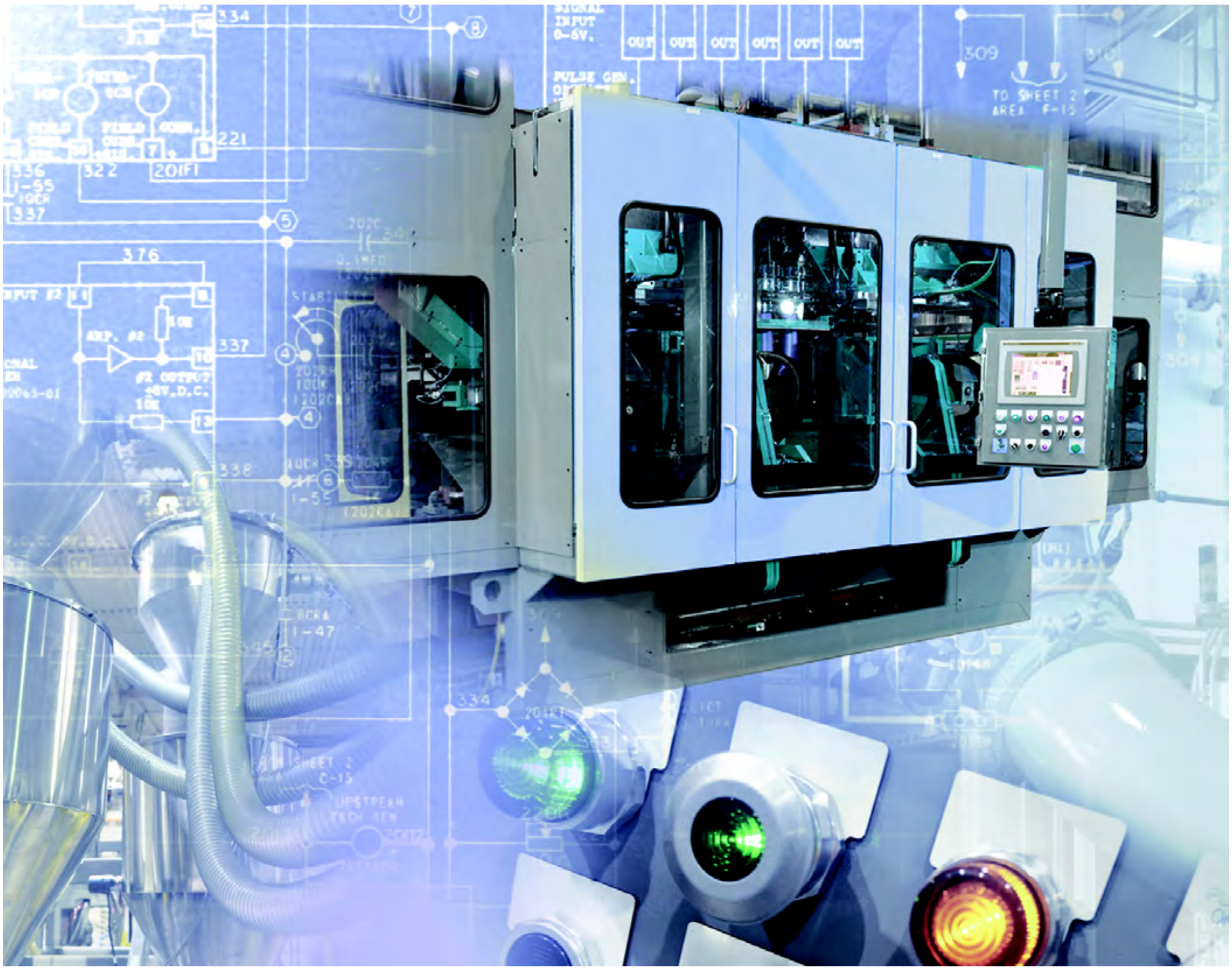
Application Profile

Allen-Bradley

Instantaneous Maintenance Mode (IMM) with Bulletin 140U Molded Case Circuit Breakers



