of the branch breaker. During a short circuit the main breaker will limit the energy to a level that is below the “stand alone” value of the branch breaker.

Example:

65 kA rated main breaker

10 kA rated branch breaker

Series combination rating between the two breakers up to 65 kA

There can be a short circuit on the branch breaker up to 65 kA where the branch will open and the main breaker will open. Although the branch breaker (CB1) has a 10 kA “stand alone” rating the main breaker has a let-through value below 10 kA. If there is a fault up to 65 kA on the network, the main breaker will limit the energy to a value less than the rating of the branch breaker (CB1). Both breakers will trip (no coordination), but the network can safely withstand a fault of 65 kA.

Miniature circuit breaker cutaway

