FUSE FUNDAMENTALS

At the Heart of Electrical Systems, Fuses Keep Operations Live

TECHNICAL PAPER

Littelfuse®

Expertise Applied | Answers Delivered

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Introduction

All electrical systems eventually experience overcurrents. Unless removed in time, even moderate overcurrents will quickly overheat system components and damage the insulation, conductors and equipment. Large overcurrents can melt conductors, burn insulation, and produce magnetic forces capable of bending and twisting bus bars. High currents can pull cables from their terminals and crack insulators and spacers.

The fires, explosions, and poisonous fumes caused by an uncontrolled overcurrent can injure and kill personnel. These injuries and deaths are easily avoidable with sufficient overcurrent protection. Electrical codes and other applicable design and installation standards help avoid these hazards with requirements for overcurrent protection.

This paper will go over everything you need to know to understand which fuse is best for your application.

If you have questions or need additional support, call the Littelfuse Technical Support at 1 (800) TEC-FUSE (1-800-832-3873), email them at techline@littelfuse.com, or visit the Littelfuse Industrial Fuse Technical Center.

What Makes for High-Quality Overcurrent Protection?

A system with good overcurrent protection has the following characteristics:

- Meets all code requirements, such as the NEC, CEC, and IEC.
- Provides maximum safety for personnel by exceeding the minimum code regulations.
- Minimizes overcurrent damage to property, equipment, and electrical systems.
- Provides coordinated protection (when only the protective device immediately on the line side of an overcurrent opens to protect the system and minimize unnecessary downtime).
- Is cost effective while providing plenty of interrupting capacity for future growth.
- Utilizes modern equipment and components requiring minimal maintenance.

Overcurrent Types: Overloads Versus Short Circuits

Overloads

An overload is an overcurrent confined to normal current paths in which there is no insulation breakdown.

The installation of excessive equipment, such as additional lighting fixtures or too many motors, is a common cause of sustained overloads. Sustained overloads are also caused by overloaded mechanical equipment and by equipment breakdown, such as failed bearings. If not interrupted within a given time, sustained overloads will eventually overheat circuit components and cause thermal damage to the insulation and other system components.

Overcurrent protection devices must interrupt circuits and equipment experiencing continuous or sustained overloads before overheating occurs. Even moderate insulation overheating can seriously reduce the life of components, equipment, or both. For example, motors overloaded by just 15% may experience less than 50% of their normal insulation life.

Temporary overloads are common. Common causes include a machine tool making too deep of a cut or simply energizing an inductive load such as a motor. Since most temporary overloads are harmless, typically overcurrent protective devices should not operate.

It is important to know that fuses must have sufficient time-delay for temporary overloads to subside. However, should the overcurrent continue, fuses must then open before components are damaged. In general, time-delay fuses hold 500% of the rated current for a minimum of ten seconds. However, they will still open quickly during high current faults.

Short Circuits

A short circuit is an overcurrent flowing outside of its normal path. There are three general types of short circuits: bolted faults, arcing faults, and ground faults.

A short circuit may be caused by an insulation breakdown or by an improper connection. During a circuit's normal operation, the connected load determines the current. When a short circuit occurs, the current bypasses the normal load and takes a "shorter path," hence the term *short circuit*. Since there is no load impedance, the system impedance from the utility generator to the point of fault is the only factor that limits the current flow.

A typical electrical system might have a normal load impedance of 10 ohms. But in a short-circuit condition, this system may have a load impedance of 0.005 ohms or less.

To compare these two scenarios, apply Ohm's Law (current = voltage ÷ resistance). Thus, a 480-V single-phase circuit with a 10-ohm load impedance will draw 48 A:

$$48\,A = \frac{480\,V}{10\,\Omega}$$

If the same circuit has a 0.005-ohm system impedance when the load is shorted, then the available short-circuit current will significantly increase to 96 000 A:

$$96\,000\,A = \frac{480\,V}{0.005\,\Omega}$$

As stated, short circuits are currents that flow outside of their normal path. Regardless of the overcurrent's magnitude, the excessive current must be interrupted quickly. If not, the high current from a short circuit can have three serious effects on an electrical system: heating, magnetic stress, and arcing.

Heating occurs in every part of an electrical system when there is current flow. When overcurrents are very high, this heating is practically instantaneous. The energy in such overcurrents is measured in ampere-squared seconds (I^2t). A 10 000-ampere overcurrent that lasts 0.01 seconds has an I^2t of 1 000 000 A^2s. If you can reduce the current from 10 000 A to 1 000 A for the same period, then the corresponding I^2t will be reduced to 10 000 A^2s, which is only 1% of the original value.

If the current in a conductor increases ten times, then the I^2t will increase 100 times. A current of only 7 500 A can melt a #8 AWG copper wire in 0.1 second. Within 8 ms (one-half electrical cycle), a current of 6500 A can raise the temperature of a #12 AWG THHN thermoplastic insulated copper wire from its operating temperature of 75 °C to its maximum short-circuit temperature of 150 °C.

Any currents larger than this may immediately vaporize conductor insulation. Arcs at the point of fault or from mechanical switching (such as automatic transfer switches or circuit breakers) may ignite the vapors and cause an arc flash, creating an explosion of extreme light and temperatures up to 19 000 °C. The molten material can start fires, injure nearby personnel and, when deposited on insulators and other surfaces, cause additional short circuits.

The longer it takes for a protective device to trip, the larger the arc flash will be. This is one reason it is so important to select the proper fuse for the application.

Magnetic stress (force) is a function of the peak current squared. Fault currents can exert magnetic stress that are high enough to damage insulation, pull conductors from terminals, and stress equipment terminals sufficiently such that significant damage occurs.

Whether the effects are heating, arcing or magnetic stress, the potential damage to electrical systems can be catastrophic.

Fuse Characteristics and Features

Time current characteristics determine how fast a fuse responds to overcurrents. A quick response time is essential to the system's protection. Fuse opening times are inversely proportional with current magnitude. The fuse opening time will decrease as the magnitude of overcurrent increases. When properly rated in accordance with NEC requirements, fuses provide both overload and short-circuit protection to the system conductors and components.

In some instances, however, such as when fuses are used to backup circuit breakers or to provide motor branch short-circuit protection and ground-fault protection, the fuses will only supply short-circuit protection.

The most important considerations when selecting fuses are:

- Operating characteristic
- Effect of ambient temperature
- Current limitation
- Physical size
- Indication
- Current rating
- Voltage rating
- Interrupting rating

Operating Characteristic

A fuse's operating characteristic defines a fuse's general performance. This may be time delay, fast acting, or very fast acting (also known as high speed).