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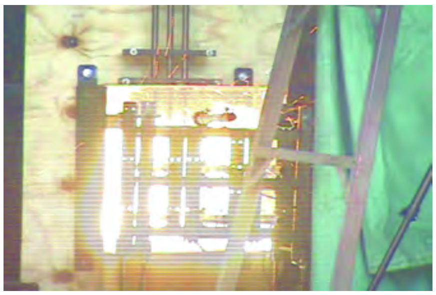
Introduction



Arc fault is a very dangerous issue that affects both machinery and people. In recent years, standards set forth by the National Fire Protection Association (NFPA) and other organizations have begun to address the danger. NFPA-70E 2012 (Standard for Electrical Safety in the Workplace), Article 100 defines an arc flash hazard as "a dangerous condition associated with the possible release of energy caused by an electric arc". Equipment damage, personal injury, and possible death can be caused by arc flash and arc blast. During both an arc flash and arc blast, the temperature, pressure, and current rise. Molten metal and shrapnel explode into the air from the panel or enclosure. Deafening sound waves, blinding light, and toxic air are other side effects. Understanding the causes of arc flash and how to mitigate the hazards are very important.

The purpose of this application profile is to illustrate the benefit of using the Instantaneous Maintenance Mode (IMM) with the Bulletin 140U Molded Case Circuit Breaker (MCCB) as a mitigating tool in the reduction of arc flash hazards. This publication will address the following:

1. Understanding arc flash causes and hazards
2. Background of standards and how the standards address the arc fault issues
3. Traditional and currently available tools that help reduce arc flashes and the associated repercussions
4. Where the IMM module fits into the whole process

Arc Flash

What is Arc Flash?

Arc flash is an electric current that passes through the air when insulation or isolation cannot contain it. The arc is either from phase to phase, phase to neutral, or phase to ground. Temperatures can reach 35 000 °F. Extreme temperatures can cause clothes to ignite or burn the skin directly. According to the NFPA-70E-2012 Annex K, the majority of hospital admissions for electrical accidents are from arc flash burns, not from electrical shock. Burn centers receive over 2000 people annually due to severe arc flash burns.

What is Arc Blast?

Arc blast is an explosive release of pressure, sound, light, and debris from an electric arc. The temperature rises when an arc is created across two phases. As the air ionizes, the copper conductor is used as fuel. Impedance of conductive plasma is much lower than air. The light intensifies and can cause temporary or permanent blindness. The expansion rates of metals, such as copper, can be a factor of 67 000 when going from a solid to a vapor. This high expansion rate can cause a dangerous energy blast. The potential danger is the release of a tremendous amount of heat energy. Debris from the blast can move at speeds of over 700 mph from the arc. Pressure can change up to 29 psi. A large sound shock wave can be produced with the thermal release, which could result in temporary or permanent deafness.

Some references to the preceding information:

- A .22 caliber bullet travels about 600 mph
- Temperature of the sun's surface is 9940 °F (5504 °C)
- Cable fire ~ 1112 °F (600 °C)
- Copper fire ~ 2012 °F (1100 °C)
- Steel fire ~ 2822 °F (1550 °C)
- A change in pressure of only 5 psi can cause 160 mph winds
- With potential noise levels over 160 dB, the ear drums could rupture

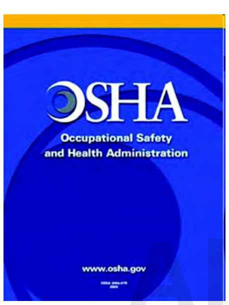
Causes of Arc Fault

- Human error
  - Accidental touching of a live conductor
  - Dropping or misplacing tools or other parts
  - Improper installation
- Mechanical
  - Closing into faulted lines
  - Loose connections
  - Mechanical/electrical dimensioning
  - Wire degradation
  - Defective cable insulation
  - Dust and impurity buildup

Duration of an Arc Fault

There are a few essential elements required to maintain the arc fault. Voltage (typically 480V and above) is needed to sustain the arc. The available short-circuit current has a major influence on the duration of the energy released in the arc. Because the vapors of the metal act as fuel, the arc keeps going until either an upstream overcurrent device clears the fault (opens the circuit), or until the fuel is depleted.

