REDUCTION OF ARC-FLASH HAZARDS IN LOW VOLTAGE MOTOR CONTROL ASSEMBLIES

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ABSTRACT

This paper introduces the concept of reducing the Arc-Flash hazard in low voltage motor control assemblies.

The construction requirements and feature set will be identified and discussed. This is particularly important on use and maintenance of equipment in facilities.

Arc-flash test procedures and results will be discussed. Testing includes the requirements to prevent an arc-flash hazard when using low voltage motor control assemblies. The test results will demonstrate the strengths of the new enhanced safety benefits and a marked reduction in Arc Flash levels. This results in improvements for low voltage motor control assemblies' startup, operation, and maintenance procedures, including reduction in Personnel Protective Equipment (PPE).

Future applications include developing improved low voltage motor control assembly diagnostic features for externally monitoring and analyzing motor current and voltage dynamics, plus providing a test position for safe access to allow for adjustment of the overload and breaker settings.

INTRODUCTION

An arc flash incident is defined as an enormous amount of concentrated radiant energy that explodes outward from electrical equipment, creating pressure waves that can damage a person's hearing; a high-intensity flash that can damage their eyesight; and a super-heated ball of gas that can severely burn a worker's body and melt metal.

Before starting out employing this Reduction of Arc Flash hazards, priorities must be set, such as:

- Has an Arc-Flash Study been done?
- Has the equipment been tested properly?
- How can I reduce the total installed cost and still provide better arc-flash protection?
- What feature sets are required to reduce arc-flash hazards?
- Can the hazard be completely removed? For example, removing all power prior to work.

Low Voltage Motor Control Centers have become a cost-effective way to package electrical distribution, automation, and centralized wiring in a single package. This single package provides a convenient, easy way to access multiple types of equipment. Restriction of personnel to access MCC's reduces the purpose of the MCC's inherit value.

Multiple factors must be taken into account to evaluate the specific arc flash energy available, such as the site's available flash energy hazard, Safety training, and Safety Program (Reference NFPA70E).

The total installed cost of MCC's shall be discussed; including arc flash test results. These results will show the construction requirements and feature set that will reduce the impact of arc flash hazards – both on personnel and equipment.

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NFPA70E Requirements

The driving force behind including enhanced arc-flash requirements is derived from changes in NFPA 70E driving customers towards equipment that provides a higher level of safety. NEC section 110.16 states "Switchboards, panel boards, industrial control panels, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential arc flash hazards. The marking shall be clearly visible to qualified persons before examination, adjustment, servicing or maintenance of the equipment."

"An arc-flash hazard occurs when electrical insulation or isolation between conductors is broken or can no longer withstand the applied voltage. The thermal temperature of an explosion can reach more than 5000 degrees." (REF 1)

The True Cost of High Quality Electrical Equipment and Installations

A very common question asked of an electrical project engineer is: "why do you always want to purchase gold plated equipment?" The answer to that question is: "because the very best equipment is actually the lowest total installed cost equipment."

To help substantiate this statement, a major oil company hired a key engineering contractor to determine what each major system of a project really costs. The engineering contractor researched its database of previously completed projects for both commercial and industrial projects that they had designed during the past 10 years. (REF 2) The database covered commercial installations including projects such as shopping malls and hotels and heavy industrial installations such as paper mills, and refineries. Some of the highlights of the electrical costs uncovered by the report are:

1. For the main power delivery system, either in commercial or industrial installations, the average installation costs of the equipment ranged from 2 to 10 times the cost of the equipment itself.
2. For commercial instillations, the equipment costs ranged from about ½% to 3% of the entire project cost.
3. For industrial installations, the equipment costs ranged from 3% to 5% of the entire project cost.
4. These costs were based on the assumption that the project was an entire hotel, shopping mall or refinery process unit, not a simple addition to an existing installation.
5. Most industrial expansion projects carry a contingency allowance of at least 25% of the entire project cost to cover unknowns that occur during the design and construction process.

