ANSI Standard C37.20.7: Arc Resistant Switchgear and Impact on Electrical Workplace Safety

May, 2016

Western Electrical Mining Association Conference
Gillette, WY – May 24-26, 2016

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Short Infomercial – IEEE IAS

IEEE Industry Applications Society: Mining Industry Committee

- Meeting in the fall at the IAS Annual Meeting
- Typically two sessions of papers (one day)
- Perhaps consider a WMEA co-located event in the future
Overview

What you will learn from today’s session?

- Review arc flash events and electrical workplace safety standards
- Become familiar with the ANSI/IEEE Standard C37.20.7
- Understand the differences between arc-resistant switchgear and non arc-resistant switchgear
- Understand the testing requirements for arc-resistant switchgear
- Overview relative costs of standard versus arc-resistant switchgear
- Comparing other technologies available that reduce arc flash energy
- Application considerations in determining what should be specified for process industries
Review of Arc Flash Hazards

An Arc Flash - An electrical arc due to either a phase to ground or phase to phase fault. Caused by many factors - dropped tools, improper work procedures, etc.

- 80 percent of all electrical injuries are burns that result from the electric arc flash
- Arc flashes cause electrical equipment to explode, resulting in an arc-plasma fireball
- Solid copper vaporizes, expands to 67,000 times its original volume
- Temperatures exceed 19,000 degrees C
- Detected sound levels of 141.5 decibels
- Pressure levels of 10,540 Kg per square meter
Standards Addressing Arc Flash Hazards

Electrical Workplace Safety
- NFPA70E-2015 Standard for Electrical Safety in the Workplace: (US) and CSA Z462-2015 (Canada)
  - Quantifies Heat Energy from arc flash in calories/cm2
  - Recommends fire rated clothing: Personal Protective Equipment (PPE) used during energized work
  - Recommends study update every 3 years

Arc Flash Calculations
- IEEE 1584-2002 “Guide for Performing Arc Flash Calculations”
  - It presents formulas for numerically quantifying heat energy from arc-flash
  - Includes an Excel Spreadsheet “Arc-Flash Hazard Calculator” that performs calculations using heat energy formulas
ANSI/IEEE Standard C37.20.7

“Guide for Testing Metal-Enclosed Switchgear Rated Up to 38kV for Internal Arcing Faults”

- First Issued in 2001
- Co-published by (ANSI) American National Standards Institute and the (IEEE) Institute of Electrical and Electronics Engineers
- Third-party testing required based on (UL) Underwriter’s Laboratories

Applies to North America switchgear assemblies
1.1 Scope

This guide establishes methods by which metal-enclosed switchgear, as defined by IEEE Std C37.20.1-2002, IEEE Std C37.20.2-1999, and IEEE Std C37.20.3-2001, may be tested for resistance to the effects of arcing due to an internal fault. This guide applies only to equipment utilizing air as the primary insulating medium and rated up to 38 kV ac. It applies to both indoor and outdoor equipment; however, special consideration must be given to the building size and construction for indoor applications (not addressed by this document).

“IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear”

- First Issued in 1987
- Co-published by (ANSI) American National Standards Institute and the (IEEE) Institute of Electrical and Electronics Engineers
- Third-party testing required based on (UL1558) Underwriter’s Laboratories
**LV Metal Enclosed Switchgear**

**DESIGN FEATURES:** 600V Class Switchgear: ANSI/IEEE C37.20.1

- Ratings through 600Vac, 100kA, 5000A
- Utilizes low-voltage drawout power circuit breakers, 800 through 5000A
- Four circuit breakers per panel
- Requires rear access for load cable terminations
LV Metal Enclosed Switchgear

**DESIGN FEATURES:** 600V Class Switchgear: ANSI/IEEE C37.20.1
**MV Switchgear: ANSI/IEEE Standard C37.20.2-1999**

“IEEE Standard for Metal-Clad Switchgear”

