

Overcurrent Protection

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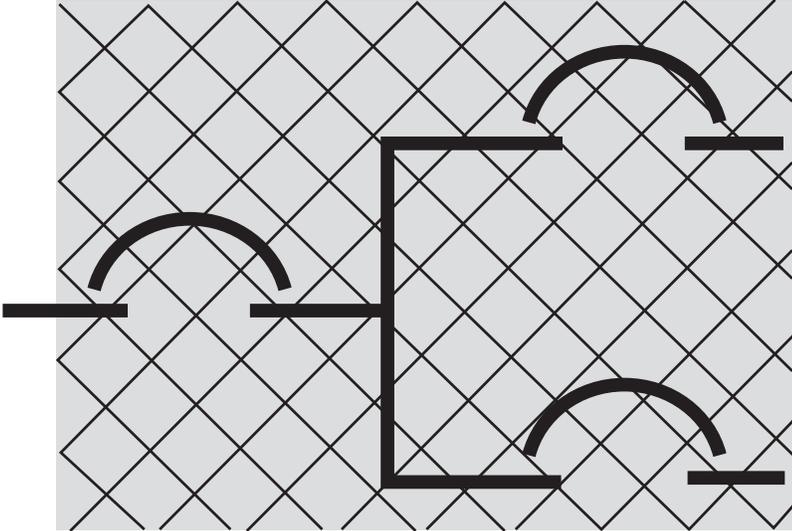


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Section 1—Overcurrent Protection

Fundamentals and Applications

As a design engineer, you have many important considerations when specifying overcurrent protection devices: cost, coordination capabilities, and, of course, safety.

When making these decisions, you must rely on applications of available technology AND a solid understanding of overcurrent protection fundamentals.

This data bulletin presents basic facts about overcurrent, various overcurrent protection devices, testing procedures and selection criteria.

The Facts about Overcurrent

Figure 1: Conductor Insulation Damage



Before you can make informed decisions about overcurrent protection, you must consider all the facts:

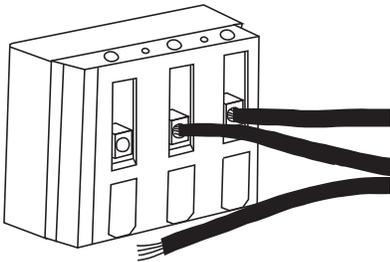
- About the various types of high- and low-level overcurrent
- How overcurrents occur in a typical system, and
- How often they can occur.

Myth: Some believe high-level bolted faults are common occurrences—that there is a high probability of short circuits occurring in a given circuit.

Fact: The majority of overcurrents are overloads and low-level arcing faults. Only a fraction are high-level, bolted faults.

Potential Damage

Figure 2: Cable Pulled Away from Lug



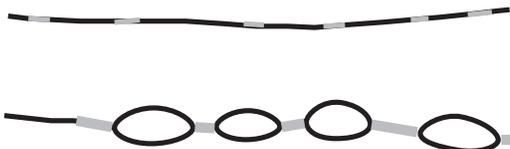
Even though only a small percentage of overcurrents are maximum short circuits, you should still understand the potential damage that can occur to system components. A bolted fault can cause:

- Thermal damage
- Mechanical stress

Thermal damage is caused by heat generated by the high-level short circuit condition. The measurement for this heat-related stress is I^2t —a measurement of energy. Stated as: I (current) squared, times t (time or duration that the fault persists), this can result in:

- Damage to conductor insulation (Figure 1)
- Burned or melted components
- Scorched paper, peeled paint or other evidence of high temperatures
- Discoloration of conductors and terminations (generally results in annealed wire), and welded contacts.

Figure 3: Reduce Dielectric Clearances



Mechanical stress is damage caused by the high level of magnetic forces generated during the fault. This is expressed as I_p (peak) current. Examples of mechanical stress include:

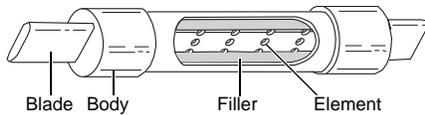
- Bus bar deformations as the result of large magnetic forces between phases during high-level short circuit condition
- Broken bus bar insulators
- Loose terminations from cable whipping and the cable actually being pulled away from lug (Figure 2)
- Reduced dielectric clearances due to the movement of the conductors (Figure 3).

Table 1: Performance Levels of Current Limiting Fuses

Class	UL Standard	Ampere Rating	$I^2t \times 10^9$	$I_p \times 10^3$	Interrupting Capacity
RK1	198	600 A	4,000 A ² s	70 A	200 kA
RK5		600 A	12,000 A ² s	100 A	200 kA
J		600 A	2,500 A ² s	70 A	200 kA
T (600V)		800 A	4,000 A ² s	75 A	200 kA
T (300V)		1,200 A	4,000 A ² s	80 A	200 kA
L		6,000 A	500 A ² s	350 A	200 kA

Overcurrent Protection Devices

Figure 4: Installing Fuses



The purpose of an overcurrent protective device is to provide protection to service entrance, feeder and branch circuit conductors and equipment. The basic types of overcurrent protection devices include **fusible switches** and **circuit breakers**.

