

WHITE PAPER

Littelfuse®

Expertise Applied | Answers Delivered

MEDIUM VOLTAGE FUSES

Selecting and Applying Medium Voltage Fuses • 2,400 - 38,000 VAC

Applying Medium Voltage Fuses (2,400 – 38,000 Volts AC)

Introduction

Medium voltage fuses are applied quite differently than fuses rated 600 volts and less. The biggest difference is that medium voltage fuses are not intended to provide overload protection. They should only be applied in situations where it will not be required to open small overcurrents. Medium voltage fuses offer a much wider range of system voltages, thereby resulting in a correspondingly large number of fuse voltage ratings.

Descriptions and ratings of Littelfuse medium voltage fuses, along with some application data, are located in the Medium Voltage Fuse section of the Littelfuse POWR-GARD® Catalog. To download a copy visit www.littelfuse.com/catalogs.

For questions, contact our Technical Support and Engineering Services Group at **800-TEC-FUSE (800-832-3873).** Definitions of terms used in this white paper can be found in the Technical Application Guide section of the POWR-GARD Catalog.

The following is a more detailed discussion of factors which must be considered when properly selecting and applying medium voltage fuses in electrical systems.

What are Medium Voltage Fuses?

Littelfuse medium voltage fuses are silver-sand, non-expulsion design, current-limiting type devices. When properly applied, they are designed to carry their nominal current rating continuously without "fatigue failure." This means that the fuse will not age, become brittle, or deteriorate under the most severe duty cycling.

When talking current-limiting medium voltage fuses, there are two basic types: general purpose and back-up. General purpose fuses have the ability to interrupt both large and small short-circuits down to currents which would cause the fuse to open within one hour. They are used to provide short-circuit protection for transformers, switchgear, and similar equipment.

Back-up fuses are designed to protect only against high fault currents, and must be used in series with equipment which provides the circuit's required overload and low value short-circuit protection.

Medium Voltage (MV) "E-rated" fuses are considered general purpose fuses. Their mounting dimensions permit them to be installed in a wide variety of medium voltage switches, in pad-mounted transformers, and at other similar locations. "R-rated" MV fuses are specifically designed to provide short-circuit protection for medium voltage motor controllers and associated equipment.

Selecting Medium Voltage Fuses

Four factors must be considered when applying MV fuses: voltage rating, current rating, interrupting rating, and the fuses' coordination with other overcurrent protective devices.

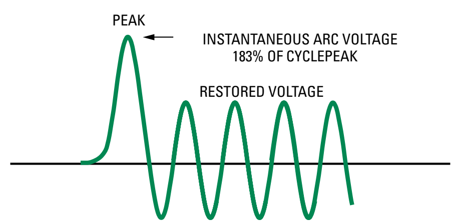
Voltage Ratings

Similar to fuses rated 600 volts and less, the minimum voltage ratings for MV fuses must be equal to or greater than the maximum voltage which the fuse will experience under the worst possible conditions. Normally, this requires the fuse voltage rating to be greater than the system's maximum line-to-line voltage. However, when fusing single-phase loads which are connected from line-to-neutral on an effectively grounded four wire wye system, the maximum design voltage of the fuse only needs to be greater than the system's maximum line-to-neutral voltage. When fuses are selected in this way, it is impossible for the fuse to experience line-to-line voltage. As a result, if more than one phase is extended beyond the fuse location, it is best to use fuses with a voltage rating greater than the maximum line-to-line voltage.

While not required for low voltage fuses, the maximum voltage rating of a MV fuse must also be considered. For a fuse to be considered 'current-limiting', it must interrupt the circuit within 180 electrical degrees (one-half electrical cycle) after the fault occurs. This is accomplished by producing an arc voltage across the fuse greater than the system voltage. This higher arc voltage forces current to zero before the available short-circuit current reaches its first peak.

Arc voltages are created in the fuse by the melting of the fuse links. This produces a number of high resistance arcs (gaps) in series, and there exists a voltage drop across each gap. When the total voltage drop exceeds system voltage, the current flow stops. As this occurs, a transient voltage spike is generated in the system as shown in **Figure 1.** It is important to make sure that this voltage does not exceed the system's basic insulation level (BIL). Arc (or transient) voltage will usually not be a problem in a system if the fuse's maximum design voltage rating does not exceed 140% of the system's voltage.

