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Arc-resistant Motor Control Centers

UL validates testing of arc-resistant motor control centers to help ensure protective features perform as designed

White Paper

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Summary
This paper describes the dangers of arc flashes in operating industrial electrical equipment. While important safety standards have evolved over time to help mitigate the injuries and damage caused by arc faults, tens of thousands of accidents still occur each year involving the wide range of electrical gear present in a typical industrial environment. Personal Protective Equipment (PPE) can help avoid or reduce the severity of injuries, and its widespread use should be seen as a top priority for industrial users. Electrical equipment manufacturers, including Siemens, have incorporated advanced technology and strengthened structural design to improve the safety potential of equipment such as Switchgear and Motor Control Centers (MCC). Standards for performance-testing their arc-resistant features have so far only been defined for switchgear, but manufacturers are using those standards for testing arc- resistant MCCs. Siemens is the first manufacturer in the industry to have taken the vital step to have Underwriter Laboratories (UL) observe and validate the testing of its arc-resistant tiastar™ MCC model. Siemens wants customers to know not only that the tiastar arc-resistant MCC successfully met the testing criteria required by the standards, but also that a qualified, independent third-party has confirmed this satisfactory performance.

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Arc flashes occur when an electric current passes through the air between two conducting metals – an arc fault. Almost instantly, an arc can superheat the air around it to a temperature up to 35,000 degrees Fahrenheit, about four times the sun's surface temperature. This extreme heat ionizes all nearby materials – copper, insulation, metal enclosures – creating explosive gaseous plasma as those materials expand many thousands of times their solid volumes. Under these conditions, for example, the copper changes to plasma, with a volume about 67,000 times that of its solid form. Or, stated differently, each cubic inch of copper converts to almost 39 cubic feet of copper vapor.

Arc faults are different from bolted faults on the load terminals of standard, metal-enclosed switchgear. Switchgear equipment is designed to withstand bolted fault currents until circuit breakers or fuses interrupt the current flow. When a bolted fault occurs, the voltage at the point of the fault is virtually zero and the total fault energy gets dissipated into the entire power system, while any arcs are contained and cooled within the circuit breaker's interrupters or the fuses.

By contrast, the incident energy of an arcing fault is much more difficult to contain and is concentrated almost entirely at the fault location. Its flash can spread hot, ionized plasma over a distance of 20 feet or more with significant accompanying sound and shock waves. This explosive force can cause significant injury to individuals in the immediate vicinity, including death.

Arc flashes are responsible for about 80 percent of electrical accidents in the U.S. each year[1]. In human terms, they are responsible for hundreds of deaths, thousands of serious injuries, and significant lost work time every year[2].

Evolving safety standards

Arc faults have numerous causes that fall into two categories. One comprises intrusive environmental factors such as cabinet moisture, insulation failures, over-voltage, corroded terminals, dust, dirt and animals, including rodents and snakes. The second category is human error such as improper work procedures, misplaced tools, loose connections, and inadvertent contact with energized components. (Note that Siemens strongly advises never to open MCC doors without de-energizing components.)Inadequate maintenance practices are often contributors to both categories. As the number of arc flash incidents suggest, they are a paramount electrical safety concern, for which a range of industry safety standards have evolved.

In North America, the main safety standard for working with electrical equipment is the National Fire Protection Association (NFPA) 70E: Standard for Electrical Safety in the Workplace. It addresses electrical safety requirements for workplaces to safeguard employees during such activities as the installation, operation, maintenance and decommissioning of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways in public and private facilities. Under NPFA 70E, employees whose work may potentially expose them to arc flashes are required to wear arc-rated protective clothing. This clothing is made of fabric that provides thermal insulation and is also self-extinguishing to minimize burns, as prescribed by ASTM F 1506-08 Standard Performance Specification for Wearing Apparel for use by Electrical Workers to Momentary Electric Arc and Related Thermal Hazards.

The Occupational Safety & Health Administration (OSHA), in turn, has said that clothing conforming to ASTM 1506 complies with OSHA 29 CFR 1910.269 Electrical Power Generation, Transmission and Distribution directive regarding the wearing of protective clothing that will not contribute to severity of burns. Protective clothing is a primary part of an arc flash injury mitigation known as Personal Protective Equipment (PPE), which can also includes other equipment such as a helmet or headgear, face shield, gloves, and ear protection.