Effect of Ambient Temperature

Fuses are a thermal device that are impacted by ambient temperatures. Elevated ambient temperatures can effectively "derate" a fuse's current carrying capacity to be much less than its marked rating. There are published derating curves that should be considered.

Current Limitation

Current-limiting fuses greatly minimize the total destructive heat energy (I^2t) to the circuit and its components. Current-limiting fuses open and clear short circuits in less than 180 electrical degrees (the first half electrical cycle).

NEC Article 240—Overcurrent Protection says that a current-limiting overcurrent protective device must reduce the peak let-through current to a value that is substantially less than the potential peak current that would have occurred without protection, or had the fuses been replaced with solid conductors of the same impedance.

Other than supplemental and Class K fuses, almost all other fuse types used in modern electrical systems and applications are considered current limiting per the above parameters.

When selecting fuses for your system, you must determine the level of current limitation that your system requires from its overcurrent protective devices. Peak let-through curves, which are discussed on page 10 in greater detail, will tell you how current limiting a specific fuse is.

Physical Size

While often overlooked, you should always consider a fuse's overall dimensions. You should use the size and dimensions of either the fuse block or the disconnect switch in which the fuse is installed.

While saving space may be an important factor when selecting fuses, other considerations should not be overlooked. Some of these include:

- Whether the smallest fuse has the most desirable characteristics for the application
- Whether the equipment where the fuse will be installed provides adequate space for maintenance
- Whether the smallest fuse coordinates well with the system's other overcurrent protection devices

If looking at just physical dimensions, a 600-volt, 60-ampere, 200 000-ampere interrupting rating, time-delay, dual-element UL Class CD fuse is smaller than a similarly rated UL Class J fuse, which is in turn, considerably smaller than a similarly rated UL Class RK1 or Class RK5 fuse. However, smaller-sized fuses may have less time-delay and be faster acting, which will cause more nuisance openings than their larger counterparts. Therefore, going with the smallest fuse is not always be the best solution.

Indication

Fuse indication allows you to quickly identify which fuses have opened. Many of the common UL fuse classes are available in both indicating and non-indicating versions. Indication can reduce downtime because it allows a maintenance technician to quickly see if the fuse has operated or not.

The Littelfuse POWR-PRO® LLSRK_ID (Class RK1), JTD_ID (Class J), and FLNR_ID, FLSR_ID and IDSR (Class RK5), fuse series have built-in indication.

Current Rating

A fuse's current rating is the ac or the dc current that the fuse is capable of continuously carrying under specified conditions. Fuses selected for a circuit must have ampere ratings that meet NEC requirements, namely those found in NEC Articles 240 and 430. These NEC requirements establish maximum ratings, and in some cases, minimum ratings. When selecting a fuse, it is recommended to select a current rating as close to the system's normal running current as possible.

Voltage Rating

A fuse's voltage rating is the maximum ac or dc voltage that the fuse is designed to operate. Fuse voltage ratings must equal or exceed the maximum circuit voltage where the fuses are installed. Fuses in dc circuits must be specifically rated for dc applications.

Fuses may be rated for ac only, dc only, or both ac and dc. However, exceeding the voltage ratings or using an ac-only fuse in a dc circuit may lead to serious fuse failure.

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Interrupting Rating

A fuse's interrupting rating is the highest available fault current the fuse can safely interrupt at its rated voltage under standardized test conditions. All UL Listed fuses must safely interrupt all overcurrents between its current rating and its interrupting rating. Standard UL fuses are available with interrupting ratings up to 300 000 A.

According to NEC Article 110.9:

> Equipment intended to interrupt current at fault levels shall have an interrupting rating at nominal circuit voltage at least equal to the available fault current at the line terminals of the equipment.

This is shown in **Figure 1**.

It is essential to select fuses with interrupting ratings that are equal to or exceed the available short-circuit current (also known as available fault current and prospective fault current).

Standardizing fuses with at least a 200 000-ampere interrupting rating ensures that all fuses have an adequate interrupting rating. It also provides a reserve interrupting capacity for future increases in available short-circuit current.

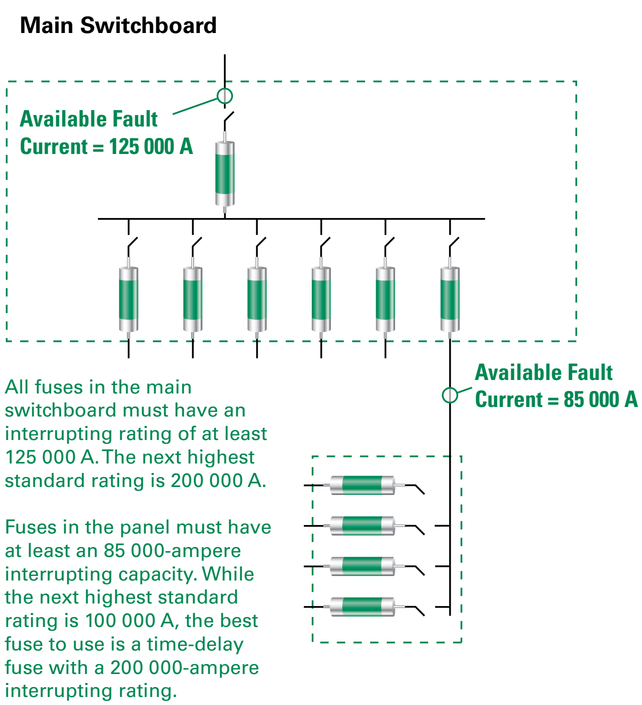

FIGURE 1. Interrupting rating requirements per NEC.

Electrical System Specifications and Fuse Selection

Some important considerations to determine the fuse size include:

- The maximum system voltage
- The average current expected
- The maximum continuous current expected
- Whether the overcurrent protective devices can tolerate an expected inrush while interrupting true overloads
  - To determine this, look at the expected inrush values on a fuse's time-current curves (refer to the Time-Current Curve section on page 9).
- Any special environmental considerations, such as dust, humidity, or very high or low temperatures
  - Refer to our technical paper Hazardous Locations Circuit Protection or contact the Littelfuse Techline: techline@littelfuse.com or +1(800) TEC-FUSE or +1(800) 832-3873
- The maximum available short-circuit current that the fuse may have to interrupt

When you select a fuse based on the above considerations, you will optimize your system's safety, reliability, and performance.