In a fusible switch, the overcurrent protection function is accomplished by the fuses installed in each pole of the switch (Figure 4). A fuse is aptly named—for it protects a circuit by fusing/melting open its current-responsive element when an overcurrent or short circuit passes through the element. Fuses are available in several different current limiting and non-current limiting types.

Many current limiting fuses are rated for 200 kA of fault current. The I^2t and I_p let-through characteristics of these fuses are very different. The let-through characteristics affect the level of fault stress that the system will be exposed to during a short circuit interruption. Take a look at Table 1 (the information is taken directly from UL 248) describing fuses, and you can see just how different fuse let-through characteristics can be.

For instance, take a look at the Class RK5 and Class J fuses—which are both designed to serve the same needs. When comparing the thermal energy, or I^2t let through by each device, the Class J fuse lets through 2,500,000 ampere squared seconds, while the RK5 lets through 12,000,000 ampere squared seconds. The RK5 lets through more than four times *more* heat energy than the Class J fuse. Similarly, the RK5 lets through almost twice as much mechanical energy, or I_p , than the Class J fuse. When deciding which type of fuse to use, it's important to consider the fault stress that the system could be subjected to during a short circuit interruption.

Figure 5: PowerPact Circuit Breakers

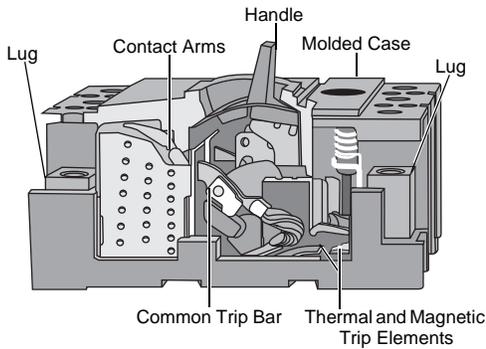


A circuit breaker is defined by the National Electrical Code (NEC) as “a device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating.” A circuit breaker is also intended to act as a perfect conductor when closed, and a perfect insulator when open.

Some people mistakenly believe all circuit breakers are slow to act, that they take a full cycle to open. Another misconception: all circuit breakers are non-current limiting devices. Fact is, there are different types—with different performance characteristics.

Molded Case Circuit Breakers

Figure 6: Standard Molded Case Circuit Breaker



All circuit breakers share these common characteristics:

- Each has a latch and a mechanism which holds the spring-loaded contacts in the closed position.
- A copper current path allows current to flow through the breaker.
- Each has a thermally-sensitive bimetal element, except for the electronic-trip circuit breaker.
- The contacts—one on the moveable arm, the other on the stationary terminal—can “make or break” the current flow.

In addition, each circuit breaker has a set of deionizing plates—the arc stack or arc plates—that act to:

- Segment the arc into smaller sections
- Act as a heat sink to cool the arc
- Draw the arc away from the contacts.

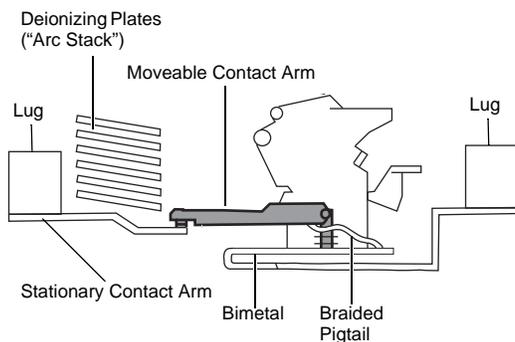
The real challenge in circuit interruption? Handling voltage. Current simply tells the circuit breaker mechanism when to separate the contacts. The real work is in extinguishing the arc quickly after the contacts have been separated. The arc plates are the actual workhorses of the circuit breaker.

Now, let’s look at the types of circuit breaker.

Circuit breaker types include:

