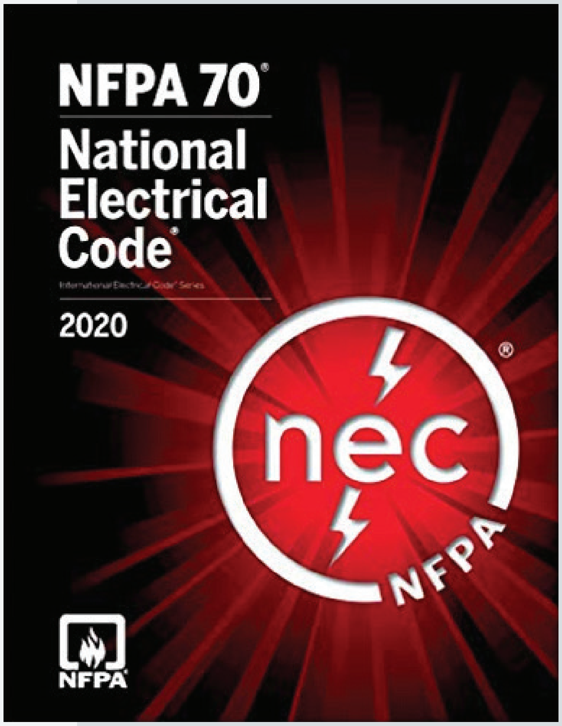
NEC UPDATE: ARTICLE 240.67 ARC ENERGY REDUCTION

TECH TOPIC
STANDARDS AND CODES NOTE 6

BY JEREMY LIELAND – SOLUTIONS ENGINEER

INTRODUCTION



On August 4, 2016 the 2017 edition of the National Electrical Code® (NEC) was released. This edition of the code introduced a requirement for Arc Energy Reduction in fused installation rated 1200A or higher.

The requirement is in Article 240.67 and reads:

"240.67 Arc Energy Reduction. Where fuses rated 1200 A or higher are installed, 240.67(A) and (B) shall apply. This requirement shall become effective January 1, 2020.

(A) Documentation. Documentation shall be available to those authorized to design, install, operate, or inspect the installation as to the location of the fuses.

(B) Method to Reduce Clearing Time. A fuse shall have a clearing time of 0.07 seconds or less at the available arcing current, or one of the following shall be provided:

1. *Differential relaying*
2. *Energy-reducing maintenance switching with local status indicator*
3. *Energy-reducing active arc flash mitigation system*
4. *An approved equivalent means"*

This application note will examine the code requirements and definitions. It is intended to help engineers understand the requirements and make recommendations to them in implementation.

CODE DEFINITIONS

As noted above, the article was set to take effect January 1, 2020. Local inspectors in jurisdictions where 2017 NEC has been adopted can begin enforcing this rule. Let's examine the rule in detail.

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First, the rule defines the subject items as "fuses rated 1200A or higher." In low-voltage power systems, these fuses will almost always be "Class L" fuses whose dimensions and performance is defined by UL standard 248-10. These will most typically be installed near the service entrance of a power system to protect switchgear, motor control centers, and large HP motors.

Sub part (A) requires that information on the installation be documented. This includes any information relevant to sub part (B) which will be discussed below. This requirement allows any engineers or inspectors to review the installation and validate that it meets the remaining code requirements.

Sub part (B) requires that the subject fuses clear the arcing fault in 0.07s (4.2 cycles) or less at the available arcing current or another of the means listed must be utilized. To understand this better, we need to define melting vs clearing time for fuses. A typical low voltage fuse is constructed of a metal element that carries the current through the fuse body and a silica sand fill. The element consists of several series and parallel cutouts called "notches" which will quickly melt under short circuit conditions. The time it takes the element to melt is referred to as the "melting time". Once the notches are melted, the gaps begin to arc, the sand fill will flow into the gaps, and the arcing will turn the sand into glass. The total time it takes to melt the fuse and turn the sand into class referred to as the "clearing time" (Figure 1).

Most fuse manufacturers publish only the average melt curve of fuses, so the clearing time may not be easily obtained. Figure 2 below illustrates the slight difference in time for average melt (red) vs total clear (green). IEEE Standard 1584-2018 offers guidance in the cases where total clearing data is not available: "If the curve only consists of the average melt time, 10% of time plus an additional .004 s should be added to determine the total clearing time." Given this information and using the required 0.07s clearing time from NEC, one can back-calculate the required average melt time to be 0.06s.