Fast-Acting Fuses, High-Speed Semiconductor Fuses, and Time-Delay Fuses

Fuses must interrupt overloaded conductors and equipment before any overheating occurs. However, fuses should not interrupt temporary overloads. To provide sufficient overload protection for system conductors, UL established maximum fuse opening times at 135% and 200% of a fuse's current rating. All UL Listed fuses in accordance with the NEC must meet these limits whether they are fast-acting fuses or time-delay fuses.

Because fuses are designed to respond to two types of overcurrents—short circuits and overloads—you must determine whether to use a time-delay fuse or a fast-acting fuse for the given application.

Time-Delay (SLO-BLO®) Fuses

By mitigating nuisance fuse openings and limiting the frequency of downtime incidents, time-delay fuses provide the best overall protection for both motor and general-purpose circuits.

Many UL Class CC, CD, G, J, L, RK5 and RK1 fuses, plus some of the miscellaneous UL Listed fuses are time-delay. You can identify time-delay fuses by looking on the label for terms such as time-delay, T-D, D, or other similar markings.

Minimum-time delay requirements vary by the fuse class. UL standards require Class J, Class RK5, and Class RK1 to carry 500% rated current for a minimum of 10 seconds.

The Littelfuse POWR-GARD® Class-RK5 fuse series include:

- FLNR dual-element time-delay fuses
- FLNR_ID RK5 dual-element time-delay fuses with indication
- FLSR RK5 dual-element time-delay fuses
- FLSR_ID indicator fuses
- IDSR dual-element time delay fuses with indication

The Littelfuse POWR-GARD® Class RK1 fuse series include:

- LLNRK dual-element time-delay fuse
- LLSRK dual-element time-delay fuse
- LLSRK_ID dual-element time-delay fuse with indication

The Littelfuse Class J fuse series include:

- JTD time-delay fuse
- JTD_ID time-delay fuse with indication

UL standards require Class CC, Class CD and Class G to carry 200% rated current for a minimum of 12 seconds. Of these classes, Littelfuse has:

- CCMR Class CC dual-element time-delay fuse
- KLDR Class CC time-delay fuse
- SLC Class G medium time-lag fuse

Although there is no UL Classification for time-delay Class L fuses, they can still be marked as "time-delay." The manufacturer determines the amount of time delay.

In addition to providing time delay for surges and for quick overloads, time-delay fuses meet all UL requirements for sustained overload protection. On higher current values, time-delay fuses are current-limiting, so they remove large overcurrents in less than one-half electrical cycle (8.33 ms).

Compared to fast-acting fuses, time-delay fuses can have a rating that is much closer to a circuit's operating current. For example, Class RK5 and RK1 fuses can be rated from 125% to 150% of a motor's full load current on most motor circuits. This provides fantastic overload and short circuit protection, and often permits the use of smaller, less expensive disconnect switches.

Time-delay fuses have gradually replaced most one-time (UL Class K5) and renewable (UL Class H) fuses. Today, most fuses sold by electrical distributors are time-delay fuses.

Dual-Element Fuses

Dual-element fuses are a sub-group of time-delay fuses.

The Littelfuse fuses with a true dual-element construction include:

- UL Class RK5 time-delay fuses (FLNR, FLNR_ID, FLSR, FLSR_ID, and IDSR),
- UL Class RK1 fuses (LLNRK, LLSRK, and LLSRK_ID), and
- some UL Class J fuses (JTD and JTD_ID).

Fuses that have dual-element construction have separate short circuit and overload elements. Time-delay elements are for overload protection, and separate fast-acting fuse elements provide current-limiting short-circuit protection.

Fast-Acting Fuses

Fast-acting fuses do not have an intentional time-delay feature. Their typical opening times at 500% of the fuse's current rating range from 0.05 second to approximately 2 seconds. Fast-acting fuses are suitable for non-inductive loads, such as incandescent lighting and general-purpose feeders, or for branch circuits that have little or no motor load.

When protecting motors and other inductive loads, fast-acting fuses must be rated at 200% to 300% of the load currents, which will prevent nuisance opening on inrush currents. Fuses with such increased ratings cannot provide adequate protection from overloads and instead, only provide short-circuit protection. When you use fast-acting fuses to protect motors or inductive loads, you must provide overload relays or other overload protection devices to properly protect the conductors and equipment from overload conditions.

High-Speed Semiconductor Fuses (Very Fast-Acting Fuses)

High-speed semiconductor fuses (also known as very fast-acting fuses, high-speed fuses, or ultra-rapid fuses) are for a limited number of applications. High-speed semiconductor fuses protect sensitive equipment, such as semiconductors found in variable frequency drives, inverters, power supplies, and rectifiers.

High-speed semiconductor fuses have special characteristics such as quick overload response, very low I^2t and I_{peak} currents, and peak-transient voltages, which protect components that are unable to withstand line surges, low-value overloads, and short-circuit currents. High-speed semiconductor fuses are very current limiting, and respond to overloads and short circuits very quickly.

Fuse Block Selection Considerations

It is important to use the correct size fuse block (also known as a fuse holder) for the given application. Fuse blocks are available using most of the same selection considerationsoutlined in the previous section for UL fuse classes.

Considerations for fuse blocks include the:

- Current rating
- Voltage rating
- Interrupting rating
- Physical size
- Indication
- Number of poles
- Mounting configuration
- Connector type (also known as wire termination)

Number of Poles

The number of poles for each set of fuses is determined by the circuit's characteristics. Most fuse block series are available in 1-pole, 2-pole, 3-pole, and 4-pole configurations. Some families have the option to gang individual fuse blocks together. This may be limited by the available panel space and the type of wire in use.

Mounting Configuration

Depending on the fuse block design, you should also consider how the fuse block is mounted or inserted into the panel. Historically, fuse blocks screwed into the back of the panel, but many newer designs have a DIN-rail mounting capability. The DIN-rail mounting feature allows the blocks to be quickly installed and removed from the rails.