- First Issued in 1987
- Co-published by (ANSI) American National Standards Institute and the (IEEE) Institute of Electrical and Electronics Engineers
- Third-party testing required based on IEEE Std 4-1995 “Standard Techniques for High-Voltage Testing”
MV Metal-Clad Switchgear

5/15kV Class MV Switchgear: ANSI/IEEE C37.20.2

- Ratings at 5/15kV up to 38kV, 63kA, 4000A
- Utilizes medium-voltage drawout vacuum circuit breakers, 1200A through 4000A
- Two circuit breakers per panel
- “Metal-Clad” means grounded steel barriers isolating breaker, bus and cable compartments
- Requires rear access for load cable terminations

Medium Voltage Metal-Clad Switchgear
MV Metal-Clad Switchgear

5/15kV Class MV Switchgear: ANSI/IEEE C37.20.2

Medium Voltage Metal-Clad Switchgear

Front

Side View (Rear Access Assembly)

Bus Compartment

Breaker Compartment

Cable Compartment

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MV Switchgear: ANSI/IEEE Standard C37.20.3

“IEEE Standard for Metal-Enclosed Interrupter Switchgear”

- First Issued in 1987
- Co-published by (ANSI) American National Standards Institute and the (IEEE) Institute of Electrical and Electronics Engineers
- Third-party testing required based on IEEE Std 4-1995 “Standard Techniques for High-Voltage Testing”
5/15kV Class MV Interrupter Switchgear: ANSI/IEEE C37.20.3

- Ratings at 5/15kV up to 38kV, 61kA, 1200A
- Utilizes medium-voltage load-break switch with current-limiting fuse, 600A or 1200A
- One switch/fuse per panel
- Requires rear access for load cable terminations

Medium Voltage Fused Load-Interrupter Switchgear
MV Metal-Enclosed Switchgear

5/15kV Class MV Interrupter Switchgear: ANSI/IEEE C37.20.3

Medium Voltage Fused Load-Interrupter Switchgear

Side View (Rear Access Assembly)
5.3 Arc Initiation

For equipment defined by IEEE Std C37.20.1-2002: The arc shall be initiated by means of a metal wire 2.6 mm in diameter or 10 AWG.

For equipment defined by IEEE Std C37.20.2-1999 and IEEE Std C37.20.3-2001: The arc shall be initiated by means of a metal wire 0.5 mm in diameter or 24 AWG.

Arc initiation via a metal wire connected across all three phases
4.3 Arcing duration

The rated arcing duration is the period of time the equipment can experience the effects of an internal arcing fault and meet the requirements specified by this guide in 6.1. Where the duration is limited by protective devices, those devices shall be identified on the equipment nameplate. See 5.2.5 for testing with device-limited duration and 6.3 for nameplate marking.

The preferred rated arcing duration is 0.5 s.

Although any value of rated arcing duration is permitted, the minimum recommended duration is 0.1 s. It is generally considered unnecessary to test for durations longer than 1.0 s.
4.1 Accessibility type

A distinction is made between two levels of accessibility to switchgear assemblies. These levels correspond directly to the indicator placement given in 5.4.2.

**Type 1** - Switchgear with arc-resistant designs or features at the freely accessible front of the equipment only.

**Type 2** - Switchgear with arc-resistant designs or features at the freely accessible exterior front, back, and sides) of the equipment only.

“Type” designations define arc protection from the front of the switchgear only (Type 1) or from all sides (Type 2).
A.2 Suffix “B”

This suffix is designated for equipment where normal operation of the equipment involves opening the door or cover of compartments specifically identified as low-voltage control or instrumentation compartments.

A.3 Suffix “C”

This suffix is designated for equipment where isolation from the effects of an internal arcing fault is desired between all adjacent compartments within a switchgear assembly.

