Shedding New Light on Branch Circuit Applications

1999 Revision of NEC 110-10

"The overcurrent protective devices, the total impedance, the component short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit protective devices used to clear a fault to do so without extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors, or between any circuit conductor and the grounding conductor or enclosing metal raceway. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section."

Designing a Lighting Control System

Almost all lighting control systems are really electrical systems. The most visible part of lighting control system design may be the control functions – zone layout, schedules, overrides, and similar considerations – but good electrical design is critical for reliable operation.

Key considerations in electrical design involve the current carrying capacities of conductors and components. Conductor sizes and overcurrent protection ratings are based on preventing excessive temperature rise under steady state conditions. The system must also be designed with equipment that meets or exceeds the short-circuit current rating available during a fault.

NFPA 70, otherwise known as the National Electrical Code (NEC), addresses current carrying capacities of both conductors and components. Unfortunately, some designers fail to recognize the limited short-circuit current ratings of some lighting controls, mistakenly placing this equipment on a circuit with higher fault currents than the product listing allows.

Electrical design safety of the lighting control system is instrumental in developing the foundation of the system before details of the control scheme are established.

Complying with the Code

The 1999 edition of the NEC contains numerous changes. Two important clarifications were made to Section 110-10 (NEC 110-10):

- A change was made from "short-circuit withstand rating" to short-circuit current rating" because electrical equipment is marked with short-circuit current ratings.
- An addition was made to minimize confusion and simplify compliance: "listed products applied in accordance with their listing shall be considered to meet the requirements of this section."

The purpose of the NEC, as stated in Article 90-1(a), is "the practical safeguarding of persons and property from hazards arising from the use of electricity." Branch circuit impedance and the short-circuit current rating (SCCR) of branch circuit devices play a critical part in complying with the code. The impedance is an important part of determining the fault current potentially available at a circuit component. The SCCR of each device indicates how much fault current the device has been designed and tested to handle. If the branch circuit impedance is not sufficient to reduce the fault current to a level below the device SCCR, not only does the device application not comply with the NEC, but using the device greatly compromises personal safety and equipment life.

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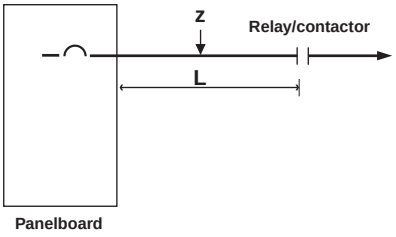
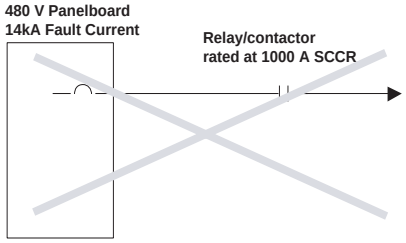


Figure 1 *The impedance, **Z**, varies directly with, **L**, the length of the conductor between the panelboard and the power switching device. As the length decreases, the impedance decreases and the potential fault current available at the device increases. Switching device ratings and circuit layout must be carefully considered during system design.*



Length of wire between panelboard and relay/contactor	Fault current available at relay/contactor
10 ft	9,808 A
15 ft	8,004 A
20 ft	6,662 A
25 ft	5,665 A

Figure 2 *The UL 508 tested relay/contactor is rated for 1000 A SCCR. When the conductor length between the panelboard and relay/contactor is 25 ft., the fault current at the relay/contactor far exceeds the 1000 A available fault current. This circuit does not comply with NEC 110-10 for a length of wire less than 25 ft.*

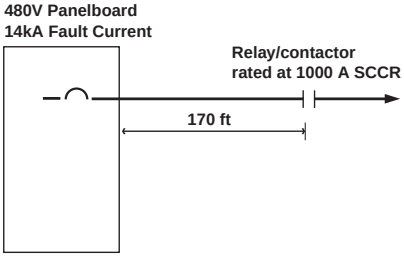


Figure 3 *The UL 508 tested relay/contactor is rated at 1000 A. In order to comply with NEC 110-10, the length of the conductor between the panelboard and relay/contactor must be 170 ft. to reduce the fault current to less than 1000 A.*

Design Considerations – The Problem

Using lighting control as an example, consider the application of relays/contactors and remotely operated circuit breakers. To specify a code compliant lighting control system, the designer must know the available fault current and the SCCR of the manufacturer's products. The procedure for determining fault current is found in the Institute of Electrical and Electronic Engineers (IEEE) Standard 141 or in IEEE Standard 241 (The Gray Book). The relay/contactor or remotely operated circuit breaker manufacturer should either display the rating on the product in accordance with its listing (e.g. UL listing) or provide rating data with the product.