Standards History

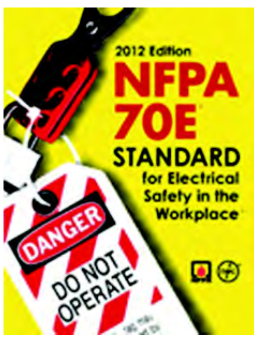


Standards that take into account the danger of arc flash have evolved during recent decades. There are many standards that pertain to arc hazards, but the primary four are discussed below.

OSHA (Occupational Safety and Health Administration) regulates the electrical safety standards for the industry. Title 29 Code of Federal Regulations (CFR) contains the **Design Safety Standards for Electrical Systems** and also **Electrical Safety-Related Work Practices Standards**. Title 29-CFR, Part 1910 Subchapter S refers to keeping workers safe around electrical equipment. OSHA requires companies to provide safe working environments. OSHA states the rules and laws in general terms. Standards and forums such as NFPA-70E,

NFPA-70-2011, National Electrical Code (NEC), and the Institute of Electrical and Electronics Engineers (IEEE) state how to accomplish them. Precautions against arc flash and other safety guidelines are required by OSHA.

One of the oldest of the standards for electrical work is the National Electrical Code. It was created in 1897, following all the developments from Thomas Edison, Charles Brush, George Westinghouse and Joseph Henry to name a few. Fourteen years later in 1911, the Electrical Committee of the NFPA took over the ownership of the responsibility of updating the NEC on a regular basis. The NEC addresses the technical specifics of the electrical system. In 2002, the NEC added Article 110.16 Flash Protection. This article discusses the need of field marking to warn of the arc flash hazards. The 1968 and 1971 versions of the NEC were used by OSHA as the sole basis of its regulations. OSHA found changing regulations difficult and the need for a new standard focused on installation, not just on employee safety, became clear.



The **Committee on Electrical Safety Requirements for Employee Workplaces** was created in January 1976 after the NFPA and OSHA were seeing a need to bridge the gap between the technical specifics of the NEC and a safe working environment for employees. In 1979, the first edition of the NFPA 70E was published and only contained Part 1 of 4 (**Installation Safety Requirements**). NFPA-70E first addressed arc flash in 1995 (Part 2 – **Safety-Related Work Practices**) with the introduction of the "arc" and the "limits of approach". The NFPA-70E is the industry's standard for electrical safety. This standard is used to determine whether or not the employer acted reasonably in protecting their workers from arc flash hazards.

Employers/employees and OSHA use the NFPA standards to get details on electrical safety requirements, including signage warning of arc flash, safe working practices, installation, and maintenance. Included in the details are the personal protection equipment (PPE) requirements and limits of approach. It is common to have identical language used in each standard, as they influence each other. To preserve the close tie of these standards, the NFPA-70E-2009 dropped Chapter 4 (**Installation Safety Requirements**) because it duplicated the NEC installation requirements and the two standards were on different revision cycles. The NFPA did not want to have conflicting or outdated information, so the chapter was eliminated.

Many changes took place in the 2012 version. "Flame-Resistant (FR)" has now been changed to "Arc-Rated (AR)", as it pertains to protective clothing throughout the standard. The level of protection from an arc has been increased in this standard. Section 110.2(D)(1)(f) addresses the need for the employer to ensure each employee is complying with the safety-related work standard. Mirror language can be found in OSHA 29 CFR 1910.269(a)(2)(iii). Section 130.1 requires either a full incident energy analysis, or the tables (130.7(C)(15) and (C)(16)) must be used. Section 130.7(C)(5) requires hearing protection within the arc flash boundary. Appropriate PPE must also be used. In addition, the provision of a safe working environment around potential hazards is the purpose of the NFPA-70E, which references the IEEE standards for calculations and other methods for arc flash.