Connector Type

Littelfuse offers three connector types (also known as *wire terminations*) with its fuse blocks:

- **Screw:** for use with spade lugs and ring terminals
- **Screw with pressure plate:** for use with solid wire and stranded wire without terminal, and recommended for applications where vibration will be a factor
- **Box lug:** the most durable of the three options and used with all types of solid wire, and Class-B and Class-C stranded wire

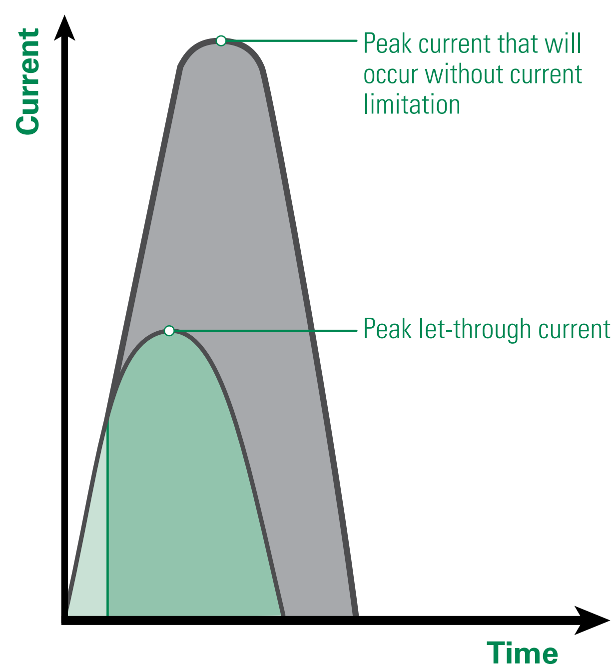

FIGURE 3. Current-limiting effect of fuses.

Understanding Time-Current Curves and Peak Let-Through Curves

The performance capabilities of various fuses are represented by two different types of fuse-characteristic curves: time-current curves and peak let-through curves.

These define the operating characteristics of a given fuse, which is essential in selecting the most suitable fuse for your application's needs.

Time-Current Curves

Time-current curves (see **Figure 2**) show a fuse's average melting (opening) time at any current. To make the curves more readable, the performance information is presented on a logarithmic plot.

Time-delay fuses, fast-acting fuses, and high-speed semiconductor fuses all respond differently based on the overcurrent. **Figure 2** compares the average melting times for 100-ampere and 600-ampere ratings of three fuse types:

- Littelfuse dual-element time-delay LLSRK series class RK1 fuses (see **Figure 2(A)**)
- Littelfuse normal-opening NLS series class K5 fuses (see **Figure 2(B)**)
- Littelfuse L60S series high-speed fuses (see **Figure 2(C)**)

To further illustrate this point, **Table 1** compares the opening times for each of these fuses.

TABLE 1. Comparative opening times for time-delay, fast-acting, and very fast-acting fuses.

AMPERE RATING	FUSE TYPE	OPENING TIME		
		500% RATING	800% RATING	1200% RATING
100 A	TIME-DELAY	12 s	0.9 s	0.14 s
	NORMAL OPENING	2 s	0.7 s	0.3 s
	VERY FAST-ACTING	1.3 s	0.02 s	> 0.01 s
600 A	TIME-DELAY	14 s	0.7 s	0.045 s
	NORMAL OPENING	10 s	3 s	1.1 s
	VERY FAST-ACTING	2 s	0.05 s	> 0.01 s

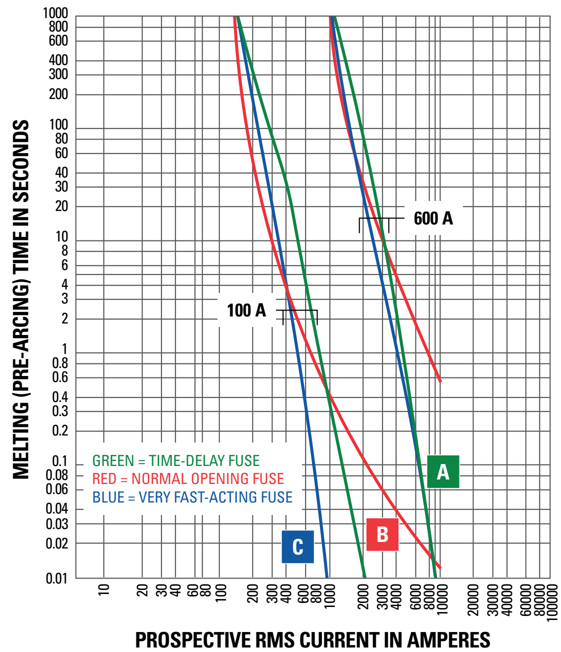

FIGURE 2. Comparison of average melting times for three fuse types.

Peak Let-Through Curves

Peak let-through curves show the maximum instantaneous current through the fuse during the total clearing time. This represents the fuse's current-limiting ability. Current-limiting fuses open severe short circuits within the first half-cycle (180 electrical degrees, which is equal to about 8.33 ms) after the fault occurs. Current-limiting fuses also reduce the peak current of the available short-circuit current to a value that is less than what would occur without the fuse (refer to the Current-limiting effect of fuses diagram on page 8).

Peak let-through curves (see **Figure 4**) show a fuse's current-limiting effects.

Peak Let-Through Curve Example

To better explain the function of these curves, let's run through an example.

Start at 100 000 rms symmetrical amperes (see **Figure 4**) and read upwards to the A–B line. From this point, read horizontally to the left and read the instantaneous peak let-through current of 230 000 A.

In a circuit with a typical 15% short-circuit power factor, the instantaneous peak of the available current is approximately 2.3 times the rms symmetrical value. This occurs since the A–B line has a 2.3:1 slope.

The diagonal curves that branch off the A–B line show the current-limiting effects of different fuse current ratings for a given fuse series.

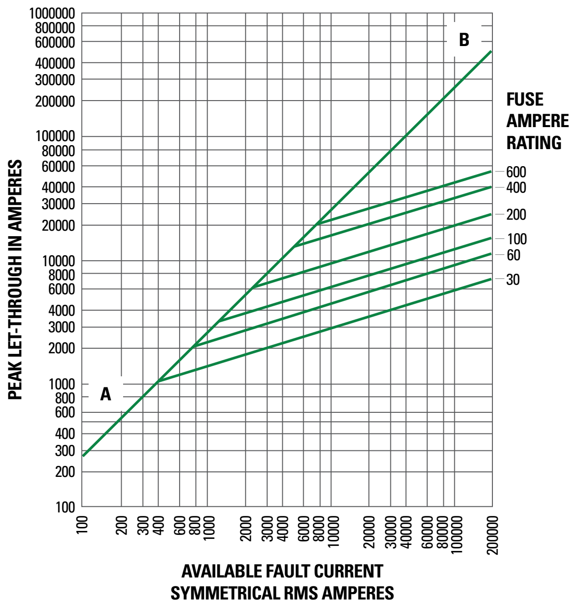

FIGURE 4. Peak Let-through curves.