The amount of PPE required is dependent on the calculated arc flash incident energy on a worker's body, which depends on arc current, system voltage and duration and distance from the arc. NFPA 70E defines five categories of PPE, each category providing progressively greater protection against higher and higher energy levels. The energy levels correspond to specified "boundaries" that define the degree of danger and required protection. The highest tops out at 40 calories/cm2 skin exposure requiring the highest levels of PPE (compared to a curable second-degree burn caused by 1.2 calories/cm2 of skin exposure). When the incident energy level goes beyond 40 calories/cm2, it becomes exceedingly difficult to provide any practical means of PPE.

Safer equipment, safer environments

Of course, the simplest and most effective measure to prevent an arc flash is to shut off all power to the equipment to be worked on. Siemens advises that individuals should only work on MCCs or other electrical equipment after all power to the equipment has been turned off. In fact, this is often done through mandated lock-out protocols. Arc flash prevention, safety training and PPE can only go so far in keeping workers out of harm's way should an arc fault occur. Although PPE can provide protection from an arc flash, it still cannot protect an operator from being struck by enclosure doors blown off or open from an arc flash – or from fragments ejected from a disintegrating enclosure.

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That is why manufacturers have taken steps to design arc flash hazard mitigation and arc-resistant features into their electrical equipment, Siemens included. These features are designed to complement each other. Arc flash mitigation features aim:
- To keep the workers beyond the Arc Flash Boundary or,
- To shorten the arc flash duration

Arc resistant equipment's goal is to make sure that, in the event of an arc flash when the MCC's doors are closed and latched, the equipment will contain the explosion, directing the arc blast, including its heat, plasma and pressure, away from workers.

In addition, the industry has codified the performance testing of arc-resistant features according to the rigorous requirements set forth in the IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults (ANSI/IEEE C37.20.7 - 2007).

Taking Siemens type WL Low Voltage Switchgear as an example, arc-resistant features can include:
- ANSI/IEEE Type 2 arc resistance to protect personnel at the front, back and sides of the equipment (Type 1 arc resistant protection only applies to the front of the cabinet)
- UL Listed, performance tested and classified as arc resistant per ANSI/IEEE C37.20.7
- Reinforced enclosure to withstand pressure from internal arcing faults
- Internal venting system with pressure dams and pressure vents to channel the flow of arc fault gases and vent these gases out the top of the gear and away from personnel
- Reinforced front with gaskets plus doors with extra hinges and stronger latching systems
- One piece circuit breaker doors with insert panels for control devices such as fuses, indicating lights and circuit breaker control switches when required
- Reinforced bolted rear covers
- Insulated bus bar system
- Shutters in circuit breaker compartments
- Sill channel with integrated arc plenum
- No configuration restrictions
- Suitable for solidly grounded or resistance-grounded configurations.

Siemens arc-resistant tiastar: the first UL test-validated MCC

Soon the ANSI/IEEE C37.20.7 standard is expected to evolve further and to include specifications for performance-testing arc resistance of specially designed MCCs. Like arc-resistant switchgear, arc-resistant MCCs incorporate many of the features above to minimize the duration of an arc fault and, with doors closed and properly latched, redirect its flash away from personnel, such as:
- ANSI/IEEE Type 2 arc resistance to protect personnel at the front, back and sides of the equipment (Type 1 arc resistant protection only applies to the front of the cabinet)
- Reinforced enclosure to withstand pressure from internal arcing faults
- Internal venting system with pressure vents to channel the flow of arc fault gases and vent these gases out the top of the gear and away from personnel
- Reinforced front with doors with extra hinges and stronger latching systems
- Reinforced bolted rear covers
- Insulated bus bar system
- Automatic Shutters in plug-in unit compartments
- No configuration restrictions

Since 2009, Siemens has offered arc flash hazard mitigation features in its tiastar MCC. Since then Siemens has taken further steps to strengthen the tiastar MCC cabinet to provide and arc-resistant product with Type 2 accessibility, same as its switchgear, along with all its previous arc flash hazard mitigation features. The tiastar arc-resistant MCC is the market's first MCC tested to ANSI/IEEE C37.20.7, with representatives of Underwriters Laboratories, Inc. (UL), present to observe and validate the testing procedures. This is important because while other manufacturers claim to have performance-tested to this standard, with tiastar arc-resistant MCC, Siemens is the first and currently the only manufacturer with its testing witnessed by a qualified third party.