The above data coupled with the very strong emphasis on safety, the growing understanding among facility owners that one unreliable system can severely limit the availability of all other systems and the increasing realization that project justification must cover the entire cost of ownership not just first cost, now gives the electrical system designer many new options. As the above cost data demonstrates, if the cost of the main electrical equipment doubles or even triples, the cost impact on the entire project is small because the electrical equipment portion of a typical project is a small percentage of the total project cost.
This additional cost can be easily covered by the project contingency allowance. Installation costs, which are usually larger than the equipment costs, will remain about the same. As a result, doubling or tripling the equipment costs, for safer, more reliable and better quality equipment will still have minimal impact on the entire project cost.

In light of the true costs of electrical equipment, and the governmental mandate to reduce the risk to electrical workers, electrical equipment manufacturers are now offering much safer electrical equipment, some of which will be discussed in this paper. In addition to being able to get safer, better quality equipment, the electrical system designer can further enhance the safety and reliability of the power delivery system by using more innovative equipment arrangements. As an example, a redundant power system, such as Figure 1, when built with arc confining or arc resistant equipment will allow entire sections of equipment to be maintained deenergized without an entire system outage.

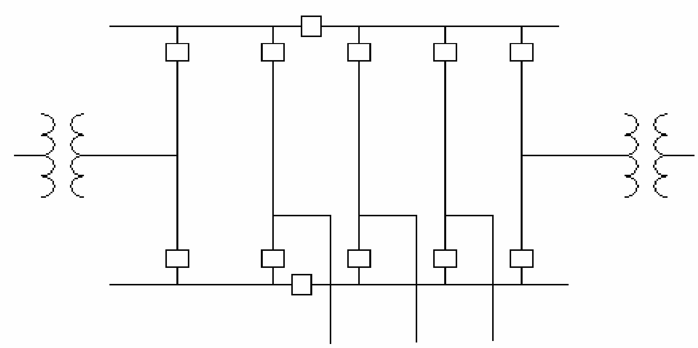

Figure 1. A double bus, double breaker, double supply equipment arrangement

ARC-FLASH Calculation

IEEE 1584 – Guide for performing arc-flash hazards calculation clarifies how to "numerically quantify the arc flash incident energy and arc flash hazard distances" (REF 3) requirements for equipment. Arc-Flash Calculations are performed to ensure proper PPE is used for work on a specific piece of electrical equipment.

“This is the amount of thermal incident energy to which the worker's face and chest could be exposed at working distance during an electrical arc event. Incident energy is measured in joules per centimeter squared (J/cm2) or in calories/cm2 (5 J/cm2 = 1.2 cal/cm2) . Incident energy is calculated using variables such as available fault current, system voltage, expected arcing fault duration and the worker's distance from the arc. The data obtained from the calculations is used to select the appropriate flame resistant (FR) PPE.” (REF 4)

IEEE 1683 is working on a Draft Standard for Motor Control Centers Rated up to 1000 Volts with Requirements Intended to Reduce Injuries and Improve Reliability. This standard will be useful to identify features that will mitigate an arc flash occurring in low voltage equipment.

ARC-FLASH TESTING

Arc Flash risk factors within a MCC lineup are generally associated with the modular design of the MCC interchangeable bucket (or unit), which are configured to house a whole range of starters and feeders. During a typical MCC lineup maintenance or troubleshooting event a bucket may be removed and plugged in with MCC energized, this requires the full PPE protection to be worn.

Particular risk concern is the primary connection points know as “stab” which consists of a moveable bucket - connector that engages a vertical bus in the MCC section. The connection is made during the removal and plugging in of the bucket at 480/600Vac levels with the MCC door open.

Arc-Flash Testing was performed in September 2006. The testing comprised of creating an arc flash incident by placing an 18AWG bare copper wire across the three phases. The available short circuit was limited to 100kA, 480V for duration of 3-cycles (50 milliseconds).