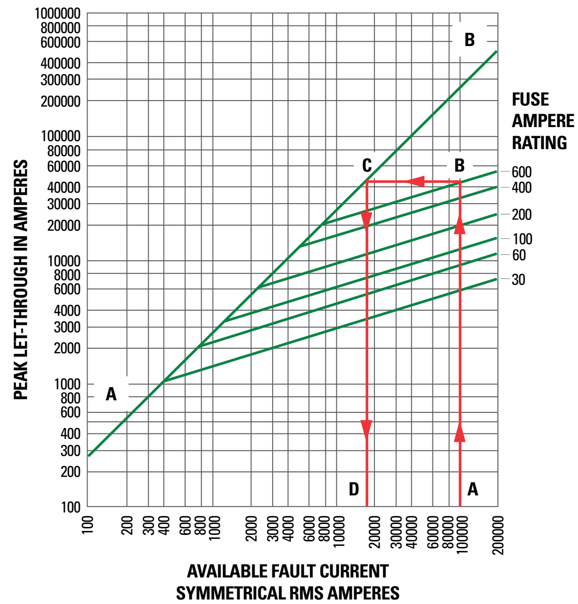

FIGURE 5. Peak let-through curve for POWR-PRO® LLNRK Class RK1 dual-element fuses using the "up-over-and-down" method.

The diagonal curves that branch off the A–B line show the current-limiting effects of different fuse current ratings for a given fuse series.

Start by reading the bottom of **Figure 4** at 100 000 rms symmetrical amperes, and read upwards to the intersection of the 200-ampere fuse curve. Now, read from this point horizontally to the left and read a peak let-through current of approximately 20 000 A.

This tells us is that the 200-ampere fuse reduced the peak current during the fault from 230 000 A to 20 000 A. This is the current-limiting effect of the 200-ampere fuse, and 20 000 amperes is less than one-tenth of the available current.

This is important because the magnetic force created by the current flow is a function of the peak current squared.

If the peak let-through current of a current-limiting fuse is one-tenth of the available peak, then the magnetic force will be reduced to less than 0.001 of what would occur without the fuse.

Using the Peak Let-Through Curves (The 'Up-Over-and-Down' Method)

Peak let-through curves are useful in determining whether a fuse can properly protect a particular piece of equipment.

For example, if we have an available fault-current of 100 000 rms symmetrical amperes and want to determine whether 600-ampere 250-volt time-delay Class RK1 fuses can sufficiently protect equipment that has a 22 000-ampere short-circuit rating (see **Figure 5**), then we will do the following:

1. Start by locating the 100 000-ampere available fault-current on the bottom of the chart (see **Figure 5(A)**) and follow this value upwards to the intersection with the 600-ampere fuse curve (see **Figure 5(B)**).
2. Follow this point horizontally to the left to intersect with the A-B line **(see Figure 5(C)**).
3. Read down to the bottom of the chart (see **Figure 5(D)**) to read a value of approximately 18 000 A.

Therefore, the POWR-PRO® LLNRK 600-ampere RK1 current-limiting fuses will protect this application's equipment. These fuses will reduce the 100 000-ampere available current to an apparent or an equivalent 18 000 A. When protected by 600-ampere LLNRK RK1 fuses, equipment with short-circuit ratings of 22 000 A may be safely connected to a system that has 100 000 available rms symmetrical amperes.

The up-over-and-down method may be used to provide back-up short-circuit protection to large air power circuit breakers, and to enable non-interrupting equipment (such as

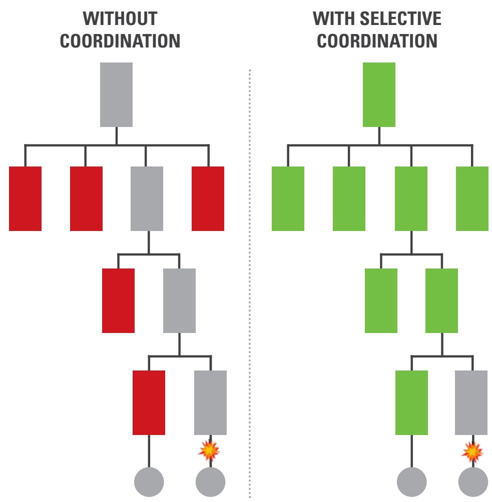

FIGURE 6. Selective coordination example.

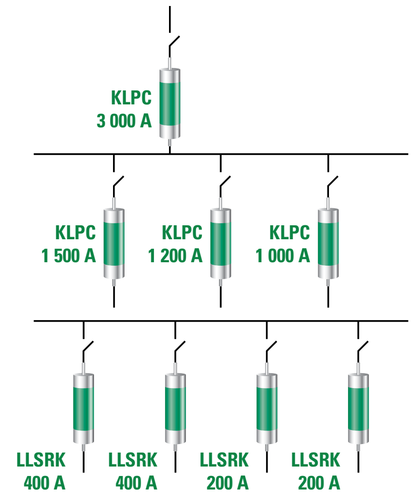

FIGURE 7. Example of selectively coordinated fused system.

bus ducts) to be installed in systems with available short-circuit currents (known as prospective currents by IEC) that are greater than their short-circuit (withstand) ratings.

However, do not use this method to select fuses for the backup protection of molded case or intermediate frame circuit breakers. NEC Article 240.86—*Overcurrent Protection, Series Ratings*—requires series ratings and says:

> Where a circuit breaker is used on a circuit having an available fault current higher than the marked interrupting rating by being connected on the load side of an approved overcurrent protective device having a higher rating, the circuit breaker shall meet the requirements specified in 240.86 (A) or (B), and (C).

UL Listed fuse-to-circuit breaker series ratings are available from most load center and panelboard manufacturers. Many local builders also have fuse-to-circuit breaker series ratings.

Short-Circuit Current Rating

The NEC requires industrial control panels to be labeled with their short-circuit current rating. These labels allow people to compare the equipment's short-circuit current rating with the available short-circuit current so that potential hazards can be avoided.

Selective Coordination

Selective coordination (see **Figure 6**) involves coordinating overprotective devices' time-current characteristics so that when an overcurrent occurs, only the closest upstream device on the line side of the problem will open. This way, only the section of the electrical system with the issue will be taken offline. This minimizes the amount of equipment removed from service, makes the overloaded circuit easier to locate, and creates a minimum amount of time required to restore to full-service operations.

Fuse Selectivity

For a system to be considered coordinated, the smaller fuse total clearing I^2t must be less than the larger fuse melting I^2t. Thus, if the downstream (branch) fuse opens the circuit before the overcurrent affects the upstream (feeder) fuse element, then it is a selectively coordinated system. You can determine this by analyzing curves that show melting and total clearing I^2t, or from minimum melting and maximum clearing time-current curves.