Figure 1 – Transient Voltage Spike



However, higher voltage fuses may be used if certain conditions are met. When tested at nominal voltage rating and the rated interrupting current, Littelfuse MV fuses are designed so that the peak arc voltage does not exceed three times the fuse nominal voltage. If the electrical system being protected has a basic insulation level (BIL) greater than three times the fuse maximum design voltage, the higher voltage fuses may be used. See the following for an example of this scenario:

Example

Given: System nominal voltage = 4,800 V

System basic insulation level (BIL) = 50,000 V

Can a POWR-GARD™ 15NLE-80E fuse, rated 14,400 V nominal and 15,500 V maximum be used in this system?

Maximum peak voltage produced by this fuse = 3 X 14,400 = **43,200 V**

43,200 V is less than the BIL of 50,000 V, so the 15NLE-80E fuse *may* be used.

Continuous Current Ratings

Available current ratings of E-rated and R-rated MV fuses are listed in the Medium Voltage Fuses section of the POWR-GARD® Catalog. Current ratings for MV fuses carry a different meaning than current ratings for fuses rated 600 volt and below. MV fuses are not intended to provide protection against overloads or other overcurrents less than two times their continuous current rating. If MV fuses are exposed to currents only slightly higher than their continuous current rating, a large amount of heat is generated within the fuse. This excessive heat causes the fuse tube to char and weaken which also affects the fuse's time-current characteristics. If a given circuit has the ability to produce sustained currents 100% to 200% of a medium voltage fuse's current ratings, then other overcurrent devices must be used in series with the fuses to provide the proper overload protection.

Medium voltage fuses are designed to carry their rated current without exceeding the temperature rise permitted by NEMA and ANSI standards. The "E" and "R" ratings help define the operating characteristics of the fuses. More specifically:

- NEMA Standards for E-rated MV power fuses require that fuses rated 100E or less open within 300 seconds (5 minutes) when subjected to an RMS (root-mean-squared) current of 200-240% of the fuse's continuous current rating. Fuses with an "E" rating larger than 100E must open within 600 seconds (10 minutes) when subjected to an RMS current of 220-264% of the fuse's continuous current rating.
- NEMA Standards for R-rated MV power fuses require that fuses open within 15-35 seconds when subjected to an RMS current 100 times the "R" rating.

These values establish one point on the fuse's time-current curve and help to define the overall performance characteristics of E- and R-rated fuses. Since all E- and R-rated fuses must meet these same basic requirements, comparing the time-current characteristics of E-rated and R-rated fuses from different manufacturers will result in similar – although not necessarily identical – results.

A long-standing rule of thumb for applying medium voltage fuses states that the minimum fuse rating should be at least 1.4 times the circuit's full load current. This generally insures that MV fuses will not be required to open overloads. If the nature of the load is such that load currents will never exceed the rating of the fuse, MV fuses may be rated as close as 1.1 times the circuit's full load current.

Short-circuit kVA Ratings

The short-circuit ratings of MV breakers and other equipment such as switchgear is often stated in terms of "short-circuit kVA". It must be remembered that MV power fuses are not constant kVA devices. In other words, if the voltage is one half of the fuse current rating, the interrupting capacity or rating does not double. Medium voltage fuse interrupting ratings are provided in symmetrical and asymmetrical amperes. These values must not be exceeded at any voltage.

When the short-circuit kVA is known, the RMS symmetrical AC component may be determined from the formula:

$$I_{sc} = \frac{kVA \times 1000}{1.732 \times E}$$

I_{sc} = RMS symmetrical short-circuit current

kVA = Three phase short-circuit kVA

E = System line-to-line voltage

Interrupting Ratings

Maximum RMS symmetrical AC component and maximum asymmetrical current interrupting ratings for Littelfuse MV power fuses are shown in the Medium Voltage Fuses section of the POWR-GARD Catalog. These medium voltage fuses are tested with a short-circuit X/R ratio of 25:1. This produces an RMS asymmetrical multiplier of 1.6 times the symmetrical component, one-half cycle after the fault occurs. It also produces an instantaneous asymmetrical peak current 2.66 times the RMS symmetrical component. The interrupting ratings represent the maximum symmetrical and asymmetrical fault currents that are permitted at the point where the fuse is installed.