Results of MCC Arc Flash Tests – 100kA, 480V 3 phase for 3 cycles			
	MCC Status	Incident Energy	Arc current
Test 1a	MCC door closed	0.1 cal/cm2	25.1 kA peak
Test 2a	MCC door open	0.7 cal/cm2	29.64 kA peak
Test 3	No bucket, door open	3.3 cal/cm2	31.44 kA peak
Test 1b	MCC door closed	0.3 cal/cm2	36.4 kA peak
Test 2b	MCC door open	0.8 cal/cm2	38.22 kA peak

Table 1: Results of Arc flash tests

The worst-case scenarios are the MCC section with the door open – with or without the bucket (Tests 2 & 3). These test results indicate that PPE is required when the door is open during servicing, or when inserting/removing MCC buckets.

Risk Mitigation
There are several solutions available that will help mitigate the dangers of MCC Arc Flash severity levels:

- Insulated vertical and horizontal bus, with durable arc resistant systems
- Using a MCC main breaker with an Arc Flash reduction maintenance switch to reduce arcing fault clearing time to a minimum.
- A MCC high speed ground fault protection system configured to detect arcing faults with the MCC.
- A Reduced Arc Flash hazard MCC should have the minimum enhanced operational safety features:
    1. Bucket insertion completed without engaging bus, with appropriate PPE.
    2. Bucket stabs can remotely engage the vertical bus from a safe distance with bucket door closed, with minimum PPE.
    3. Bucket main disconnect is interlocked OFF during insertion or removal.
- Performing the operational maintenance from behind a dead front will significantly decrease the exposure to Arc Flash. The sheet steel MCC enclosure being more akin to a metal clad switchgear lineup.
- Enhanced safety diagnostic features, which allow access to voltage test points.
- A bucket test position that allow for safer access to the control circuit components, as Stab connections are isolated from the 480/600Vac bus system.
- Finger safe IP20 protection on live parts.
- 24Vdc control power should be used whenever possible.

The Goal is to minimize personnel exposure to the arc flash incident energy by applying the above solutions into a modern MCC configuration, minimizing arc flash energy levels. Note: 1.2 cal/cm2 max. (Hazard category 0).

MCC operational and maintenance - comprehensive improvements are obtainable through simple, clear safety procedures together with solution recommended above.

Figure 2: Test 1b: MCC Door closed

CONSTRUCTION REQUIREMENTS

Industrial facility managers want the ability mark enclosures based on the potential of an arc-flash hazard. They have identified the top ten requirements for Arc-Flash reduction in motor control center applications.

The top 10 List was compiled from interviewing over 100 customers and compiling the results into a comprehensive list of features. The study lasted approximately 8 months and included multiple market segment customers. The Quality Functional Deployment was used to mathematically weigh the most important features against the features required. The following table (Table 2) indicates the top 10 most important features to be included for arc-reduction in low voltage motor control assemblies.

Top 10 List

Feature	Definition
Component Rejection features	Ensure compatible components are used as a system.
Voltage Test Points	Provide means of testing for presence of voltage outside the unit
Correctly applied torque to electrical joint connections	Provide capability of ensuring all electrical joints have been correctly torqued.
IP20 - Finger safe	Prevent exposure of live parts
External Voltage Indication	Provide voltage indication on outside of unit.
Proper Component Selection	Ensure properly rated components are used in the system.
Labyrinth Bus shutters	Provide isolation of bus with shutters wherever possible
Remote Racking Mechanism	Provide capability of racking the unit in/out outside of the arc-flash boundary
Correct Instruction Materials	Provide correct and adequate instruction material
Use Current limiting Interrupters	Fuses and High interrupting breakers shall be used

Table 2: The "Top 10 List" identifies the feature set to reduce the possibility of arc-flash incidents and injuries.

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FEATURE SET

The motor control center should be designed to minimize the arc-flash hazard. Using the "Top-Ten List" (Table 2); Individual features should be incorporated into the equipment to work together as a system to mitigate the risks associated with arc-flash hazards. Each individual feature is identified with appropriate requirements

Based on Table 2, some features can be incorporated together to address multiple issues. For example, component rejection features, Proper Component Selection, IP20 finger safe, and using current limiting interrupters are similar. This similarity allows users to address four of the top 10 issues by selecting correct components to reduce arc flash hazards.

Voltage Test Points are important to verify the presence or lack of voltage prior to opening any bucket door. External Voltage Indication should include positive position indicators and provide the capability to perform voltage checks, motor insulation checks, and phase sequence checks. The voltage test points should be accessible outside the bucket dead front.