A.4 Suffix “D”

This suffix is designated for equipment specifically designed for installations where some external surfaces of the equipment are inaccessible and no need exists to use a Type 2 design.
5.4 Indicators (for observing the thermal effects of gases)

Indicators are constructed from pieces of black cotton fabric… arranged so that the cut edges do not point toward the test sample and each indicator is isolated from the others to prevent multiple ignitions from a single source. …The frame shall be mounted with the frame sides perpendicular to the plane of the test sample and the fabric parallel to the plane of the test sample. The dimensions of the exposed fabric are to be 150 mm × 150 mm (–0, +15 mm) (6 in × 6 in). Refer to Figure 1 for indicator assembly dimensions.

Vertical indicators are to be located from floor level to a height of 2 m (79 in) from the floor and at a distance of 100 mm ± 15 mm (4 in.) from the surface of the cloth to the switchgear.

Horizontal indicators are to be located at a height of 2 m (79 in) from the floor and horizontally covering the whole area between 100 mm ± 15 (4 in) and 800 mm (31 in) from the test sample.
Arc-Resistant Switchgear (ANSI C37.20.7)

Arc Rated ANSI/NEMA/IEEE Standard C37.20.2 Medium-Voltage Metal-Clad Switchgear

- 15 kV Arc Resistant Switchgear
- Control Section
- VT drawer
- Arc Flaps
- 1200A can be 1 high or 2 high
- 2000A or 3000A breaker with Vent

Redirects Arc Energy and Particulates
Arc-Resistant Switchgear – Type 2C Construction

ANSI/IEEE C37.20.2 Switchgear tested to ANSI/IEEE C37.20.7 Arc Resistant Standard – Type 2C

- Each of eight compartments is isolated
- Initiating an arc event in compartment 4 will not propagate to adjacent compartments or vertical sections
- Gasses will be vented up through the plenum 2 meters above the floor level

❗ = Arcing fault in compartment 4
MV Metal Enclosed Motor Control Centers

7.2kV Class Motor Control Center, tested to ANSI/IEEE C37.20.7 Arc Resistant Standard – Type 2B

- Ratings through 7.2kV, 30kA and 50kA, 0.5 seconds, 3000A bus
- Utilizes fused isolation switch and vacuum contactor, 400 and 800A
- Two starters per panel
- Front access design
- Option: Arc Resistant design tested to ANSI/IEEE C37.20.7
- UL 347 standard to complete the draft annex for arc resistant MV MCCs
MV Metal Enclosed Motor Control Centers

7.2kV Class Motor Control Center, tested to ANSI/IEEE C37.20.7 Arc Resistant Standard – Type 2B

Arc Resistant Medium-Voltage MCC

Type 2B Test

123.6” (3140)

52.25” (1327)

Side View (Front Access Assembly)
LV Metal Enclosed Motor Control Centers

DESIGN FEATURES: 600V Class Motor Control Center: UL845 Standard

- Ratings through 600Vac, 100kA, 5000A
- Utilizes low-voltage molded case circuit breakers and starters, 50 through 4000A
- Typically six starters per panel
- Front access design

ANSI C37.20.7 does not apply! Recommend CSA C22.2.022
# IEC Standards

## Medium-Voltage is certified in accordance with:

<table>
<thead>
<tr>
<th>IEC Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 62271-1</td>
<td>Common specifications</td>
</tr>
<tr>
<td>IEC 62271-100</td>
<td>Circuit-breakers (E1/E2, M2, C2)</td>
</tr>
<tr>
<td>IEC 62271-102</td>
<td>Disconnectors and earthing switches (E2, M0)</td>
</tr>
<tr>
<td>IEC 62271-200</td>
<td>Metal enclosed switchgear and controlgear</td>
</tr>
<tr>
<td>IEC 60044-1</td>
<td>Current transformers</td>
</tr>
<tr>
<td>IEC 60044-2</td>
<td>Voltage transformers</td>
</tr>
<tr>
<td>IEC 60529</td>
<td>Degrees of protection (IP Code)</td>
</tr>
</tbody>
</table>