Effect of Frequency and Altitude on Interrupting Ratings

Interrupting ratings of MV fuses shown in the Medium Voltage Fuses section of the POWR-GARD® Catalog are valid for 50 and 60 Hertz systems. For 25 Hertz systems, multiply the interrupting ratings listed by a factor of 0.74.

The continuous current ratings and interrupting ratings of MV fuses shown in the same section of the Catalog are valid up to an altitude of 3,000 feet. Since the density of air and its dielectric strength decreases as altitude increases, continuous current ratings and interrupting ratings are affected at altitudes exceeding 3,000 feet. **Table 1** provides correction factors for higher altitudes.

ALTITUDE ABOVE SEA LEVEL		CONTINUOUS CURRENT MULTIPLIER	INTERRUPTING RATING MULTIPLIER
FEET	METERS		
4000	1200	.99	.98
6000	1800	.98	.92
8000	2400	.97	.86
10000	3000	.96	.80
12000	3600	.95	.75
14000	4300	.93	.70
16000	4900	.92	.65
18000	5500	.91	.61
20000	6100	.90	.56

Table 1—Altitude Correction Factors per ANSI C37.40-2.3

Medium Voltage Fuses Used With Lightning Arresters

When MV fuses are in the same circuit with lightning arresters, some precautions must be taken to insure that the transient voltage spike, which occurs when the fuse is interrupting a fault, does not cause lightning arresters to spark over. When checking the BIL (basic insulation level) of the system, lightning arresters are the first things that should be investigated. The lightning arrester spark-over voltage must be higher than the transient voltages which can be produced by the MV fuses. If arc voltages produced by the fuses cause lightning arresters to spark over, a relatively high current will be shunted into the arresters, although they are not designed to interrupt such currents.

If the fuses have a voltage rating higher than the arrester and are installed on the arrester's load side, the arrester may spark over when the fuse is interrupting a large fault. If the system has only distribution class arresters, there will seldom be a problem since distribution class arresters have sufficient impedance to prevent large amounts of current from passing through them. However, intermediate, line, and station type arresters have low impedance, and if spark over, sufficient current may flow in an arrester to cause severe damage to it. Intermediate, line, and station type arresters should not be applied on the line side or in parallel with current-limiting MV fuses unless the arresters' spark over voltages are greater than the arc voltages the fuses can produce. If the lightning arresters and fuses have the same voltage rating, arc voltages will be within desired limits, and the problem is eliminated.

Another approach in some instances is to place the fuses on the line side of the arresters, however, in many cases this is impossible to accomplish. Utilities prefer to locate fuses on the load side of lightning arresters to prevent lightning from damaging the fuses. In other instances, fuses are mounted on the primary transformer bushings or within pad-mounted transformer enclosures so that lightning arresters will be on the line side of the fuses.

Machine protection lightning arresters, such as those used to protect large motors and motor controls, have very low spark-over values and may be easily damaged if located on the fuse's line side. However, arresters should always be mounted directly on the machine terminals, thereby placing them on the load side of the fuses.

Motor Protection

To properly select medium voltage fuses for motor protection, several factors should be considered. First, R-rated fuses are only intended for short-circuit protection and should be applied in conjunction with motor overload relays. An R-rated fuse does not have an ampere rating, and the "R" rating refers to the opening time of the fuse. R-rated fuses are designed to safely interrupt any current between their minimum and maximum interrupting ratings. When applying R-rated fuses, it is recommended to follow the fuse sizing guidelines established by the motor starter manufacturer.

When engineering an electrical system, time-current characteristic curves of the fuse and overload relay should be compared and analyzed to insure the overload relay opens before the fuse does during overload conditions. The following table is provided as a guideline for sizing medium voltage R-rated fuses.