IEEE
Advancing Technology for Humanity

The Institute of Electrical and Electronics Engineers (IEEE) Standard 1584-2002 is the most commonly used method for performing arc flash hazard calculations to determine the personal protection equipment (PPE) requirements. The IEEE as a whole provides a standards forum that provides consistent engineering practices. Methods and equations needed for arc flash incident energy analysis is stated in 1584 standard. This method is not mandated by the NFPA-70E, but is the recognized industry standard. Evaluating the time current characteristic of the upstream overcurrent is part of the process.

To summarize, OSHA makes it a law to protect the employees, while the NFPA and the IEEE standards provide the methods for complying with the law. NEC deals with the installation. OSHA points at consensus to determine whether or not an employer has taken enough precautions to protect their employees.

What Is Available

Protecting people is the most important goal of arc fault detection and mitigation. An increasing number of devices to help reduce the hazards of arc flash are being introduced to the market. These products range from optical arc flash sensing to arc resistant cabinets. In 2009 Rockwell Automation introduced ArcShield™, an Arc Resistant Motor Control Center (MCC), and in 2011 SecureConnect to help de-energze all conductors inside individual MCC buckets. These designs take into account the ability to extinguish, control, and/or prevent propagation of arc faults, while also providing additional risk mitigation features.

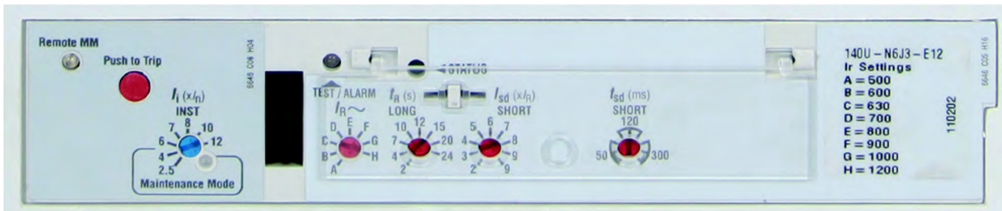
- SecureConnect™ enables operators to disconnect power from a CENTERLINE® MCC plug-in unit without opening the enclosure door. The optional remote operator also allows qualified workers to disconnect power without being inside the arc flash boundary. This feature is available on standard and CENTERLINE ArcShield MCCs.
- CENTERLINE MCCs with ArcShield helps protect workers in the event of an arc blast. ArcShield is designed with Type 2 accessibility, as defined by the IEEE C37.20.7-2007, the IEEE guide for testing internal arcing faults. Type 2 accessibility means that personnel are provided protection at the front, rear, and sides of a MCC during an arc blast.
- On the component level, the IMM module, used with the Bulletin 140U MCCB, was introduced to lower the tripping current and minimize the damage in a panel.

More information on SecureConnect and ArcShield designs can be found on the Rockwell Automation website.

IMM

The duration of the arc fault can be controlled by a faster responding current sensing device. A new way of reducing the damage from an arc fault is limiting the amount of fault current. The IMM module on an MCCB (shown here removed from the MCCB) can reduce the trip time while doing maintenance. It can provide a lower instantaneous trip setting. Adding the protection of the IMM module will help to prevent damage. Using the IMM with the Bulletin 140U MCCB as a mitigating tool can detect and react to lower level faults earlier than the standard breaker or fuse, thus helping protect equipment and potentially the life of a person.

IMPORTANT	Any brand of MCCB is only as good as the maintenance performed after it has been installed. The longer the time between maintenance of a breaker, the greater the likelihood the breaker will not perform as designed. Using publications such as ANSI/NEMA AB-4 will help keep the MCCB performing correctly.