Relays were one of the first solutions for automated lighting control applications. Years ago, relays were placed at the loads, a substantial distance from the panelboard. The length of the conductor between the panelboard and the relay provided sufficient impedance to minimize the fault current available at the relay. Today, for convenience and maintainability, relays are located in a central cabinet located next to the panelboard. Therefore, branch circuit impedance is critical to determining whether relays meet the required SCCR requirements (see Figure 1). The shortened conductor length between the panelboard and relay cabinet decreases the impedance and significantly increases the available fault current at the relay. Consequently, relay based systems require additional design considerations to ensure compliance with Section 110-10.

Standard Practices – How to Select Components

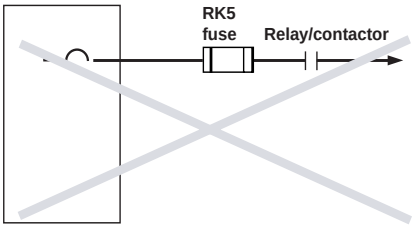
UL standards have been established to determine the short-circuit current ratings for electrical components.

- **Basic Requirements – UL 508 and UL 916**
  Relays/contactors are typically listed under UL 508 – Industrial Control Equipment. The standard defines a set of tests that establishes a peformance level at specific fault current levels with a specified branch circuit protection device. The standard short circuit current test is 1000 A for relays and contactors rated 1.5 HP and below. Figure 2 illustrates an installation that is clearly a violation of NEC Section 110-10. Figure 3 is an example that shows the approximate distance required between the panelboard and relay/contactor to comply with a 1000 A rating.

  Note: Current calculations in Figures 2 through 4 that follow are not intended for design purposes but for illustration only. The following assumptions apply: a) copper conductor with THHN/THWN insulation (X&R data); b) X/R = 5; c) several single conductor cables in steel conduit; d) calculations based on IEEE Std 141-1993; e) 480Y/277 3P 4W f) #12 conductor (20 amp); f) available fault current at panelboard is 14kA.

  UL 916 – Energy Management Equipment is intended primarily for control panels used with energy management equipment. This standard also includes a short circuit test but is limited to 1000 symmetrical amperes for control relays under 1.5 HP. UL 916 does not require markings for this rating to be on the product or literature.

480V Panelboard
14kA Fault Current



Length of wire between panelboard and relay/definite purpose contactor	Fault current available at relay/definite purpose contactor
10 ft	9,808 A
15 ft	8,004 A
20 ft	6,662 A
25 ft	5,665 A

Figure 4 *The UL 508 tested relay/definite purpose contactor is rated at 5000 A when used with a RK5 fuse. When the conductor length between the panelboard and the relay/definite purpose contactor is 25 ft., the fault current at the relay/definite purpose contactor still exceeds the 5000 A rating. This circuit does not comply with NEC 110-10 for a length of wire less than 25 ft.*

480V Panelboard
with Square D Type EHB
circuit breaker;
14kA Fault Current

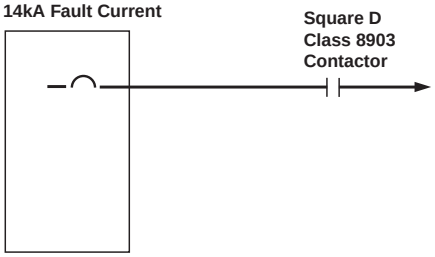


Figure 5 *Square D Class 8903 Lighting Contactors are designed specifically for lighting applications. Evaluated in accordance with UL 508, these lighting contactors are rated substantially above the standard 1000 A. When used with a Square D Type EHB branch circuit breaker, the Class 8903 contactor has a certified rating of 14,000 A – the fault current available at the panelboard in this example.*