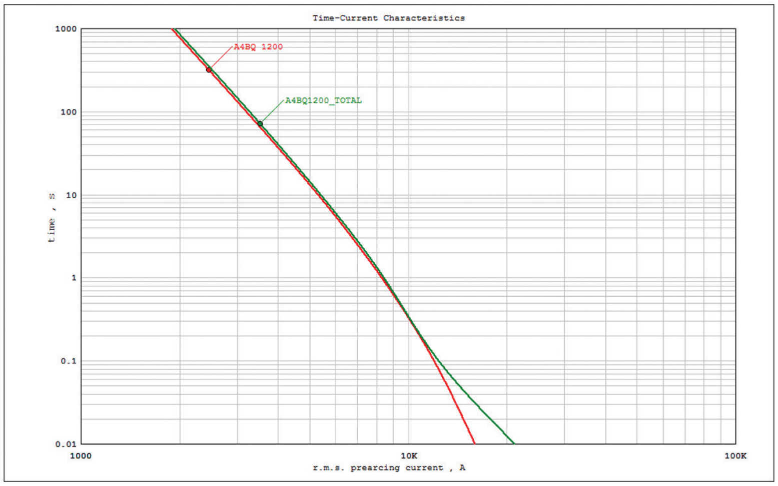

Figure 2: Ave Melt vs Total Clear

An analysis of available arcing currents for the installation should be completed utilizing methods for calculating short circuit currents from IEEE Std 551 and arcing fault currents from IEEE Std 1584. Once this analysis is complete, it can be compared to the minimum clearing current for the fuse at

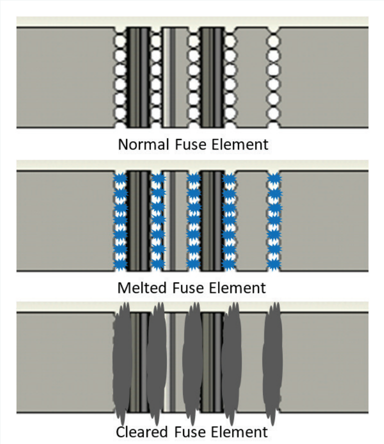

Figure 1: Fuse Melting vs Clearing

0.07s. If the available arcing current is higher than the fuses melting current at 0.07s, no further analysis is needed. IEEE1584 defines two different arcing currents. The first is the arcing current and the second is the minimum arcing current. Since NEC 240.67 does not clearly define which of these to use, we will utilize the worst case which is the minimum arcing current. This current can greatly vary by voltage and electrode configuration. See Figure 3 below for a graphical representation.

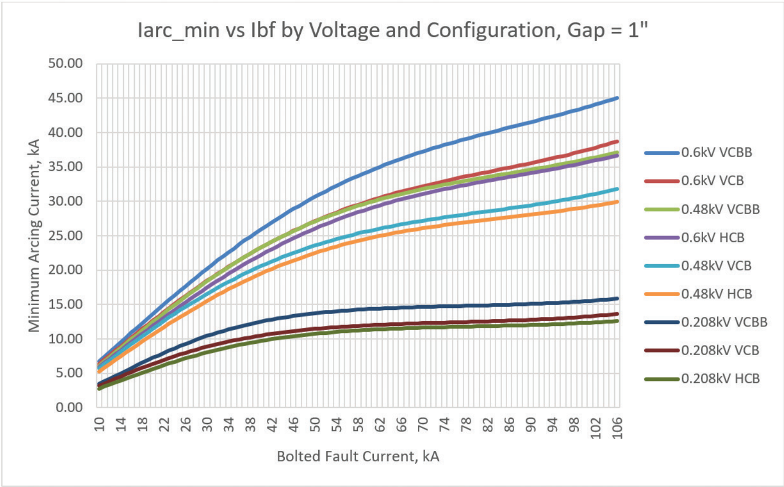

Figure 3: Minimum Arcing Current vs Bolted fault current by voltage and electrode configuration

If for whatever reason the fuse is unable to clear the circuit in the required 0.07s, one of the methods listed in the code should be employed. Methods 1 through 3 listed above would all require additional components. At a minimum, all three would require current transformers, a relay, and a device capable of opening the circuit such as shunt trip switch or contactor. Differential relaying would require two sets of current transformers to measure the difference in current in the protected zone (Figure 4a). An energy reducing maintenance switching with local status indicator would require a switch to change a trip setting to a lower level with an indicating light to show the protected area is operating at reduced energy. This switch is often keyed to keep personnel from inadvertently changing the state of the relay (Figure 4b). An active arc flash mitigation system typically consists of a specialized relay with light detection and current measurement (Figure 4c). The fourth method, an approved equivalent means allows flexibility to meet the requirement with other technologies.