- Thermal-magnetic
- Electronic trip (withstand rated)
- Current limiting

Figure 7: Thermal-Magnetic Circuit Breaker

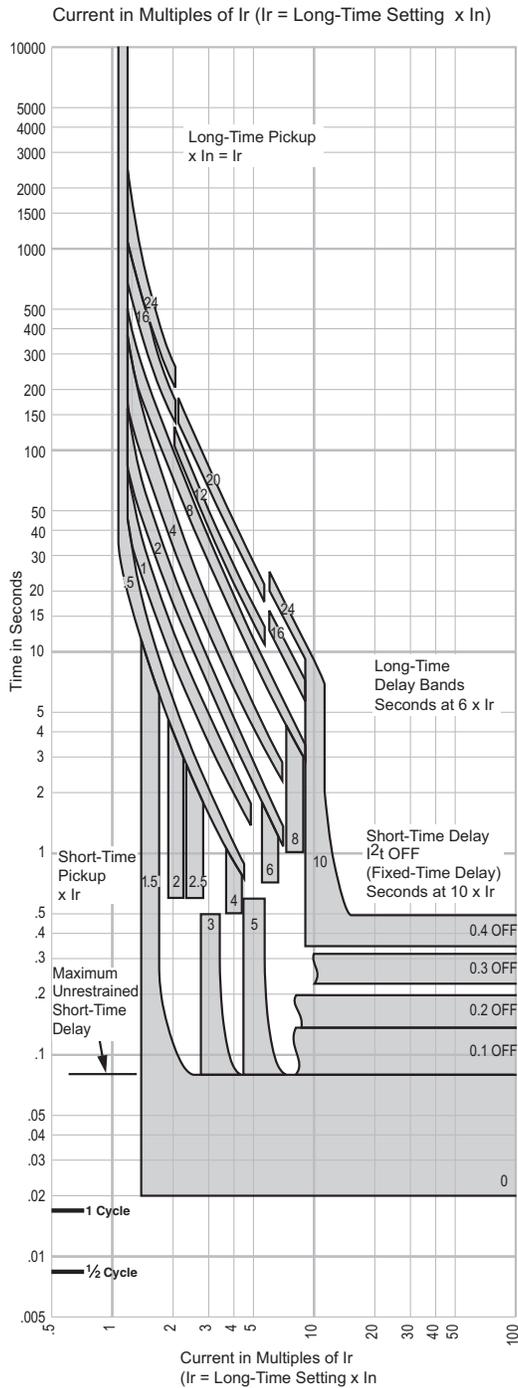


Thermal-magnetic circuit breakers (Figure 7).

Thermal-magnetic circuit breakers use bimetals and electromagnetic assemblies to provide both thermal and magnetic overcurrent protection.

The current path of a thermal-magnetic circuit breaker—such as the Square D™ QO™ circuit breaker—begins at the lug on the left. Current moves along the stationary contact arm to the stationary contact, to the moveable contact, to the moveable contact arm down to the braided pigtail (which allows free movement of the moveable contact arm), to the bimetal protective element, to the other lug.

Figure 8: Electronic Trip Molded Case Circuit Breakers



Electronic trip circuit breakers

Electronic trip (withstand rated) circuit breakers (Figure 8) use current sensors and electronic circuitry to sense, measure and respond to current levels. They are designed to be capable of “delaying before trip”—that is, to withstand high levels of current before tripping. The withstand rating is defined as the level of rms symmetrical current the circuit breaker can safely carry in the closed position for a specified period of time before opening.

The advantage of using an electronic trip circuit breaker can be illustrated in a coordination study in which the main is an electronic-trip circuit breaker and the branches are fast-acting thermal-magnetic breakers or fuses (see Figures 13, 14 and 15 on pages 12 and 13). The main circuit breaker can be programmed to delay before tripping—anywhere from 0.080 to 0.500 seconds, as shown in Figure 8.

This will give the downstream components time to operate, thus keeping the main intact and available to supply power to unaffected areas of the system. This is true “selective coordination.”

Figure 9: Symmetrical Available Fault Current

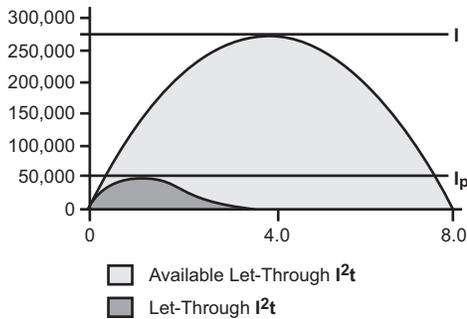
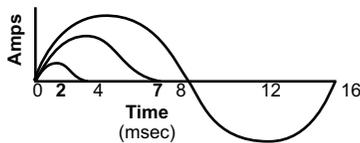


Figure 10: 100 A Circuit Breakers

Standard - 18 kA rms at 480 V (7 msec)
Current Limiting - 200 kA rms at 480 V (3 msec)



Current-limiting circuit breakers

Current limiting circuit breakers can be either thermal-magnetic or electronic trip. They are different from standard circuit breakers in two ways:

- They CANNOT contain a fusible element.
- They must operate to limit the available current and energy to a value less than the energy available during the first one-half cycle of unrestricted current flow.

The diagram in **Figure 9** represents the mechanical stress factors on an electrical system. It shows:

- The maximum available current, I_A
- Peak let-through current, I_p
- Available energy, I^2t
- Let-through energy, shaded I^2t

Square D current limiting circuit breakers operate with a total clearing time which is noticeably less than that of a regular circuit breaker. [“Total clearing time” equals “opening time” (time to separate the contacts) plus “arcing time” (time to extinguish the arc).]

Contrary to myth, this is NOT a “one cycle opening time.” You can see the difference from the comparative graph (Figure 10) of:

- standard (non-current limiting) circuit breaker
- current limiting circuit breaker

The let-through energy is limited to less than one-half cycle of the available energy. The total clearing times at 480 volts (and at their respective maximum interrupting capabilities) are:

- standard: 7 milliseconds
- current limiting: 3 milliseconds

By definition, a current limiting circuit breaker “must limit current and energy in less than one-half cycle.” Even the non-current limiting circuit breaker is current limiting at 480 volts. So why doesn’t Schneider Electric market them as current limiting circuit breakers?

For that reason, don’t assume for circuit protection purposes that non-current limiting circuit breakers require a full cycle opening time. Even many non-current limiting circuit breakers have a “typical clearing time” of less than one-half cycle.

Section 2—Testing Overcurrent Protection Devices

The Facts about Testing

UL®/CSA® Standards define **construction** and **performance requirements** for electrical products, with the objective of verifying that the products will operate safely in their intended applications. The NEC® (National Electrical Code®) and CEC® (Canadian Electrical Code®) provide guidelines for how to **install** electrical products safely in the real world.