480V Panelboard with POWERLINK AS
remotely operated circuit breakers;
14kA Fault Current

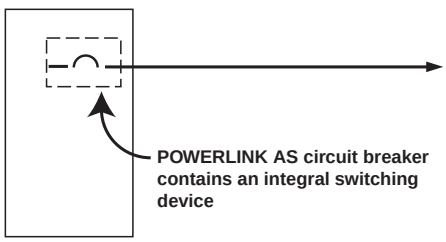


Figure 7 *POWERLINK AS remote operated circuit breakers fit in any conventional breaker panelboard enclosures. Series connected ratings up to 200,000 rms amperes. UL ratings include HACR, HID, and SWD.*

- **Higher Fault Current Testing – UL 508**
  Listing a device to UL 508 often requires branch circuit protection in order for the product to pass the test sequence. The overcurrent device, branch circuit breaker or fuse, is then required to be marked on the Listed UL 508 device. To meet UL 508 the device must have a minimum of 1000 A SCCR. Some relays have a 5000 A SCCR when used with an RK5 fuse. In order to ensure a NEC compliant installation, the relay/ contactor must be installed per the manufacturer's instructions with the required circuit breaker or fuse for protection (see Figure 4.)

  Square D, a market leading supplier of electrical distribution, industrial control and automation products, systems and services, offers a code compliant contactor solution. Square D Class 8903 lighting contactors provide a time-proven design and are used wherever reliable, convenient and economical lighting control is required. This line of contactors is designed and intended specifically for lighting. Square D lighting contactors are tested with both fusible disconnect switches and circuit breakers (see Figure 5). In addition to the product markings required under UL 508, the short circuit current ratings for Square D lighting contactors are fully disclosed and readily available (see Figure 6).

UL Listed Short-Circuit Rating
Contactors Protected by Fusible Disconnect Switches

Contactor Continuous Rating Amps	Maximum Class RK5 Fuse Rating	Maximum Voltage	Available Amperes (RMS Sym.)
20, 30	30	600	100,000
60	60	600	100,000
100	100	600	100,000
200	200	480	100,000
300	400	600	100,000
400	400	600	100,000

Contactors Protected by Circuit Breakers

Contactor Continuous Rating Amps	Maximum Circuit Breaker Rating Amps	Recommended Square D Circuit Breaker Types	Maximum Voltage	Available Amperes (RMS Sym.)
20	25	EH-EHB, FH-FHL	240	22,000
20	25	EH-EHB, FA-FAL, FH-FHL	480	14,000
30	40	FA-FAL, FH-FHL	600	10,000
30	40	IF-IFL	480	100,000
60	80	FH-FHL	600	18,000
60	90	IF-IFL	480	100,000
100	125	KA-KAL, KH-KHL	600	10,000
100	125	IK-IKL	480	100,000
200	250	LA-LAL, LH-LHL	600	14,000
200	225	IK-IKL	480	100,000
300	400	LA-LAL, LH-LHL	600	22,000
400	800	MA-MAL, MH-MHL	600	22,000
600	800	MA-MAL, MH-MHL	600	22,000

Figure 6 *Published ratings for Square D Class 8903 Lighting Contactors*

- **Remotely Operated Circuit Breakers**
  Remotely operated circuit breakers are designed to switch branch circuits while providing overcurrent protection and are Listed under UL 489 – Molded Case Circuit Breakers and Enclosures. UL 489 requires the maximum interrupting rating be displayed on the circuit breaker. The NEC and UL 489 both indicate the primary function of circuit breakers is to protect the conductors.

  POWERLINK® AS remotely operated circuit breakers from Square D are another lighting control option. The remotely operated circuit breakers provide both overcurrent protection and switching functions and fit into any existing standard panelboard enclosure. No additional wiring or enclosures are required (see Figure7). Branch circuits can be switched by a motor operating the breaker contacts. The POWERLINK AS system offers the capability to control lighting and other loads to preset time schedules or from external control devices such as wall switches, occupancy sensors, or building management systems. The breakers are designed to handle high-inrush current loads and today's high short circuit current requirements. Tested under UL 489, UL listed interrupting ratings are on the circuit breaker and widely published for each type of POWERLINK AS circuit breaker (see Figure 8). As shown in Figure 9, series ratings for POWERLINK AS panelboards and remotely operated circuit breakers are also available.