FOR MOTORS WITH AN ACCELERATION OF 10 SECONDS		FOR MOTORS WITH AN ACCELERATION OF 3 SECONDS	
MAX. MOTOR FLA	R-RATED FUSE	MAX. MOTOR FLA	R-RATED FUSE
28 A	2R	32 A	2R
40 A	3R	45 A	3R
55 A	4R	65 A	4R
80 A	6R	95 A	6R
125 A	9R	140 A	9R
165 A	12R	190 A	12R
250 A	18R	280 A	18R
330 A	24R	360 A	24R
500 A	36R	550 A	36R

Table 2—Medium Voltage R-rated Fuse Sizing Table for Motors

© 2015 Littelfuse POWR-GARD® Products

Transformer Protection

A principle use of medium voltage fuses is to provide primary short-circuit protection for transformers. When selecting MV fuses to protect transformers, the following factors must be considered in descending order of importance:

1. As explained earlier, the fuse's voltage and interrupting ratings must equal or exceed system requirements at the point where fuses will be applied.
2. The fuse's continuous current rating must be large enough to withstand transformer magnetizing (in-rush) current. (Minimum Fuse Rating).
3. The fuse's continuous current rating must be able to withstand transformer overloading and emergency operation, and meet all NEC® requirements. (Maximum Fuse Rating).
4. Fuses must protect the system on the line side of the fuse from the effects of short circuits on the load side of the fuses. (Utility System Coordination).
5. Fuses must coordinate with the transformer secondary protection where and whenever possible. (Facility System Coordination).
6. Fuses must protect transformer against secondary bolted faults.
7. Where and whenever possible, fuses should protect the transformer against higher impedance secondary faults.

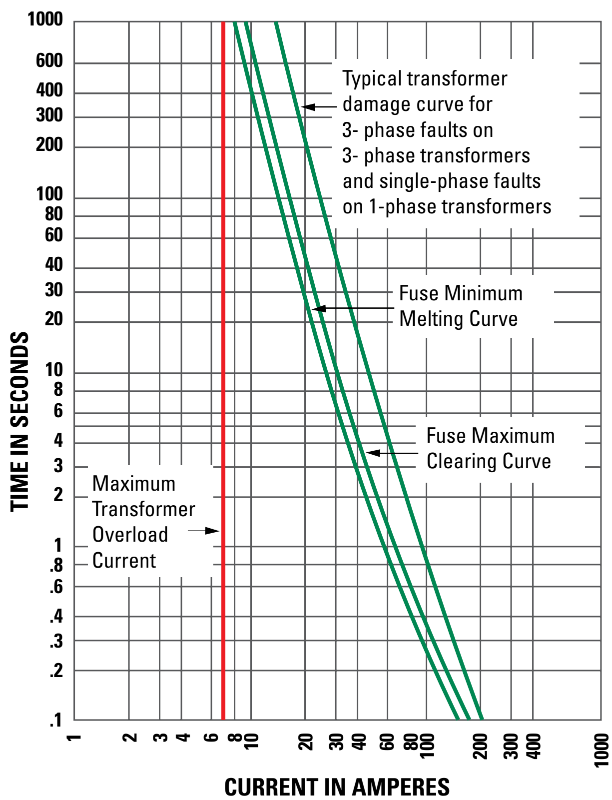


Figure 2—Time-current Curves for Transformer Protection Application

Transformer magnetizing or inrush current depends on several factors including the transformer's design, the amount of residual flux in the transformer core at the instant the transformer is energized, the point on the voltage wave at which the switch is closed, and the characteristics of the electrical system powering the transformer. A power transformer's in-rush current approximates 12 times the transformer full load current, while a distribution transformer's in-rush current can exceed 25 to 40 times of the full load current. The current generally lasts less than 1/10 second.

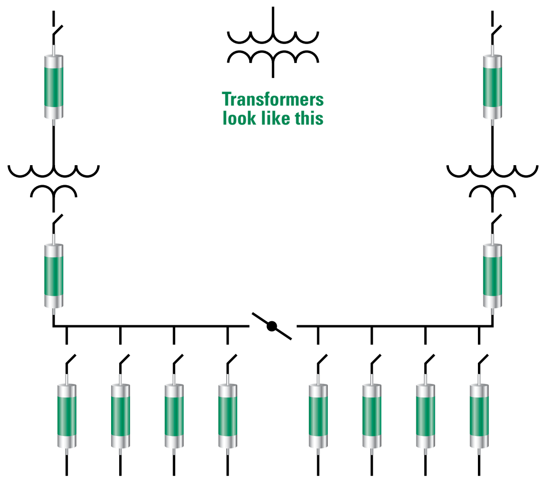


Figure 3—Typical Example of Double-ended Loadcenter Operated with Normally Open Bus Tie

To determine the minimum size fuse that will withstand the in-rush current, it is recommended to obtain the in-rush current from the transformer manufacturer and note the current on the fuse's minimum melting time-current curves at 0.10 second. This is illustrated in **Figure 2.** The minimum fuse rating to then use will be the fuse whose minimum melting curve is just to the right and above the transformer inrush point.