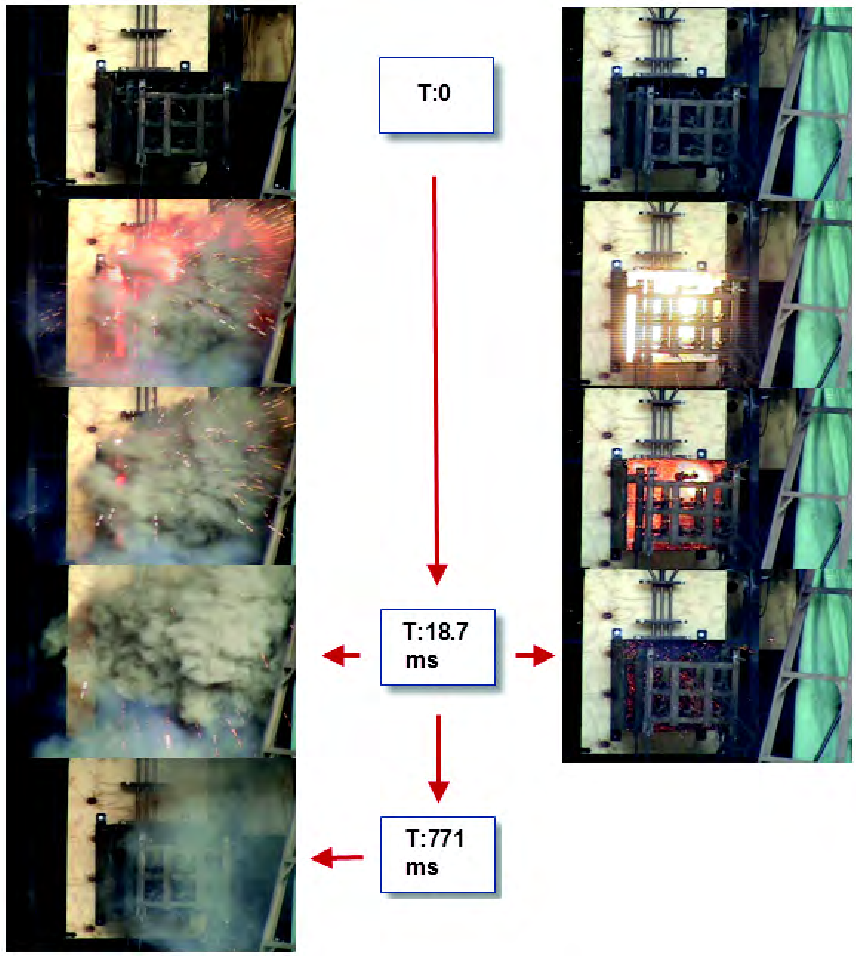


Some of the features of using the IMM are as follows:

- Reduced let-through energy under arcing fault conditions, which results in less potential damage.
- IMM provides a separate maintenance mode that is externally enabled. This could possibly allow maintenance personnel to wear less PPE with a reduction in fault hazard. The overall assessment of the panel/motor control center, etc., determines what PPE isnecessary.
- Selectable instantaneous trip settings of between 2.5…4 x the MCCB rating.
- The adjustability reduces nuisance trips.
- When an arcing fault occurs with the IMM enabled, the MCCB is designed to trip in approximately 30 ms, improving arcing fault response time.
- When not enabled, the MCCB operates as a standard MCCB.
- Ability to provide additional confirmation that the MCCB with the IMM module is in maintenance mode. A blue indicator appears in the setting window.
- A dedicated contact within the breaker closes to allow an external indication that the MCCB is in maintenance mode.

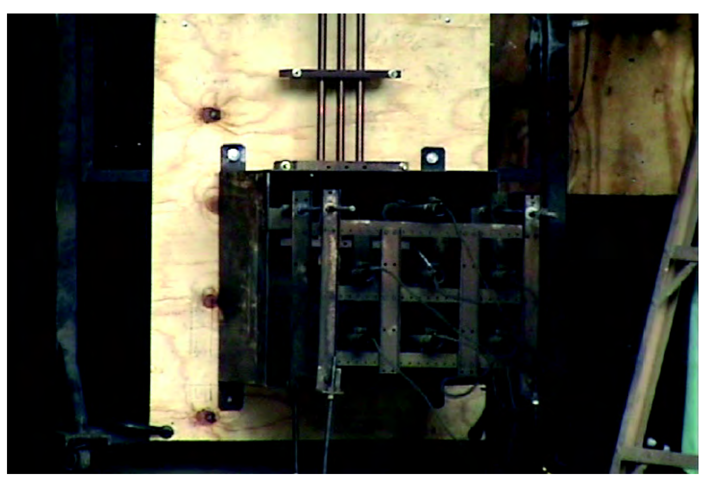
Over 2500 % Reduction in Fault Energy, 98 % Faster than not Using the IMM for Mitigating an Arc Flash