Here's one example of how the standards seem to clash. The NEC/CEC says a circuit breaker rated 100 amperes can only be **loaded continuously** to 80 amperes, while UL/CSA requires that it be tested to carry the full 100 amperes indefinitely. The difference is that UL/CSA tests continuous current rating in 40° C "free air" rather than in an enclosure. On the other hand, NEC/CEC recognizes that under normal conditions, there will be some heat build-up in an enclosure, so the "80 percent" rule, or 20 percent de-rating factor, compensates for heat that could build up. From a very practical standpoint, the NEC rule is good because it helps eliminate the potential for nuisance tripping.

Now, let's look at UL standards for fuses. UL 248 is actually a series of comprehensive standards for both current-limiting and non-current limiting fuses. These standards include test sequences and pass/fail criteria for evaluation of fuses. UL 248 defines test procedures, performance characteristics and physical size characteristics. (For example, all 400 A Class T fuses are the same physical size, regardless of the manufacturer.)

In effect, these size and performance requirements standardize our industry. One additional point: fuse manufacturers don't manufacture fusible equipment, and the manufacturers of fusible equipment—switches, panelboards and switchboards—do NOT manufacture the fuses.

Additional facts about UL 248 testing:

- NEW test samples are used for each low-level and high-level overcurrent test. Once a fuse is blown, it's thrown away and the next test is run with a new sample.
- Short circuit testing for fuses is done by connecting the fuse directly to terminals of the test cell. This is NOT the way circuit breakers are tested.
- Since short circuit testing is done without wire, the fuse is not required to demonstrate that it can protect and connect rated wire.

While UL 248 governs fuse testing, UL 489/CSA C22.2 No. 5 is the standard for molded case circuit breakers—specifically, those intended to provide service entrance, feeder and branch circuit protection in accordance with the National Electrical Code/Canadian Electrical Code.

The UL 489/CSA C22.2 No. 5 test sequence on a new product is actually a series of more than ten tests. UL and CSA require that one set (usually three samples) of circuit breakers undergo all test sequences—or, as an alternative, that three sets of samples each be subjected to a specific portion of the total test program. The standard tests include:

- Calibration (200%, 135%)
- Overload
- Temperature rise
- Endurance
- Re-calibration (200%, 135%)
- Short circuits
- 200% trip out
- Dielectric

By successfully passing all these tests, Schneider Electric™ can place the UL label on the product.

The first test is for **calibration**. Each pole of a circuit breaker is tested at 200%, or twice the handle rating. The UL standard specifies minimum and maximum trip times—the “window” of time in which a circuit breaker must operate at twice its handle rating. Once all the samples pass the 200% calibration test, they are tested at 135% with all poles connected in series, and again, UL requires that every sample trip within specified limits.

The **overload** test consists of 50 switching operations at six times the handle rating and at rated voltage.

Next, the **temperature** test: the circuit breaker samples undergo a 100 percent calibration test in a 40° C ambient chamber...to verify that the circuit breaker will still carry 100% of its handle rating without tripping. This test also verifies that the circuit breaker will not exceed UL-specified temperature limits at the terminations.

The test for **endurance** involves 10,000 operations—switching on and off 10,000 times for a 100 A circuit breaker. The first 6,000 operations are done with a load applied—600 volts at 100 A. The remaining 4,000 operations are done without load, simply to check the mechanisms of all samples. Once again, each pole of each sample is tested at 200% of handle rating. Then all samples are tested again at 135% with all poles connected in series.

Next comes the **short circuit** test program, with each circuit breaker mounted in an enclosure. The test circuit allows for four feet of rated wire on the line side, with an optional ten inches of wire on the load side to act as a “shorting bar.”

The circuit breakers are required to pass two operations—the “O” or “open” test, and the “C-O” or “close/open” test. For the “O” operation, the circuit breaker is in the closed position and then a fault is initiated at the test cell. The circuit breaker must safely open the circuit. For the “C-O” operation, the fault current is available at the terminals and the circuit breaker closes into the fault. Then it must open safely. Both sequences are done on all samples.

The samples still have NOT passed until each pole of each circuit breaker has again passed a 200% calibration test, and each has been checked for dielectric integrity.

Dielectric testing is used to check the insulation resistance of each phase-to-phase and each phase-to-ground. For a circuit breaker with a voltage rating of 600 volts, twenty-two hundred volts are applied for 60 seconds across all poles of every circuit breaker sample.

At the end of the entire test sequence, each circuit breaker sample is disassembled and checked for internal component damage, such as contact erosion or current path welds.

Throughout the entire sequence, calibration checks ensure that nothing has changed as a result of various overload and endurance tests.

All poles of all samples must pass all tests for a circuit breaker to earn the UL label. If any circuit breaker or pole of a circuit breaker fails any test, the problem must be resolved and the test program repeated.

This rigorous testing doesn't stop here. As part of an ongoing follow-up testing program, a UL inspector can select any sample—from the manufacturing line, central warehouse, or any distributor—for random testing.

Myths About Short Circuit Testing

Now that you're familiar with the UL 489 test standard for circuit breakers, let's clear up some prevalent myths in the overcurrent protection industry.

Myth: Circuit breaker ampere interrupting **capacity** (AIC) does not equal its ampere interrupting **rating** (AIR).