## Low-Voltage is certified in accordance with:

<table>
<thead>
<tr>
<th>IEC Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61439</td>
<td>Switchgear and control gear systems</td>
</tr>
<tr>
<td>IEC 60947-1</td>
<td>Breaker and Control general rules</td>
</tr>
<tr>
<td>IEC 60947-2</td>
<td>Circuit-breakers</td>
</tr>
<tr>
<td>IEC 60947-3</td>
<td>Switches, disconnectors and switch-disconnectors</td>
</tr>
<tr>
<td>IEC 60947-4</td>
<td>Contactors and motor starters</td>
</tr>
<tr>
<td>IEC 60529</td>
<td>Degrees of protection (IP Code)</td>
</tr>
</tbody>
</table>
**IEC 62271-200: Definition & Test Criteria**

**DEFINITION:**

- **Internal Arc Classified switchgear and controlgear (IAC)**
  
  Metal-enclosed switchgear and controlgear for which prescribed criteria for protection of persons are met in the event of internal arc as demonstrated by the appropriate tests.

**TEST CRITERIA**

- **Criterion No. 1:** Correctly secured doors and covers do not open. Deformations are acceptable, provided no part comes as far as the position of the indicators or the walls.

- **Criterion No. 2:** No fragmentation of the enclosure occurs within the time specified for the test. Projections of small parts up to 60 g are accepted.

- **Criterion No. 3:** Arcing does not cause holes in the accessible sides up to a height of 2 meters.

- **Criterion No. 4:** Indicators do not ignite due to the effect of the hot gases.

- **Criterion No. 5:** The enclosure remains connected to it’s earthing point. Visual inspection is generally sufficient.
### IEC 62271-200: Designation of IAC Classifications

<table>
<thead>
<tr>
<th>Internal arc classification</th>
<th>IAC</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility type</td>
<td>A (F, L, R)</td>
<td>A: restricted to authorised personnel only</td>
</tr>
<tr>
<td></td>
<td>B (F, L, R)</td>
<td>B: unrestricted accessibility</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>C: not accessible e.g. pole mounted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F: front</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: lateral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: rear</td>
</tr>
<tr>
<td>Arc test current</td>
<td>kA</td>
<td></td>
</tr>
<tr>
<td>Arc test duration</td>
<td>s</td>
<td></td>
</tr>
</tbody>
</table>

- Example: IAC metal enclosed switchgear rated for 12.5kA, 0.5 seconds. Public accessibility from the rear, authorized personnel both front and lateral.

Classification: IAC BR - AFL  
Internal Arc: 12.5kA, 0.5 seconds
Redirect Blast Energy
Arc-Resistant/Arc-Rated Switchgear

Internal Arc Classified IEC Assemblies

- Type Tested to IEC 62271-200

- Type Tested to IEC61439-1 (and IEC 61641 criteria 1 through 7)
MV Internal Arc Classified IEC Switchgear

12/24kV Class MV Switchgear: IEC 62271-200

Medium-Voltage Metal-Enclosed Switchgear

Arc Plenum
Bus Compartment
Breaker Compartment
CT’s
Cable Compartment
VT’s

Side View (Front Access Assembly)

105.1” (2670)
52.2” (1325)
Arc Test Certifications: IEEE & IEC Standards
Application Considerations: e-House Design

Before:
ANSI/IEEE Assemblies installed in e-House based on rear access

After:
Exterior wall of e-House is designed so that switchgear removable panels are part of the exterior wall.
Application Considerations: Move people away

Optional Accessory - Electrical Levering Device

- External Remote Racking
- Integral Remote Racking
- Remote Isolation Switch
- Universal Remote Racking

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Application Considerations: Faster Clearing Times

Before:
2000kVA Substation with very high arc flash energy at the switchgear bus

2000kVA 5.75%Z

Fault at 480V Switchgear Bus
- 31.8kA Symmetrical Fault current
- 1167’’ AF Boundary
- 702.4 calories/cm² @ 18”
- UNAPPROACHABLE:

After:
Secondary CTs and relay at transformer reduces arc energy!