Overall MCC robustness addresses two of the primary bus feature requirements from Table 2. With labyrinth insulation and shutters for vertical bus, Vertical bus shroud, insulated horizontal bus and correctly applied torque to all bus connections and wire terminal points. Enhanced bus withstand ratings should be considered, such as 150ka bus at 3 cycle and 6 cycle withstand; 100ka bus at 1 second withstand ratings.

A minimum 3-position indication should be used to mitigate the risks of arc-flash hazards when working on low voltage motor control assemblies. These positions should be Connected-Test-Withdrawn. "Connected" provides primary power and control power connected. "Test" provides primary power isolated and control power available. "Withdrawn" isolates primary power and control power.

Remote connectivity capability – with door closed – is one solution to provide a safe distance between the operator and a potential arc flash hazard. This feature is discussed in depth in the next section.

REMOTE CONNECTIVITY

One of the most important features to prevent arc-flash injuries is remote connectivity. This allows the operator to remain outside of the arc-flash boundary while stabbing the unit on/off the vertical bus.

The remote connectivity feature allows indication of connection to the primary voltage source from the outside of the unit. Remote connectivity also provides ease of connecting stabs to the bus with little insertion force required.

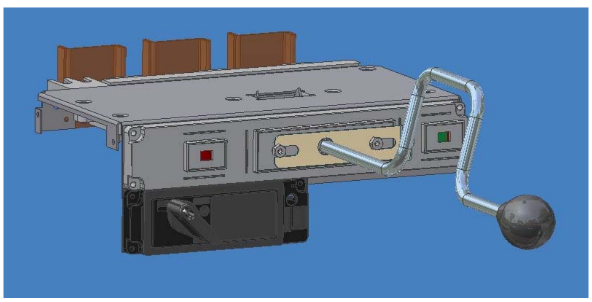

Figure 3: Example of Remote connectivity equipment.

HOW TO GET STARTED WITH ARC FLASH EQUIPMENT

Regardless of the equipment in use, reduction of an arc-flash hazard is important.

- Ensure your equipment complies with the appropriate standards.
- Perform an arc flash study for your site, including an up to date electrical system diagram for your facility.
- Clearly label equipment with an arc flash warning label per NEC.
- Instructional material is available for equipment installation and servicing.
- Ensure personnel are properly trained in electrical safe work practices and the use of PPE.

CONCLUSION

Reduction of Arc-Flash hazards in equipment is an essential requirement for the future of motor control center applications.

There are many benefits and advantages when using properly designed equipment to reduce the arc-flash hazards available. The benefits can be broken down into a few significant categories, such as design, reduced cost, maintenance, personnel, and equipment longevity

Motor Control Assemblies Equipment can be designed to limit the risk of an arc-flash hazard. Ensure that the correct feature sets are available to meet your arc-flash requirements. Equipment design features provide mechanical advantages with an enhanced feature set to mitigate an arc flash incident.

Reduction in overall system cost; particularly overall operational cost should be achieved with a reduction in arc-flash hazards.

Results of arc-flash testing clearly shows maintenance performed behind a dead front provide superior protection than with the door open. A design, which allows this, reduces the arc-flash hazard that should simplify maintenance procedures. As long as the doors are closed, the PPE requirements are minimized.

Minimize PPE requirements for personnel, which reduce the physical stress on personnel. It is important to note that the level of PPE that is recommended by NFPA 70E is "intended to protect a person from arc-flash and shock hazards. Even with PPE, some arc-flash conditions may result in burns to the skin or include arc blast pressures, toxic vapors, and propelled particles and materials. These factors must be considered when selecting PPE." (REF 5) Reduction of arc-flash hazards in equipment allows the Equipment to be operated for a longer lifespan.

The best arc-flash protection for low voltage motor control assemblies needs to be addressed in a comprehensive manner. The best solutions take into account multiple aspects of design, maintenance and operations of equipment. Enhanced design features and capabilities provide a better environment for personnel. The bottom line is to provide a system that reduces the likelihood of an arc-flash hazard to occur!

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