Below are actual photos of the Bulletin 140U MCCB with an IMM using the IEEE 1584 method, compared with a standard Brand X Class L 1200 A fuse in the same time base. Times shown are actual clearing times of fuses and the Bul. 140U with the IMM module.



Fuse (similar behavior with standard MCCB): BAD SCENARIO

Bul. 140U MCCB with IMM: BETTER SCENARIO



BEST SCENARIO

In this test, the IMM is mitigating the arc fault energy. The fault is more controlled and reduces the damage; the standard fuse is slower to react and more damage is caused. As you can see from the pictures, when the arc has been extinguished with the IMM, the fuse continues to allow the arc to continue. The longer duration allows more current and damage to continue.

The best scenario is to have no arc at all. In an ideal situation, nothing goes wrong. In this scenario, the better protection is provided by the IMM module with the MCCB, greatly reducing the amount of current to the arc flash.

A less than ideal scenario is to have less-effective protection provided by using a standard fuse or MCCB and waiting until the normal trip curve is reached and the overcurrent device opens the circuit.

Here is the data for the preceding test:

Following the IEEE 1584 calculation standards, the results above were obtained by simulating an arcing fault of 9800 A RMS at 480V AC with the 1200 A MCCB and 1200 A fuses.

Brand X Class L 1200 A fuses

- Fuse tripped at 771 ms
- 15.7 kA peak
- 17.89 calories/cm^2 (74.90 joules/cm^2)

1200 A MCCB with IMM

- Maintenance Mode enabled, IR = 1220 A
- Maintenance Mode ON
  - Breaker tripped at 18.7 ms
- 16.8 kA peak
- 0.71 calories/cm^2 (2.97 joules/cm^2)

Comparing the joules/cm^2 results in the test, the damage caused by the arc flash in this test was reduced by a factor greater than 25 times using the IMM module with the Bul. 140U MCCB.

While this test was accomplished in a lab environment, and is only a one-time test, the actual arc flash calculations take into account a variety of factors within a specific application.

With the results above, based on the NFPA 70E risk category, the following might be a possibility. The following chart only shows the minimal clothing, but does not show other required equipment such AR face shields or arc flash suit hoods, arc-rated hard hat liners, safety glasses/goggles, hard hats, hearing protection, boots, tools and appropriate rated gloves. A service person may only need to wear untreated cotton clothing with the combination of the IMM module and the MCCB, plus any other additional required safety equipment. With the standard fuse or MCCB, based on the findings of this one test, the service person would have to wear AR shirt, pants, and coveralls. Of course, in addition to the equipment calculation, other factors, such as training and work procedures, installation, and maintenance conditions all play a role in the selection of appropriate PPE for a given work site.

MCCB with IMM

	Incident Energy From (cal/cm²)	Incident Energy To (cal/cm²)	Hazard Risk Category	Clothing Description	Clothing Layers	Required Minimum Arc Rating of PPE (cal/cm²)	Notes
1	0.0	1.2	0	Untreated Cotton	1	N/A	MCCB with IMM
2	1.2	4.0	1	AR Shirts & Pants	1	4.0	
3	4.0	8.0	2	Cotton Underwear + AR Shirt & Pants	1 or 2	8.0	
4	8.0	25.0	3	Cotton Underwear + AR Shirt & Pants + AR Coverall	2 or 3	25.0	Standard Class L Fuse
5	25.0	40.0	4	Cotton Underwear + AR Shirt & Pants + Multi-layer Flashsuit	3 or more	40.0	

Fuse or MCCB without IMM

NOTE: A complete arc flash assessment of the panel or MCC would have to be completed to arrive at the appropriate hazard risk category and appropriate PPE for the given circumstance. The IMM does not eliminate the arc flash hazard, but can help mitigate arc energy levels.