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UL Listed Interrupting Ratings for POWERLINK AS Circuit Breakers

Catalog Number Prefix	Number of Poles	Continuous Current Rating	Maximum Voltage Rating	Ampere Interrupting Rating
QO(B)-AS QO(B)-AS QO(B)-AS	1 2 3	15A, 20A, 30A	120/240Vac 120/240Vac 240Vac	10,000A 10,000A 10,000A
EHB-AS	1	15A, 20A, 30A	120Vac 277Vac	65,000A 14,000A
EHB-AS	2	15A, 20A	120/240Vac 480Y/277Vac	65,000A 14,000A
EHB-AS	3	15A, 20A	240Vac 480Y/277Vac	65,000A 14,000A

Figure 8 *Published ratings for POWERLINK AS remotely operated circuit breakers.*

NQOD Series Ratings

System Voltage (Maximum)	UL Series Connected Rating (AIR)	Main		Branch		
		Type	Max. Amperes	Type	Amperes	Poles
240Vac	22,000	QO(B)-VH	150	QO-AS QOB-AS	15-30 15-30 15-30	1 2 3
	25,000	KD	250	QO-AS QOB-AS	15-30 15-30 15-30	1 2 3
	100,000	FC	100	QO-AS QOB-AS	15-30 15-30 15-30	1 2 3
		KC	250	QO-AS QOB-AS	15-30 15-30 15-30	1 2 3
	200,000	FI	100	QO-AS QOB-AS	15-30 15-30 15-30	1 2 3
		FI	100	QO-AS QOB-AS	15-30 15-30 15-30	1 2 3

NEHB Series Ratings

System Voltage (Maximum)	UL Series Connected Rating (AIR)	Main		Branch		
		Type	Max. Amperes	Type	Amperes	Poles
480Y/ 277Vac	65,000	FC	100	EHB-AS	15-30 15-20 15-20	1 2 3
		KC	250	EHB-AS	15-30 15-20 15-20	1 2 3
	200,000	FI	100	EHB-AS	15-30 15-20 15-20	1 2 3
		KI	250	EHB-AS	15-30 15-20 15-20	1 2 3
	100,000	Class J/T Fuse	200	EHB-AS	15-30 15-20 15-20	1 2 3

Figure 9 *UL tested and listed series combination ratings for POWERLINK AS panelboards and remotely operated circuit breakers. The ratings apply to either an integral main located in the same enclosure or a remote main located in a separate enclosure.*

Spotting Potential Code Violations

Square D has published ratings for its remotely operated circuit breakers and Class 8903 lighting contactors that have been tested and listed. You must know the short-circuit current rating of the relay/contactor or the interrupting rating of the circuit breaker to determine whether the circuit complies with NEC 110-10. If the ratings are not marked on or published with the device, you must contact the manufacturer to verify the ratings.

Installations that deserve a second look to confirm compliance with NEC 110-10:

a) Relay/contactor not protected by a branch short circuit protective device
b) Lighting controls mounted in enclosure electrically near the panelboard
c) Branch circuit protection that does not match markings on the relay/contactor
d) UL 916 (Listed Energy Management Equipment) is on a circuit that exceeds 1000A of available fault current
e) Lighting contactors are identified as Definite Purpose

Summary

The clarifications in Section 110-10 of the 1999 NEC have significant impact on the safe application of branch circuit components. Individual devices may meet the appropriate test standards required for the device, but more importantly, all elements of the branch circuit – overcurrent protective devices, total impedance, short-circuit current ratings – must be selected to permit the protective devices to clear a fault without extensive damage to the circuit components.

If any component of the branch circuit cannot meet the available fault current, the circuit does not meet code requirements. Concerns for personal safety, reliability, and equipment damage warrant a close examination of common branch circuit switching and protection applications.