Medium voltage fuses with current ratings that equal or exceed a transformer's self-cooled, full load current will usually meet such a requirement when the in-rush current does not exceed 12 times transformer full load current, However, transformers are generally operated at close to full load current on a continuous basis and are often overloaded under emergency conditions. A typical example is a double-ended loadcenter operated with a normally open bus tie. See **Figure 3.** Each transformer is rated to carry 150% of the load on its half of the loadcenter. With loss of service to one transformer, the main switch for that line is opened and the bus tie switch is closed. This shifts all load to the remaining transformer. The system is operated in an overloaded state until the other line is back in service. If the outage continues for a long period of time, manual load shedding can be used to control transformer overloading.

Other similar operating schemes also result in transformer overloading. As a result, medium voltage fuses usually have continuous current ratings larger than required to withstand transformer in-rush current.

NEC® Article 450 covers transformer installations and establishes the maximum ratings of transformer overcurrent protective devices. Regarding medium voltage fuses, Article 450.3 states, in part:

> Overcurrent Protection of transformers shall comply with NEC Article 450.3(A) – Transformers Over 1000 Volts, Nominal, and shall be provided in accordance with **Table 3.**

NOTE : In this section, the word "transformer" shall mean a transformer or polyphase bank of two or more single-phase transformers operating as a single unit.

Table 3—Based on NEC® Table 450.3(A) Maximum Rating or Setting of Overcurrent Protection for Transformers Over 1000 Volts (as a Percentage of Transformer-Rated Current)

		Primary Protection Over 1000 Volts		Secondary Protection (See Note 2)		
				Over 1000 Volts		1000 Volts or Less
Location Limitations	**Transformer Rated Impedance**	**Circuit Breaker (see Note 4)**	**Fuse Rating**	**Circuit Breaker (see Note 4)**	**Fuse Rating**	**Circuit Breaker or Fuse Rating**
Any Location	Not more than 6% (see Note 1)	600%	300%	300%	250%	125%
	More than 6% but not more than 10% (see Note 1)	400%	300%	250%	225%	125%
Supervised Locations Only (see Note 3)	Any (see Note 1)	300%	250%	Not Required	Not Required	Not Required
	Not more than 6% (see Note 5 for Secondary Protection)	600%	300%	300%	250%	250%
	More than 6% but not more than 10% (see Note 5 for Secondary Protection)	400%	300%	250%	225%	250%

Note 1 – If the required fuse rating or breaker setting does not correspond to standard ratings/settings, the next higher rating/setting may be used.

Note 2 – If secondary overcurrent protection is required, no more than six breakers or sets of fuses may be grouped in any one location. When multiple overcurrent devices are used, the sum of all device ratings shall not exceed the allowed value of any single device. If both breakers and fuses are used, the total of device ratings shall not exceed that if using only fuses.

Note 3 – A "supervised location" is one where maintenance and supervision conditions ensure that only qualified persons are allowed to monitor and perform installation service on the transformer.

Note 4 – Electronically actuated fuses set to open at a specific current shall be set and calibrated in accordance with the corresponding settings of the circuit breakers involved.

Note 5 – Separate secondary protection is not necessary if the transformer is equipped with a coordinated thermal overload protection provided by the manufacturer.

Note 6 – This table covered transformers over 600 volts through the 2011 NEC. It has been increased to 1000 volts effective with the 2014 NEC.

Additional technical information and application data for Littelfuse POWR-GARD® protection relays, fuses and other circuit protection and safety products can be found on **www.littelfuse.com**. For questions, contact our Technical Support Group **(800-832-3873)**. Definitions of terms used in this white paper can be found in the Technical Application Guide section of the POWR-GARD Catalog. To download a copy visit **www.littelfuse.com/catalogs**.

Form No. PF752

© 2015 Littelfuse POWR-GARD® Products