EXAMPLES

Let's look at a couple of examples where 1200A or higher fuses could be applied.

For the first example, assume the application to consist of a transformer rated a 750kVA with a primary voltage of 34.5kV, secondary voltage of 480V, and 5.75% impedance (Fig 5). The area of interest will be the main distribution board at the service, with approximately 100 feet of cable between the transformer and the equipment. Electrode configuration is assumed to be vertical conductor in a box (VCB) with 1" spacing between conductors. For this application, secondary full load current would be 902 Amps and using NEC Table 450.3 the secondary fuse would be sized at a maximum of 125%, or 1200A. Since the fuse

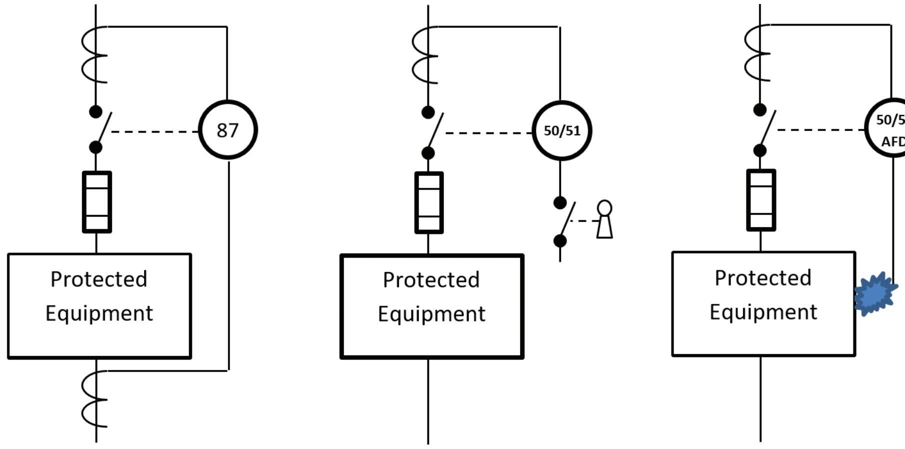

Figure 4a: Differential Relay

Figure 4b: Maintenance Relay

Figure 4c: Arc-Fault Detector

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meets the code requirement, a further evaluation is required as per NEC 240.67. Assuming a utility with 250MVA or higher available and secondary cabling of 4 x 300MCM per phase, the bolted fault current is approximately 14.1kA. Given the parameters above, the arcing current is calculated to be 9.51kA. Examining table 1 below for the Mersen A4BQ1200 fuse, a minimum of 12.8kA is needed in order to clear the circuit in 0.07s. In this case, the installation would not meet the code requirement. However, the very next step would be to examine the load study on this service. Many installations are loaded much less than their full rated currents. If this is the case, the NEC allows to fuse to the actual load. Assume that the actual load currents are less than 800A. In this case, a 1000A fuse can be used, which is below the maximum size required by the code. If this were the case, an A4BQ1000 could be used. Further analysis would show that worst case incident energy is less than 8 cal/cm² which would allow workers to use daily wear for tasks justified per NFPA70E.

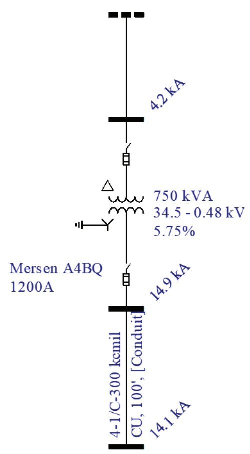

Figure 5: Example Circuit

For the second case, suppose an engineer is designing a system with a 2000kVA transformer with primary voltage of 12,470V, 480V secondary, and 5.75% impedance feeding a 3000A motor control center (Figure 6). Electrode configurations in an MCC vary from HCB in an empty bucket to VCB and VCBB in a filled bucket. For this case we assume HCB since arcing currents will be the lowest. Fuses sized for motor control centers by NEC430.94 are required to be 100% of the bus rating. Since Class L fuses are 100% rated fuses when utilized with a 100% rated switch, A4BQ3000 can be chosen.