Specifically, UL validated that the Siemens arc-resistant tiastar MCC model successfully met the five criteria listed in ANSI/IEEE Std C37.20.7-2007 as follow:

Criterion 1:
That properly latched or secured doors, covers, and so on, do not open. Bowing or other distortion is permitted provided no part comes as far as the position of the indicator mounting racks or walls (whichever is closest) on any assessed surface.

To extend the acceptance criterion to an installation mounted closer to the wall than tested, two additional conditions shall be met: the permanent deformation is less than the intended distance to the wall; and exhausting gases are not directed to the wall.

The Siemens tiastar arc-resistant model is the industry's first MCC with its testing validated by Underwriters Laboratories Inc. (UL).

Criterion 2:
No fragmentation of the enclosure occurs within the time specified for the test. The ejection of small parts, up to a individual mass of 60 g, from any assessed external surface above a height of two meters and from any external surface not under assessment, is accepted. No restriction is placed on the number of parts allowed to eject.

Criterion 3:
Assessment of burn-through: It is assumed that any openings in the switchgear caused by direct contact with an arc will also ignite an indicator mounted outside of the switchgear at that same point. Since it is not possible to cover the entire area under assessment with indicators, any opening in the area under assessment that results from direct contact with an arc is considered cause for failure. Openings above the indicator mounting rack height (two meters) that do not cause ignition of the horizontally mounted indicators are ignored.

- Accessibility Type 1: That arcing does not cause holes in the freely accessible front of the enclosure.
- Accessibility Type 2: That arcing does not cause holes in the freely accessible front, sides and rear of the enclosure.

Criterion 4:
That no indicators ignite as a result of escaping gases. Indicators ignited as a result of the burning of paint or labels, glowing particles, and so on, are excluded from this assessment. High speed movies or video may be used to evaluate the cause of indicator ignition. Holes in horizontally mounted indicators caused by particles that do not ignite the indicator are ignored. Surface discoloration or charring that does not result in glowing or flaming of the indicator cloth is allowed. Any indicator cloth with surface discoloration or charring shall be replaced with new cloth before additional testing.

Criterion 5:
That all the grounding connections remain effective.

Other safety-engineered innovations:
Siemens has pioneered many innovations to increase the protection its electrical equipment can provide against arc flash injuries. Among them are:

• Dynamic Arc Flash Sentry (DAS)
This is a patented feature available in both Siemens MCCs and type WL Low Voltage Switchgear.

In brief, a Siemens tiastar MCC incorporates a Siemens type WL Main circuit breaker to provide two trip level settings. In normal mode, trip coordination (selectivity) is

optimized for operational efficiency and reduced nuisance tripping. The second setting, a maintenance and repair mode, is designed to lower arc flash energy using the WL circuit breaker's instantaneous trip function.

As an example, the first setting would have Category 3 hazard/risk potential per NFPA 70E definitions, while the second would have Category 0 hazard/risk potential. DAS effectively flips the equipment's priority from operational optimization to worker protection.

Facilities can install automated triggers, such as pressure sensitive floor pads, motion sensors, key locks or lasers, which indicate workers' presence and instantly switch to the safer second, more protective setting.

Considering the previous example, while the second setting's Category 0 hazard/risk potential can still injure workers, that potential is significantly less and the worker can use less cumbersome PPE to get their jobs done more quickly and easily. In addition, the distance from the equipment to the Category 0 hazard boundary is much less, so workers performing nearby tasks, even sweeping the floor, are better protected from an arc- flash incident.

• Smart MCC Technology with PROFIBUS DP
With advances in technology, especially remote sensors and network communications, Siemens offers "Smart MCC" control. This enables technicians to perform many functions at a safe distance in another room from a PC or even a handheld device. Meter readings, resetting trip units and many other monitor and control tasks no longer require a worker to visit the electrical equipment room.

Conclusion
Arc flashes present a serious safety risk. While the best protection is prevention by enforcing strict safety rules, mandate proper maintenance, and support that with regular safety training, advances in technology have enabled electrical equipment manufacturers such as Siemens the means to design and engineer much more arc-resistant safety features into their products and systems such as switchgear and MCCs. While standards continue to evolve, they inherently follow these kinds of innovations. Nonetheless the proper performance testing of new and innovative arc-resistant safety features cannot await standards. At the same time it is important that the application testing of new safety features be validated by a qualified third party like the UL to ensure that the safety features work as intended and to prevent tragic accidents.

References
1) Bureau of Labor Statistics
2) Census of Fatal Occupational Injuries

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