Many installation codes allows unprotected secondary conductor
Transformer Secondary Conductors Not over 3 meters long
US Chemical Plant – Review of an Arc Flash incident occurring during energized work

- “Implementation of an Arc Flash Reduction Maintenance Switch – A Case Study” Thomas Domitrovich, Ken White, IEEE IAS ESW-2012-08
- Energized Task: Removing cables from de-energized Cubicle 4 using a rope. “Tool” changed from a rope to a come-along
ARMS Case Study: Olin Chemical

- 1000kVA transformer upstream
- 20,918 amps of available fault current
- Energy:
  - 17.7 Cal/cm²: No arc reducing technology
  - 2.9 Cal/cm²: With arc reducing technology
- PPE utilized - 8 cal/cm² (the site standard PPE clothing)
A Look at Light Detection: LV Systems

Light Sensing Relay Marketing Claims

Manufacturer 1

Substantial reductions in arc-flash hazards and Hazard/Risk Category (HRC) levels are achievable with arc-flash detection and mitigation solutions.

Manufacturer 2

the incoming CB may have to be delayed hundreds of milliseconds for selectivity reasons. This delay can be avoided using REA 10 arc protection system: Total fault clearance time can be reduced to max 2.5 ms plus circuit breaker’s action time.

Manufacturer 3

<table>
<thead>
<tr>
<th>Information Center</th>
<th>Electrical Characteristics</th>
<th>Technical Resources</th>
<th>Related Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features and Benefits</td>
<td>FEATURES</td>
<td>BENEFITS</td>
<td></td>
</tr>
<tr>
<td>4 arc sensor inputs</td>
<td>Supports both point and fiber sensors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arc Flash trip time</td>
<td>Limits arc-flash damage and risk of injury</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A Look at Light Detection: LV Systems

Using Olin Case Study as an example

Arc Flash Incident Energy is dictated by total clearing time

- 1,000kVA, 480V, 5.75%Z Transformer, \( I_{FL} = 1,204A \), \( I_{SC} = 20,918A \), \( I_{ARC} = 11,134A \)
- Software Instantaneous Trip: 17.7 Cal/cm\(^2\) @ 18”
- Light & Current Relay Trip: 15.2 Cal/cm\(^2\) @18”
- Air Circuit Breaker with Arc Reduction Maintenance System Trip: 2.57 Cal/cm\(^2\) @ 18”

Light Detection offers only a marginal benefit versus instantaneous trip and does not match ARMS total clearing time!
Light Detection Systems – Other Considerations

Our Company Position

- Cannot be responsible for enhanced level of protection
- Cannot be responsible for possible nuisance operation
- Glass fiber breaking/ shipping splits
- UL has no test standard (UL508)

Questions to Ask

- What is the total clearing time improvement with light detection?
- What clearing time values should be included in the arc-flash study?

Our company PSE’s model arc flash exposure with light detection relays with zero total clearing time improvement versus instantaneous
Application Considerations: Safety By Design

Arc Preventive MCC
Low-voltage MCC with a rackable starter unit!
Application Considerations: Safety By Design

Only Two LV MCC Activities While Energized

1) Insertion/Removal of starter unit from energized bus
2) Troubleshooting with starter unit door open

Recommendation: Specify integral unit racking and ARMS!

Eaton Freedom Low-Voltage Metal-Enclosed MCC

ANSI C37.20.7 does not apply! Recommend CSA C22.2.022
Conclusions

- ANSI/IEEE Standard C37.20.7 is a supplementary arc testing “add-on” Standard for existing ANSI/IEEE low-voltage and medium-voltage switchgear and medium-voltage MCCs.
- Today, ANSI/IEEE Standard C37.20.7 does not apply for LV MCCs.
- IEC Standards include arc testing for both LV and MV switchgear and controlgear assemblies.
- Arc rated assemblies simply redirect the heat energy. Reducing the energy can only be accomplished by reducing the source MVA, moving people further away or reducing the total clearing time.
- It is important to understand the Standards and the product designs manufactured to these Standards in selecting the right technology for your mine application.
Thank you!

Questions?

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