Fact: The UL 489 test standard calls for four feet of rated copper wire on the **line** side and an optional 10 inches of rated wire on the **load** side for a multi-pole circuit breaker. The circuit breaker is tested in an enclosure. However, when testing its circuit breakers, Schneider Electric often uses a shorting bar instead of 10 inches of wire on the load side.

Some industry members persist in believing and perpetuating the argument that four feet of wire affects the validity of a device's interrupting rating because of the effects of wire impedance in the test circuit. So, why specify four feet of wire? UL 489 established four feet as the standard length for testing **all** circuit breakers—regardless of frame size.

Why are the wires included in short circuit tests at all? UL states that wires are used in field applications, and, therefore, safety requires demonstration of performance in the following areas:

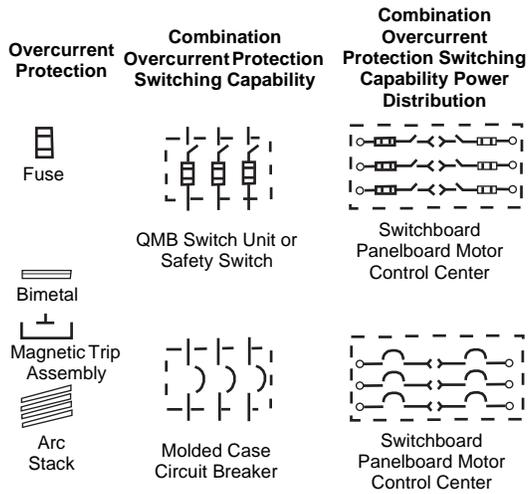
- Protection from wire damage due to heat
- Protection from wire pull-out
- Protection of the structural integrity of the circuit breaker (or the molded case) from the effects of wire whip.

UL stipulates the use of rated wire in its test sequences to **prove** that the circuit breaker can protect it. Our industry therefore recognizes that AIC and AIR are the **same** and that they can be used **interchangeably**.

What about testing of fusible elements? As a manufacturer of fusible equipment Schneider Electric has a vital interest in UL standards and testing for fusible switches.

For example, consider the UL 98 standard for safety switches. The UL 98 short-circuit test for enclosed fusible switches calls for four feet of rated wire for each pole on the line side and it allows for four feet of rated wire on the load side of the test circuit. Commercially available fuses are not used in this test; an umbrella test limiter is used as a "worst case" fuse. If the worst case fuse passes the test, it's assumed any manufacturer's fuse will work safely in the switch.

Figure 11: Low Voltage Electrical Distribution Equipment

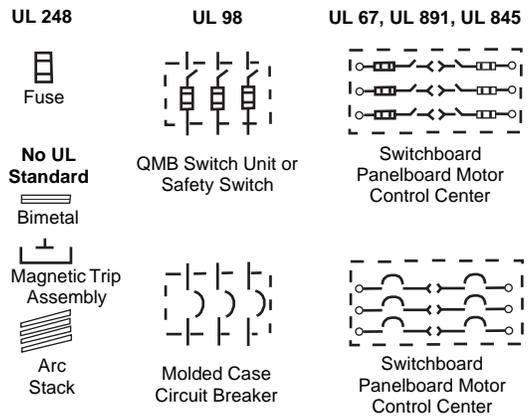


And, for short circuit testing of panelboards and switchboards, the standards—UL 67 and UL 891—use the same schematic diagram for testing circuit breaker branch units and fusible branch units.

When examining test standards for electrical equipment, it's important to look at these standards in terms of testing equivalent units of equipment. For example, when examining the application of overcurrent protection **components**, you'll see that a fuse falls into the same category as the combined bimetal element, the magnetic trip assembly and the arc stacks of a circuit breaker (**see** Figure 11).

For overcurrent protection only, we have a category that includes fuses and the internal components of a circuit breaker. When we add **switching capability** to basic overcurrent protection, we have a category that includes fusible switches and molded case circuit breakers. Then, when we add **power distribution** to our overcurrent protection and switching capabilities, our category includes fusible switchboards, panelboards and motor control centers and circuit breaker-equipped switchboards, panelboards and motor control centers.

Figure 12: UL Standard for Low Voltage Electrical Distribution Equipment



Myth: Some fuse manufacturers compare the UL 248 standards with those of the UL 489 test for molded case circuit breakers. But the comparison is NOT valid because fuses and circuit breakers fall into different categories. Some fuse manufacturers would have you believe that fuses are “superior” because, unlike circuit breakers, they are tested without the added impedance of wire.

Fact: A more appropriate comparison would be to compare safety switch standards (UL 98) with circuit breaker standards (UL 489) (**see** Figure 12). These are equivalent products—and they are both tested with four feet of wire in a test circuit.

As a fusible switch manufacturer, Schneider Electric can attest to the fact that not all safety switches that accept 200 kA current limiting fuses can be rated for 200,000 amperes.

Remember, fuses are governed by UL 248 and they are tested without wire. There is no standard testing for the internal components of a circuit breaker alone.