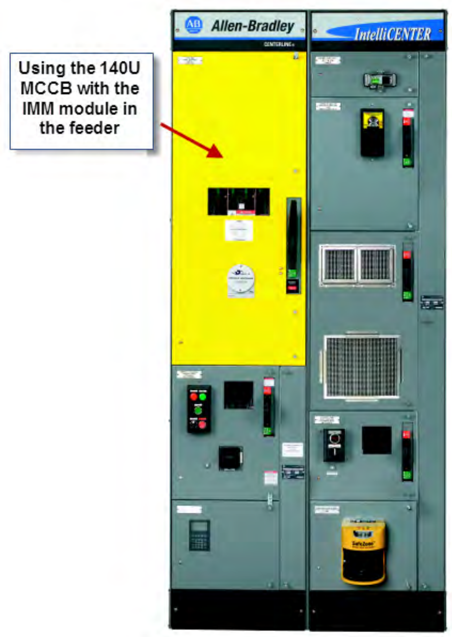
An example of the appropriate clothing based on Hazard Risk Category would be the following.

Although the MCCB is an instantaneous trip breaker, NEC 2011 article 240.87(3) Noninstantaneous Trip, has an informational note directed at an energy-reducing maintenance switch to reduce the clearing time when a worker is within the arc-flash boundary doing maintenance. After the completion of the maintenance, the breaker is put back to normal. Essentially, that is what the IMM module is trying to accomplish. The IMM is attempting to reduce the amount of energy while maintenance is being accomplished.

IMM Placement Suggestions

Because the load side of the Bul. 140U MCCB with the IMM module will provide a lower fault current, safety is increased for the personnel working around the hazard. Knowing that maintenance is performed on or near the panel/MCC, two possible placement scenarios for the IMM would be in the feeder bucket of an MCC or mounted outside of/feeding a control panel. Remotely setting the IMM enhances the safety.

Putting the MCCB with the IMM module in maintenance mode as the feeder could potentially reduce arc fault downstream of the breaker. The most dangerous part is the line feeding the MCCB and that specific MCC bucket itself.



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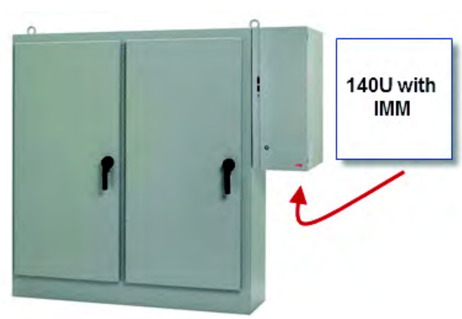
The other suggestion would be to have the MCCB with the IMM module mounted in a separate enclosure feeding the control panel or MCC, for example, putting the MCCB with the IMM module in an appropriate disconnect enclosure (shown below). When in maintenance mode, the power being fed to the main panel would be more protected and potentially decrease the amount of arc flash having a lower trip level. The overcurrent protection provided from the IMM will decrease the amount of damaging current that would be allowed to generate with standard fuses and breakers. See the details in the following curves.