However, the simplest method for coordinating low-voltage fuses is by using a fuse coordination table (see **Table 2**). This table is only applicable for the Littelfuse POWR-PRO® and POWR-GARD® fuse series listed.

Fuse coordination tables greatly reduce design time. For example, the coordination table shows that POWR-PRO KLPC Class-L fuses coordinate at a 2:1 ratio with other Class-L fuses, with POWR-PRO LLNRK / LLSRK / LLSRK_ID series Class RK1 fuses, and POWR-PRO JTD / JTD_ID series Class J fuses. In the system shown in **Figure 7**, the 3 000-ampere Class-L main fuses have at least twice the ratings of the 1 500-ampere, 1 200-ampere, and 1 000-ampere Class L feeder fuses. Using this 2:1 ratio, we we know these fuses will coordinate.

TABLE 2. Fuse Coordination Table. Selecting the correct fuse current ratio to maintain selectively coordinated systems. (Ratios are expressed as line-side fuse to load-side fuse.)

LINE-SIDE FUSES			LOAD-SIDE FUSES									
			TIME-DELAY FUSES AMPERE RANGE, UL CLASS AND CATALOG NO.						FAST-ACTING FUSES AMPERE RANGE, UL CLASS AND CATALOG NO.			
AMPERE RANGE	UL CLASS	LITTELFUSE CATALOG NUMBER	601 A–6000 A	601 A–4000 A	30 A–600 A	30 A–600 A	30 A–600 A	0 A–30 A	30 A–600 A	30 A–1200 A	30 A–600 A	1 A–60 A
			L	L	RK1	J	RK5	CC	RK1	T	J	G
			KLPC LDC	KLLU	LLNRK LLSRK_ID	JTD ID JTD	FLNR_ID FLSR_ID IDSR	CCMR	KLNR KLSR	JLLN JLLS	JLS	SLC
601 A–6000 A	L	KLPC	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
601 A–4000 A	L	KLLU	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
601 A–2000 A	L	LDC	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
30 A–600 A	RK1	LLNEK	N/A	N/A	2:1	2:1	8:1	2:1	3:1	3:1	3:1	4:1
30 A–600 A	RK1	LLSRK ID	N/A	N/A	2:1	2:1	8:1	2:1	3:1	3:1	3:1	4:1
30 A–600 A	J	JTD ID	NA	NA	2:1	2:1	8:1	2:1	3:1	3:1	3:1	4:1
30 A–600 A	RK5	IDSB	N/A	N/A	1.5:1	1.5:1	2:1	2:1	1.5:1	1.5:1	1.5:1	1.5:1
30 A–600 A	RK5	FLNR ID	N/A	NA	1.5:1	1.5:1	2:1	2:1	1.5:1	1.5:1	1.5:1	1.5:1
30 A–600 A	RK5	FLSR ID	N/A	N/A	1.5:1	1.5:1	2:1	2:1	1.5:1	1.5:1	1.5:1	1.5:1
30 A–600 A	RK1	KLNR	NA	N/A	3:1	3:1	8:1	N/A	3:1	3:1	3:1	4:1
30 A–600 A	BK1	KLSR	N/A	N/A	3:1	3:1	8:1	N/A	3:1	3:1	3:1	4:1
30 A–1200 A	T	JLLN	N/A	N/A	3:1	3:1	8:1	N/A	3:1	3:1	3:1	4:1
30 A–1200 A	T	JLLS	N/A	N/A	3:1	3:1	8:1	N/A	3:1	3:1	3:1	4:1
30 A–600 A	J	JLS	N/A	N/A	3:1	3:1	8:1	N/A	3:1	3:1	3:1	4:1
1 A–60 A	G	SLC	N/A	N/A	3:1	3:1	4:1	N/A	2:1	2:1	2:1	2:1

The coordination table also shows that the Littelfuse LLSRK_ID series time-delay RK1 feeder and branch circuit fuses coordinate at a 2:1 ratio with the Class L feeder fuses, so the entire system in **Figure 7** can be considered completely coordinated.

Circuit-Breaker Coordination

As a result of the numerous types of circuit breakers and circuit breaker trip units available in the market, developing a coordinated circuit breaker system or coordinating circuit breakers with fuses is beyond the scope of this paper.

NEC Requirements for Selective Coordination

Component Short-Circuit Protecting Ability

The NEC requires equipment protection to be coordinated with overcurrent protective devices and for the available short-circuit current to prevent extensive damage to the equipment. This means that electrical equipment must be capable of withstanding heavy overcurrents without becoming damaged, or to be properly protected by overcurrent protective devices that will limit damage. When a severe fault occurs in an unprotected circuit, the current will immediately increase to a very high value. This is known as the available short-circuit current (or sometimes as the prospective fault current).

Current-limiting fuses respond so quickly to the increasing current that they interrupt the current within the first half-cycle—or before the current even reaches its first peak (see **Figure 3**). Current-limiting fuses stop currents from damaging equipments faster than any other protective device. They also greatly reduce or even completely prevent component damage from high-fault currents. This performance capability helps people meet NEC Article 110.10 requirements and keep their systems safe.

> Current-limiting fuses stop currents from damaging equipments faster than any other protective device

UL and CSA Fuse Classes

Fuse labels must include the:

- UL or the CSA fuse class
- manufacturer's name or trademark
- current rating
- ac or the dc voltage rating or both
- ac or the dc interrupting rating or both

Fuses that meet the requirements for current-limiting fuses are required to be labeled "current limiting."

"Time Delay", "D", "TD" or equivalent may also be included on the label when the fuse complies with the time-delay requirements of its class.

Current-Limiting Fuse Classes

The classes for current-limiting fuses include:

- Class R
  - Class RK1
  - Class RK5
- Class L
- Class J
- Class CC/CD
- Class T
- Class G
- Class K
  - Class K5

There are no classes for special-purpose fuses and fuses for supplementary overcurrent protection.

Plug fuses do not have a UL letter class designation.

CLASS R	
STANDARDS:	UL Standard 248-12 CSA Standard C22.2 No. 248.12-11
VOLTAGE RATINGS:	250 V and 600 V, ac; 125 V and 300 V dc
CURRENT RATINGS:	0 A–600 A
INTERRUPTING RATING:	200 000 A rms symmetrical
TWO CLASSES:	RK1 and RK5

Time delay is optional for Class R fuses.

Time delay fuses are required to hold 500% current rating for a minimum of ten seconds.