Section 3—Selecting Overcurrent Protection Devices

Two Methods for Selecting Components

Figure 13: Fully-Rated System

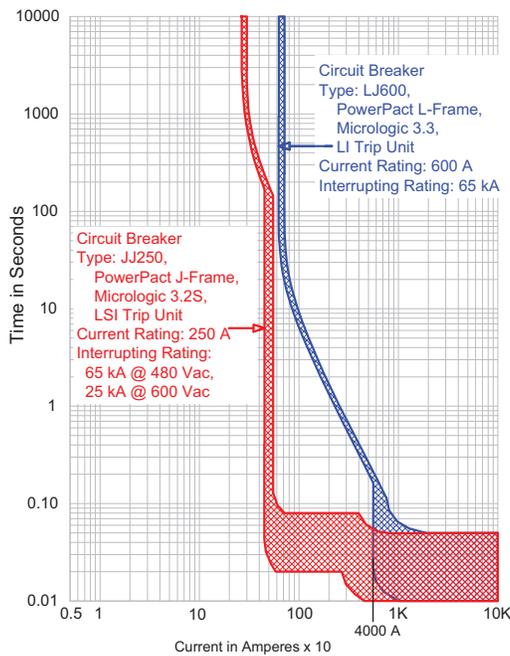
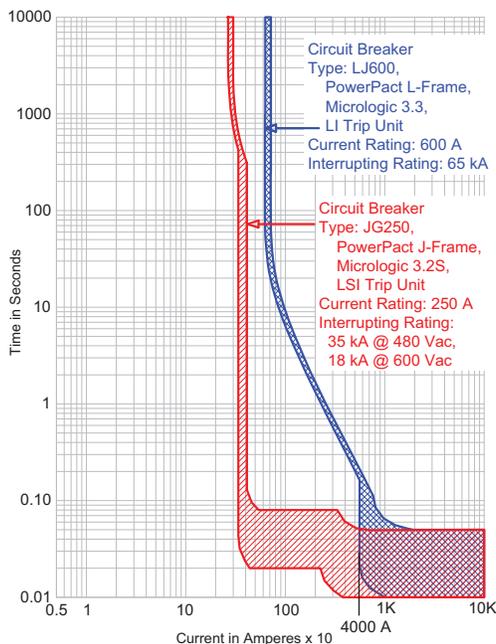


Figure 14: Series-Rated System with Main Circuit Breaker



NEC Section 110 requires electrical system components to be “selected and coordinated as to permit the circuit protective devices used to clear a fault without the occurrence of extensive damage to the electrical components of the circuit.” This means that the overcurrent protective devices need to be able to interrupt safely under any type of fault conditions. Electrical equipment must be chosen so that its short circuit current rating is equal to or greater than the fault current available at the line side of the equipment.

A UL Listed/CSA Certified short circuit current rating (SCCR) can be achieved using two different design approaches:

- Fully rated components
- Series rated components.

With a **fully rated system**, the SCCR is equal to the interrupting rating of the lowest rated device. For example, a 65 kA panelboard with a 14 kA circuit breaker would be **fully rated** at 14,000 amperes. For a fully rated system, the chain is only as strong as the weakest link.

On the other hand, with a **series rated system**, lower-rated downstream components are permitted only if they are tested, listed and labeled in accordance with UL 489/CSA C22/2 No. 5 and the NEC/CEC.

For example, on a 480 volt system with 65 kA symmetrical short circuit current available, a 250 A main circuit breaker rated for 65 kA is applied with one or more 100 A branch circuit breakers rated 18 kA. The **series connected rating** for this system would be 65 kA:

- IF this combination has successfully passed the required UL/CSA tests
- IF the combination is listed by UL, CSA, or other third-party certification
- IF the equipment housing the branch circuit breakers is appropriately tested and labeled according to UL/CSA and the NEC/CEC.

In other words, this combination may be safely applied on systems capable of delivering up to 65 kA at 480 volts.

Testing requirements for components in a series rated system include:

- Maximum interrupting capacity tests
- Intermediate-level short circuit tests
- Calibration and dielectric tests
- A follow-up test program every two or three years for each series rated combination
- Testing for each combination in the end-use equipment in which it is intended to be used.

As an additional requirement, all combinations must be **listed**—meaning that the test program has been witnessed by a third party, and there is proper documentation of test results by both the manufacturer and UL/CSA.

Figure 15: Series-Rated System with Main Fuse

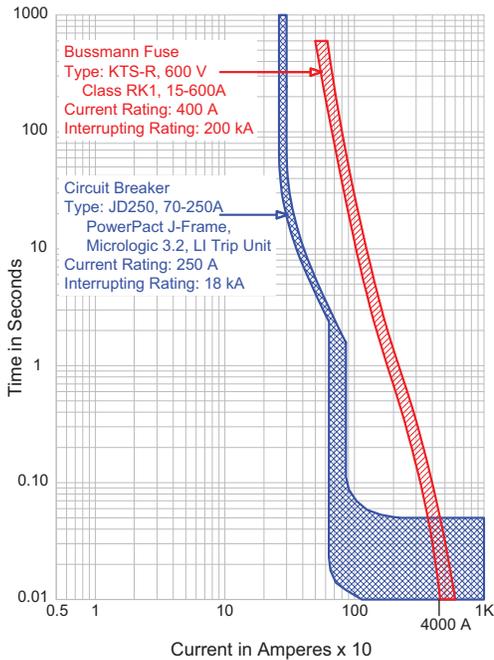
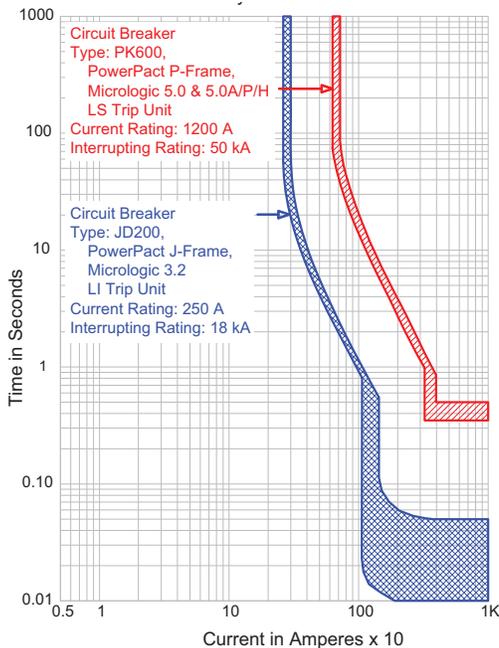