Bolted fault currents would be 32kA for a utility with 75MVA or higher fault available and a total of 55 feet of 8x500MCM cables to the MCC. Minimum arcing current would be 19.5kA. For the A4BQ3000 fuse, currents would need to be 33.1kA or higher for a 0.07s clearing time. In this case, lowering the fuse current is not an option since it is sized to the MCC. Rather than add an active mitigation system, the engineer could split the MCC into multiple sections. NEC 230.71 allows up to six disconnecting means per service if they are grouped at one location. For this example, the MCC is split into two equal 1500A units. Now we can feed each MCC with an A4BQ1500 fuse. Due to now only needing 4x 500MCM cables per phase to each switch and MCC, the bolted fault current at each MCC will go down slightly to 30.9kA. Minimum arcing current would be 18.9kA which is above the 16.3kA required to clear the fuse in 0.07s. In fact, the available arcing current would be well within the current limiting range of the fuse and reduce the incident energy in the MCC below 1.2 cal/cm². However, there is a drawback to this arrangement. The primary fuse will need to be sized for overload protection of the transformer. If the primary fuse is undersized, it could lead to nuisance fuse openings during transformer energization. A careful analysis is warranted.

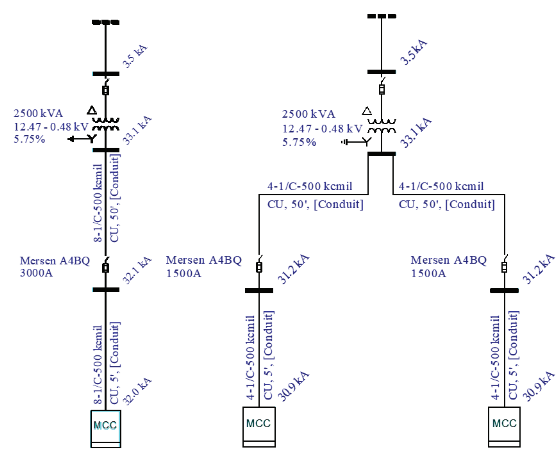

Figure 6: Example 2

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RECOMMENDATIONS

Wherever practical, down-sizing L class fuses will reduce incident energy and help meet the requirements of 240.67. Other design considerations such as splitting equipment into lower amperage sections can help to lower incident energies.

REFERENCES

- NFPA 70: National Electric Code
- IEEE Standard 551
- IEEE Standard 1584-2018
- UL Standard 248-10
- TT-AFN5 Reduce Arc Flash Energies by Reducing Fuse Amperage Rating

Fuse Ampere rating (A)	Minimum Arcing Current (kA) Required to Meet NEC 240.67		
	A4BQ	A4BY	A4BT
1200	12.8	15.4	19.3
1201	n/a	15.4	n/a
1350	14.9	16.7	n/a
1400	15.1	17.8	23.4
1500	16.3	18.3	24.8
1600	17.1	19.9	25.3
1601	n/a	19.9	n/a
1800	19.8	21.9	27.2
1900	20.8	n/a	n/a
2000	21.9	24.5	31.1
2001	n/a	24.5	n/a
2200	n/a	28.7	n/a
2500	27.7	32.7	n/a
3000	33.1	40.8	n/a
3001	n/a	40.8	n/a
3500	42.9	45.6	n/a
3800	46.1	n/a	n/a
4000	50.7	51.9	n/a
4001	n/a	51.9	n/a
4500	n/a	58.7	n/a
5000	58.5	64.9	n/a
6000	73.8	79.9	n/a

Table 1: 0.07s Clearing Currents for Mersen Fuses

CONTACT

USA
374 Merrimac Street, Newburyport, MA 01950
T 978 462 6662 | F 978 462 0181
info.nby@mersen.com

CANADA
6200 Kestrel Road, Mississauga, ON L5T 1Z1
T 905 795 0077 | F 905 795 2508
technicalservices.mis@mersen.com

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