Same dimensions as UL Class H fuses, terminals modified to provide rejection feature.

Fits UL Class R fuse holders which reject non Class R fuses.

Physically interchangeable with UL Class H, NEMA Class H, and UL Classes K1 & K5 when equipment has Class H fuse holders.

CLASS RK1	
High degree of current limitation. Provides IEC Type 2 (no damage) protection for motor starters and control components. Time delay optional, LLSRK_ID series provides visual indication of blown fuse.	
LF SERIES:	Time Delay: LLNRK, LLSRK, LLSRK_ID Fast Acting: KLNR, KLSR

CLASS RK5	
Moderate degree of current limitation, adequate for most applications. Time Delay otional. FLNR_ID, FLSR_ID and IDSR series provides visual indication of blown fuse.	
LF SERIES:	FLNR, FLNR_ID, FLSR, FLSR_ID, and IDSR

CLASS L	
STANDARDS:	UL Standard 248-10 CSA Standard C22.2 No. 248.10-11
VOLTAGE RATINGS:	600 V, ac and/or dc
CURRENT RATINGS:	100 A–6 000 A
INTERRUPTING RATING:	Ac: 200 000 A rms symmetrical Dc: 50 000, 100 000, or 200 000 A
Not interchangeable with any other UL fuse class.	
Time delay: Class L fuses may be marked "Time-Delay" although UL does not investigate time-delay characteristics of Class L fuses.	
KLPC & KLLU:	10 seconds at 500% current rating
LDC:	4 seconds at 500% current rating
LF SERIES:	KLPC, KLLU, LDC

CLASS J

STANDARDS:	UL Standard 248-8 CSA Standard C22.2 No. 248.8-11
VOLTAGE RATINGS:	600 V, ac
CURRENT RATINGS:	0 A–600 A
INTERRUPTING RATING:	200 000 A rms symmetrical

Not interchangeable with any other UL fuse class.

Time delay optional: Minimum of 10 seconds at 500% current rating.

LF SERIES:	Time Delay: JTD_ID, JTD Fast Acting: JLS

CLASS CC AND CLASS CD

STANDARDS:	UL Standard 248-4, 248-18 CSA Standard C22.2 No. 248.4-00; C22.2 No. 248.18:22
VOLTAGE RATINGS:	600 V, ac
CURRENT RATINGS:	UL Class CC: 0 A–30 A UL Class CD: 35 A–60 A
INTERRUPTING RATING:	200 000 A rms symmetrical

Time delay optional: Minimum of 12 seconds at 200% current rating.

LF SERIES:	Time Delay: CCMR (motors), KLDR (transformers) Fast Acting: KLKR

CLASS T

STANDARDS:	UL Standard 248-15 CSA Standard C22.2 No. 248.15-18
VOLTAGE RATINGS:	300 V and 600 V ac, 125 V and 300 V dc
CURRENT RATINGS:	0 A–1200 A
INTERRUPTING RATING:	200 000 A rms symmetrical

Fast-Acting fuses. High degree of current limitation.

Very small fuses; space-saving and non-interchangeable with any other UL fuse class.

CLASS G

STANDARDS:	UL Standard 248-5 CSA Standard C22.2 No. 248.5-00
VOLTAGE RATINGS:	480 V ac and 600 V ac
CURRENT RATINGS:	0 A–60 A
INTERRUPTING RATING:	100 000 A rms symmetrical

Not interchangeable with any other UL fuse class.

Time delay optional: Minimum of 12 seconds at 200% current rating.

LF SERIES:	SLC

CLASS K

STANDARDS:	UL Standard 248-9 CSA Standard C22.2 No. 248.9-00
VOLTAGE RATINGS:	250 V and 600 V dc, ac
CURRENT RATINGS:	0 A—600 A
INTERRUPTING RATING:	Three permitted: 50 000, 100 000, and 200 000 A rms symmetrical

Time delay is optional for Class K fuses.

Time Delay fuses are required to hold 500% current rating for a minimum of ten seconds.

Same dimensions and physically interchangeable with UL Class H fuse holders.

Class K fuses are not permitted to be labeled Current Limiting because there is no rejection feature as required by NEC Article 240-60(B).

CLASS K5

Same prescribed degree of current limitation as RK5 fuses when tested at 50 000 or 100 000 A rms symmetrical.

LF SERIES: NLN, NLS

FUSES FOR SUPPLEMENTARY OVERCURRENT PROTECTION

STANDARDS:	UL Standard 248-14; CSA Standard C22.2 No. 248.14-00. Three Classifications covered:

NOTE: Fuses may be rated for ac and/or dc when suitable for such use.

(1) Micro fuses

Voltage ratings:	UL, 125 V; CSA, 0 V–250 V
Current ratings:	UL, 0 A–10 A; CSA, 0 A–60 A
Interrupting rating:	50 A rms symmetrical (CSA classifies these as Supplemental Fuses)

(2) Miniature fuses

Voltage ratings:	UL, 125 V or 250 V; CSA, 0 V–600 V
Current ratings:	UL, 0 A–30 A; CSA, 0 A–60 A
Interrupting rating:	10 000 A rms symmetrical (CSA classifies these as Supplemental Fuses)

(3) Miscellaneous Cartridge fuses

Voltage ratings:	UL, 125 V–1 000 V; CSA, 0 V–100 V
Current ratings:	UL, 0 A–30 A; CSA 0 A–60 A
Interrupting rating:	10 000, 50 000, or 100 000 A rms symmetrical

Time delay (optional); Minimum delay at 200% fuse rating:

- 5 seconds for fuses rated 3 A or less
- 12 seconds for fuses rated more than 3 A

LF SERIES:	BLF, BLN, BLS, FLA, FLM, FLQ, FLU, KLK, KLQ KLKD, SPF

NOTE: Littelfuse electronic fuses are also covered by these standards; see electronic section of this catalog, or littelfuse.com for complete listing.

SEPECIAL PURPOSE FUSES

There are no UL Standards covering this category of fuses. These fuses have special characteristics designed to protect special types of electrical or electronic equipment.

Fuses may be UL Recognized for use as a component in UL Listed equipment.

UL Recognized fuses are tested for characteristics such as published interrupting capacity. They are also covered by UL re-examination service.

VOLTAGE RATINGS:	up to 1 000 V ac and/or dc
CURRENT RATINGS:	up to 6 000 A
INTERRUPTING RATING:	up to 200 000 A

Many of these fuses are extremely current limiting. When considering application of these fuses, or if you have special requirements, contact Littelfuse Technical Support Group for assistance.