Figure 16: Fully Rated Selectively Coordinated System



A third set of requirements: all combinations must be **labeled** according to:

- UL/CSA requirements for the short circuit rating label for end-use equipment
- NEC Section 110 which requires the manufacturer’s SCCR label (on end-use equipment) to contain specific combinations and which requires a field-applied label which reads “Caution—Series Rated System....”

Myth: Using series ratings sacrifices selective coordination.

Fact: Take a look at a typical system application: a 480 volt system with 65 kA available, requiring a 600 A main and a 250 A branch circuit breaker.

These would be the components for a **fully rated system** (see Figure 13).

- Main: a 600 A LJ circuit breaker—rated for 65 kA at 480 volts
- Branch: 250 A JJ circuit breaker—also rated for 65 kA at 480 volts.

Coordination for this combination exists up to 4,000 amperes, which is the level of current where the main circuit breaker would trip with no intentional delay.

For a **series-rated system**, this would be the UL Listed/CSA Certified combination (see Figure 14):

- Main: the same LJ circuit breaker—rated for 65 kA at 480 volts
- Branch: **less expensive JG** circuit breaker—rated for 35kA at 480 volts.

Coordination for this combination ALSO exists up to 4,000 amperes.

Reality: By substituting a lower-rated branch circuit breaker in the series-rated system, we did NOT CHANGE the level of coordination.

Coordination is limited by the fast-acting operation of the **main** device. And, in our example, the main did not change.

Even with the substitution of a 400 A current limiting fuse for the main (see Figure 15), the coordination would still be limited to 4,000 amperes due to the fast action of the current limiting fuse.

The best solution? To optimize selective coordination in this example, use a 600 A electronic trip circuit breaker and a series rated or fully rated branch circuit breaker (see Figure 16).

By turning OFF the adjustable instantaneous feature on the electronic trip circuit breaker, we now have coordination up to the **withstand rating** of the circuit breaker. Withstand rating is defined as the level of rms symmetrical current a circuit breaker can carry in the closed position for a certain amount of time. The time increment is typically adjustable by using the short-circuit delay feature. In this case, we have coordination up to 18 kA @ 480 Vac, 14 Ka @ 600 Vac, for much improved selectivity.

The “Up, Over and Down” Method

Figure 17: Sample Fuse Let-Through Curve

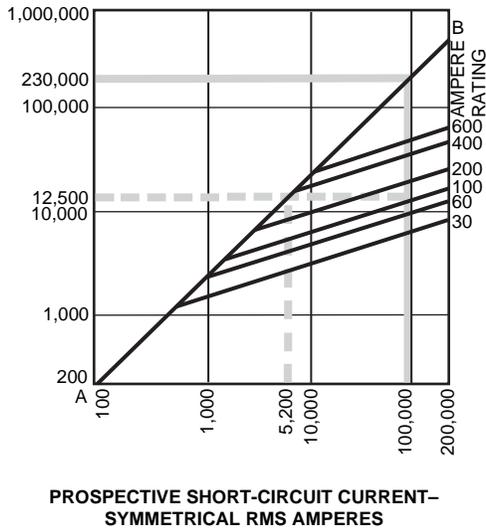
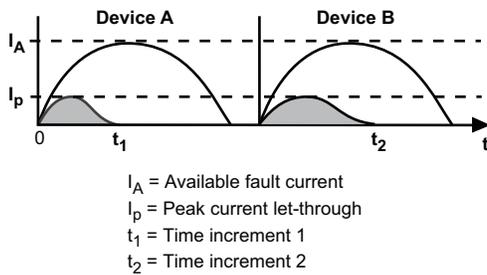


Figure 18: Peak Let-Through Energy



Myth: The “up, over and down” method is an engineering solution to equipment selection.

Reality: “Up, over and down” is a **non-tested** method of selecting series combinations of main fuses and branch circuit breakers—using fuse peak let-through curves.

Fuse let-through charts (see Figure 17) are used to determine the current limiting effects for several ampere ratings of fuses. These charts are made up of four major components:

- Prospective or available short-circuit current (in rms symmetrical amperes), listed across the x-axis
- Let-through characteristics for a family of fuses
- Instantaneous peak let-through current (in amperes), listed along the y-axis
- The A-B line—also referred to as the power factor line—defines the maximum peak current based on an established 15 percent power factor in the faulted circuit.