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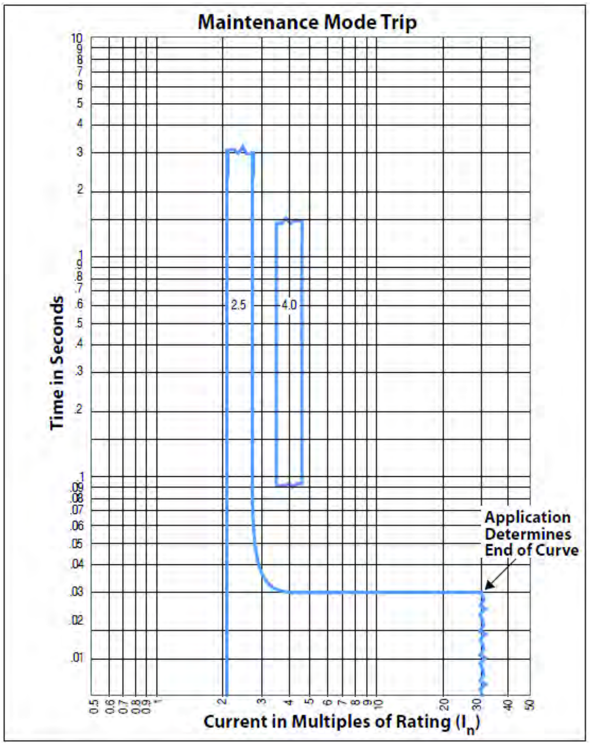
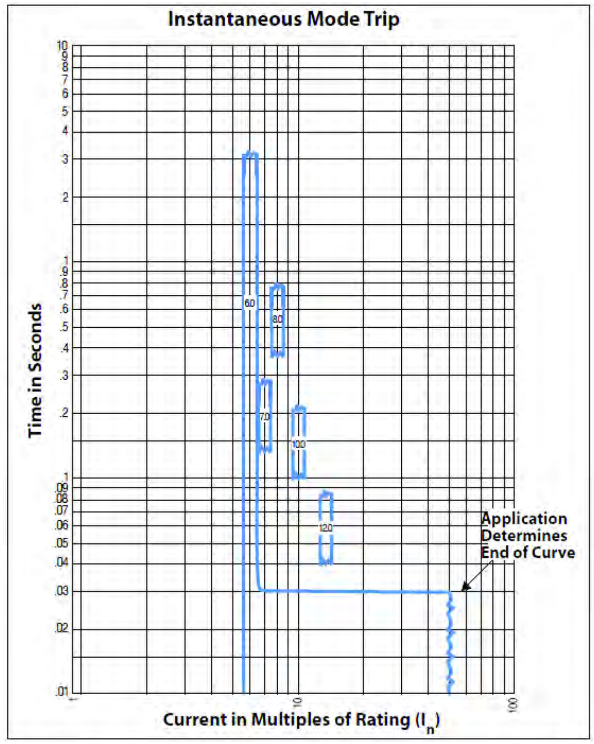
Trip Curves

Arcing fault levels are typically less than 10 000 A. A main feeder breaker, such as a 1200 A MCCB or a fuse, may treat this condition as a high overload and may take longer to react. Looking at this curve for a 1200 A breaker, an arcing fault would be best served by a 2.5x setting.

Below are the trip curves when using the IMM module, illustrating that a current level passing the current setting on the IMM module will cause the module to open the circuit in 30 ms.





- In order for these curves to apply, the maintenance mode feature must be enabled via the maintenance mode switch.
- The end of the curve is determined by the interrupt rating of the circuit breaker.
- Total clearing times shown include the: response times of the trip unit, breaker opening, and interruption of the current.
- Nominal values (pickup) (tolerance is ±15%): 2.5 x I_n, 4 x I_n, 6 x I_n, 7 x I_n, 8 x I_n, 10 x I_n
- These curves are comprehensive for the complete family of L-Frame electronic breakers, including all frame sizes, ratings, and constructions. The total clearing times shown are conservative and consider the maximum response times of the trip unit, the circuit breaker opening, and the interruption of the current in worst-case conditions (e.g., maximum rated voltages, single-phase interruption, and minimum power factor). Faster clearing times are possible depending on the specific system conditions.

Conclusion

An arc fault is a serious situation that should not be taken lightly. Proper evaluation and assessment are essential to improving safety for people working around 3-phase power in panels and in MCCs. Using the IMM module with the MCCB is a useful tool to mitigate an arc hazard and reduce the risk of a person getting hurt.

Remember that the IMM module **CANNOT** eliminate arc faults, but can potentially reduce the amount of damage by reacting more quickly. The proper safety evaluation of the system determines the ultimate safety. The full responsibility of the evaluation and implementation of the safety of the system and personnel in question relies on the owner/end user.

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If you experience a problem within the first 24 hours of installation, review the information that is contained in this manual. You can contact Customer Support for initial help in getting your product up and running.

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