LF SERIES:	KLC, L15S, L25S, L50QS, L50S, L60S, L70QS, L70S

CLASS H

STANDARDS:	UL Standard 248-6, 248-7 CSA Standard C22.2 No. 248.6-00; C22.2 No. 248.7-00. Also known as NEMA Class H, and sometimes referred to as "NEC" or "Code" fuses
VOLTAGE RATINGS:	250 V and 600 V, ac
CURRENT RATINGS:	0 A–600 A
INTERRUPTING RATING:	10 000 A rms symmetrical

Two types: one-time and renewable

Physically interchangeable with UL Classes K1 & K5;

Fits UL Class H fuse holders which will also accept K1, K5, RK5, and RK1 fuses.

Manufacturers are upgrading Class H one-time fuses to Class K5 per UL Standard 248-9D, See Class K fuses.

ONE-TIME FUSES (NON-RENEWABLE)

Time delay: Optional
Time-delay fuses must hold 500% current rating for a minimum of ten seconds.

LF SERIES: Discontinued - Please cross to RK5 or RK1 class fuses.

RENEWABLE FUSES

Only Class H fuses may be renewable. While time delay is optional, no renewable fuses meet requirements for time delay.

Some renewable fuses have a moderate amount of time delay, referred to as "time lag" to differentiate from true time delay.

LF SERIES: Discontinued - Please cross to RK5 or RK1 class fuses

PLUG FUSES

STANDARDS:	UL Standard 248-11 CSA Standard C22.2 No. 248.11-11
VOLTAGE RATINGS:	125 V ac only
CURRENT RATINGS:	0 A–30 A
INTERURUPTING RATINGS:	10 000 A rms symmetrical. Interrupting rating need not be marked on fuse.

Two types: Edison-base and Type S

Edison-base: Base is the same with an E26 light-bulb base. All amp ratings interchangeable. NEC permits Edison-base plug fuses to be used only as replacements for existing fuses, and only when there is no evidence of tampering or overfusing.

Type S: Not interchangeable with Edison-base fuses unless non-removable Type S fuse adapter is installed in Edison-base fuse socket. To prevent overfusing, adapters have three current ratings: 10 A–15 A, 16 A–20 A, and 21 A–30 A.

Time delay: Fuses may be time delay, if so, they are required to hold 200% of rating for 12 seconds minimum.

LF SERIES:	Edison-base: TOO, TLO Type S: SOO, SLO Type S Adapters: SAO

NOTE: Plug fuses may be used where there is not more than 125 V between conductors or more than 150 V from any conductor to ground. This permits their use in 120/240 V grounded, single-phase circuits.

Codes and Standards

Codes

National Electrical Code (NEC)

- **NEC ARTICLE 110** Requirements for Electrical Installations
- **NEC ARTICLE 240** Overcurrent Protection
- **NEC ARTICLE 430** Motors, Motor Circuits, and Controllers

International Electrical Code (IEC)

- **IEC 60269-1** Low-voltage fuses: Part 1: General requirements
- **IEC 60269-2** Low-voltage fuses: Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application): Examples of standardized systems of fuses A to I
- **IEC 60269-3** Low-voltage fuses: Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications): Examples of standardized systems of fuses A to F
- **IEC 60269-4** Low-voltage fuses: Part 4: Supplementary requirements for fuse-links for the protection of semiconductor devices
- **IEC 60269-5** Low-voltage fuses: Part 5: Guidance for the application of low-voltage fuses

Standards

UL

- **UL 248-1** Low-Voltage Fuses - Part 1: General Requirements
- **UL 248-4** Standard for Low-Voltage Fuses - Part 4: Class CC Fuses
- **UL 248-5** Standard for Low-Voltage Fuses - Part 5: Class G Fuses
- **UL 248-8** Low-Voltage Fuses - Part 8: Class J Fuses
- **UL 248-9** Standard for Low-Voltage Fuses - Part 9: Class K Fuses
- **UL 248-10** Low-Voltage Fuses - Part 10: Class L Fuses
- **UL 248-12** Low-Voltage Fuses - Part 12: Class R Fuses
- **UL 248-13** Low-Voltage Fuses - Part 13: Semiconductor Fuses
- **UL 248-14** Standard for Low-Voltage Fuses - Part 14: Supplemental Fuses
- **UL 248-15** Low-Voltage Fuses - Part 15: Class T Fuses
- **UL 248-18** Low-Voltage Fuses - Part 18: Class CD Fuses
- **UL 248-19** Standard for Low-Voltage Fuses - Part 19: Photovoltaic Fuses

IEEE

- **IEEE 3004.3-2020 IEEE 3004.3** Recommended Practice for the Application of Low-Voltage Fuses in Industrial and Commercial Power Systems

Additional Resources

Industrial Fuses

Fuses by Class

- Class CC fuses
- Classs G fuses
- Class H renewable fuses
- Class J fuses
- Class K: Class K1 fuses & Class K5 fuses
- Class L fuses
- Class R: Class RK1 fuses & Class RK5 fuses
- Class T fuses
- Medium Voltage Fuses
- Hazardous Location Circuit Protection
- The Importance of Effective Motor and Motor Circuit Protection

Semiconductor Fuses

- 10 x 38 fuses
- POWR-SPEED very fast-acting fuses

Fuses for Battery Energy Storage Systems

- Class T fuses
- Energy-storage rack (ESR) fuses
- PSX high-speed fuses
- High-speed semiconductor fuses
- Surface-mount fuses

Renewable Energy Fuses (Solar)

- 600 V dc to 1500 V dc fuses

With nearly 100 years' experience in electrical components, Littelfuse is always happy to help. Speak with one of our experts directly.

Technical Support

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Product Purchasing and Support

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Application and Field Support

Our experienced product and application engineers will determine the best solution for your specific needs, and work with you from design to installation.
Littelfuse.com/ContactUs

Stay Informed With Us

Join our mailing list

General Inquiries and Information

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Additional Information

Technical Papers

- High-Speed Fuse Protection
- Battery Energy Storage Systems Demand a Comprehensive Circuit Protection Strategy
- Reducing the Cost of Solar with In-Line Fuses
- Fuses Outshine Circuit Breakers in Cost, Reliability
- How to Determine and Increase Short Circuit Current Ratings for Industrial Control Panels
- How to Calculate Fuse Sizes for Photovoltaic Installations
- Fuses for Energy Storage Systems

Selection Guide

- Fuseology Selection Guide

NOTES

For more information, visit
Littelfuse.com/TechnicalCenter