Here are two legitimate ways to determine peak let-through:

1. Start at the 100 kA prospective short-circuit current line and read **up** to the A-B power factor line and **over** (shows 230 kA) to determine peak current with no current limiting device in the system;

OR

2. Start at the 100 kA line and read **up** to the 100 kA fuse performance curve from the 100 kA base line and **over** to the y-axis to determine peak let-through current (shows 12,500 A)—or mechanical stress.

Fuse manufacturers, however, recommend using this chart to select series connected downstream components. Assume 100 kA of prospective or available short-circuit current and a 100 A current limiting fuse.

From the 100 kA line on the horizontal axis, read **up** to the 100 A fuse performance curve. Then, read **over** to the A-B power factor line, then down to the horizontal axis to discover with this method that the 100 A fuse will reduce the *apparent* rms current let-through from 100 kA to 5,200 A. In other words, the “up, over and down” chart would tell us that this 100 A fuse would protect any downstream component that is rated at 5,200 amperes or above.

Unfortunately, the “up, over and down” method has proven **inaccurate** in many cases. Remember, there are two components of damage:

- Peak current (mechanical stress); AND
- I^2t energy (thermal stress).

BOTH of these are important. Yet the “up, over and down” method uses *peak let-through information ONLY*.

How can downstream components be accurately selected by using **ONLY** peak let-through curves of fuse stand-alone performance?

The graphs in **Figure 18** represent let-through performance of two different current limiting devices. They show *identical* peak let-through values. But there’s a significant difference in **total clearing time**—which means there’s a significant difference in let-through I^2t or thermal energy.

What about time or energy—the thermal portion? For how long will the peak current be present? The answer: I^2t data for Class R, J and T fuses hasn't been made public. Therefore, it is impossible to predict whether or not these fuses will series rate with a circuit breaker unless the combination is tested.

Myth: Branch circuit breakers require a cycle or more to operate.

Fact: Tests have proven that many circuit breakers operate in **less than one-half cycle**. Even the oldest technology, non-current limiting FA circuit breaker has a 480-volt “total clearing time” of 7 milliseconds (total clearing time being the opening time PLUS the arc extinguishing time). And, by definition, a **current limiting** circuit breaker **MUST** operate in less than one-half cycle without assistance of a fusible element.

Testing of some fuse/circuit breaker series combinations that were selected with the “up, over and down” method showed that the branch circuit breaker was subjected to the **entire fault**...while the main fuse **did not operate**. The circuit breaker was too fast. It operated faster than the “up, over and down” method assumed it would. In fact, in actual tests performed by independent teams of circuit breaker and fuse manufacturers, 42 percent of the main fuse/branch circuit breaker series combinations selected with the “up, over and down” method **FAILED**.

The most important question design engineers should consider: For selection of lower-rated downstream circuit breakers, should the “up, over and down” method be used **AT ALL?**

Remember, series combinations may **ONLY** be applied if the following criteria are met:

- UL third-party-witnessed testing of the specific combination;
- The manufacturer's SCCR label contains specific combinations to meet NEC 110;
- A field-applied label which states: “Caution—Series Rated System...” to meet NEC 110.

Fact: Untested combinations selected with the “up, over and down” method **do not meet these criteria, and are not supported by manufacturers of end-use equipment**.

All current limiting fuses are not the same. Published data from fuse manufacturers states that some 400 A RK5 fuses will protect a downstream 25 kA circuit breaker. A 250 volt, 400 A fuse lets through 21 kA rms; a 600 volt, 400 A fuse lets through 25 kA rms. This data would lead an unsuspecting engineer to assume that this series-rated combination is valid.

Achieving Selective Coordination

Increasing demands for selective coordination in certain low voltage applications requires both overcurrent protection and selective coordination.

Selective coordination is the process of localizing an overcurrent condition to restrict an outage only to affected equipment. Only the upstream device closest to the fault should trip—leaving the rest of the system intact to continue supplying power to unaffected areas. Selective coordination does not exist when more than one device opens simultaneously during an overcurrent condition.

The proper selection of overcurrent protection devices—whether fusible switches or circuit breakers—is the key to optimizing systems design and achieving selective coordination.

When designing electrical systems, it is a challenge to come up with the best approach in selecting overcurrent protective devices. Many different factors and ratings play a part in defining the best devices to use, and there usually is not only one right answer.

Different applications require different approaches to system design. For instance, a continuous process plant may not want a current-limiting main—or a main that would trip with no intentional delay in the event of a fault. This could cause more damage to the plant than if a downstream device would be allowed to clear the fault (as in a selectively coordinated system). Then again, in an installation where continuity of service is not the number one priority, choosing devices using series-rated combinations (with or without current-limiting mains) is an economical alternative.

It is important that the designer understand all of these criteria so that he can deliver the optimum system solution for the customers' needs.

For More Information

See the following publications for additional information on selectivity:

0100DB0501 *Short Circuit Selective Coordination for Low Voltage Circuit Breakers*

and

0600DB0001 *Reducing Fault Stress with Zone-Selective Interlocking*

For more information on overcurrent protection and system design, or other topics relating to the use and application of circuit breakers, contact your local Schneider Electric Field Office at 1-888-778-2733.

**Overcurrent Protection
Data Bulletin**

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