Overview of IEEE Standard 1015-1997
(IEEE Blue Book)

Recommended Practice for Applying
Low-Voltage Circuit Breakers Used in
Industrial and Commercial Power Systems

IEEE/IAS S.F. Chapter
September 27, 2005
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Eaton Electrical

Chapter 1 - Classifications/Types

Two main classifications of low-voltage

circuit breakers:

• Molded-case circuit breakers
• Low-voltage power circuit breakers

Three types of circuit breakers:

• MCCB Molded-case circuit breakers
• ICCB Insulated-case circuit breakers
• LVPCB Low-voltage power circuit breakers

Chapter 1 - Standards

Molded-case circuit breakers

UL 489 - MCCB
UL 1087 - Molded Case Switches (MCS)
NEMA AB1 - MCCB & MCS
NEMA AB3 - MCCB Application

Insulated-case circuit breakers

Same as MCCBs

Low-voltage power circuit breakers

ANSI Std C37.16 - Preferred Ratings
ANSI Std C37.17 - Trip Devices for LVPCB
ANSI Std C37.50 - Test Procedures
IEEE Std C37.13 - LVPCB Used in Enclosures
UL 1066 - LVPCB

Contents

Chapter 1 Overview
Chapter 2 Definitions and Acronyms
Chapter 3 Rating and Testing
Chapter 4 Specific Applications
Chapter 5 Selective Coordination
Chapter 6 Special-Purpose Circuit Breakers
Chapter 7 Acceptance and Maintenance Requirements
Chapter 1 - Description (MCCB)

Molded-case circuit breakers
• Molded case of insulating material
• Over-center toggle
• Quick-make-quick-break mechanism
• Manually operated
• Trip free
• Intermediate trip position
• Field maintenance not intended

Chapter 1 - Description (ICCB)

Insulated-case circuit breakers
• Case designed for inspection of contacts and arc chutes
• Stationary and drawout construction
• Stored energy mechanism
• Larger frame sizes
• Higher short-time withstand ratings

Chapter 1 - Description (LVPCB)

Low-voltage power circuit breakers
• Designed for maintenance and parts replacement
• Spring charged stored-energy mechanism
• Two-step closing
• Fixed or drawout
• Connected-test-disconnected positions
• Primary and secondary disconnects

Chapter 2 – Definitions

Alarm switch
Auxiliary switch
Circuit breaker
Coordination
Current-limiting CB
Drawout-mounted
Dynamic impedance
Instantaneous-trip-only
ICCB
Inverse time
LVPCB
MCCB
Molded-case switch
Overcurrent
Overload
Panelboard
Peak current
Peak let-through current
Pickup
Prospective fault current
Rated short-time withstand current
Rating plug
RMS sensing
Selectivity
Sensor
Series rating
Setting
Short-circuit
Short-time current
Short-time delay
Short-time rating
Shunt trip device
Stored-energy mechanism
Switchboard
Switchgear
Tripping
Transient recovery voltage
Zone selective interlocking
Chapter 2 – Acronyms

Markings designating circuit breaker ratings:
• 40C – Acceptable for use in ambient temperature up to 40°C
• AIR – Amperes interrupting rating
• CTL – Class CTL circuit breaker prevents more circuit breaker poles from being installed than the number intended
• HACR – Heating, Air Conditioning, and Refrigeration. Designates compliance with NEC for group motor installations.
• HID – High Intensity Discharge. Indicates construction suitable for switching HID lighting loads.
• SWD – Switching Duty. Designates compliance with requirements for circuit breakers used as switches in fluorescent lighting circuits.

Chapter 3 - Rating and Testing

Selection criteria:
• To carry the required full-load current without overheating
• To switch and isolate or disconnect the load from the source at the given system voltage
• To interrupt any possible abnormally high operating current or short-circuit current likely to be encountered during operation
• To be able to perform these functions over an acceptably long period of time under the operating and environmental conditions that will actually prevail in the application

The role of standards

Chapter 3 - MCCB

Molded-case circuit breakers
• Tested and rated according to UL 489
• Completely contained within a molded case of insulating material
• 15A – 6000A with various interrupting ratings
• Fast interruption short-circuit elements
• With electronic trip units can have limited short-delay and ground fault sensing capability
• Interrupt fast enough to limit the prospective fault-current let-through
• Some are identified as current limiting
• Not designed to be field maintainable

Chapter 3 - ICCB

Insulated-case circuit breakers
• Tested and rated according to UL 489
• Larger frame sizes
• Fast in interruption
• Can have electronic trip units with short-time ratings and ground-fault current sensing
• Utilize stored-energy operating mechanisms
• Partially field maintainable
Chapter 3 - LVPCB

Low voltage power circuit breakers

- Tested and rated according to ANSI C37 standards
- Used primarily in drawout switchgear
- Short-time ratings
- Designed to be maintainable in the field

Chapter 3 - Endurance

<table>
<thead>
<tr>
<th>Number of Operating Cycles</th>
<th>Frame Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Servicing</td>
<td>With Current</td>
</tr>
<tr>
<td></td>
<td>Without Current</td>
</tr>
<tr>
<td>UL489</td>
<td>ANSI C37.50†</td>
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<tr>
<td>225</td>
<td>3000</td>
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<td>400</td>
<td>5000</td>
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<td>800</td>
<td>8000</td>
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<td>1200</td>
<td>12000</td>
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<td>2400</td>
<td>24000</td>
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</table>

Chapter 3 - MCCB/ICCB Interrupting Ability

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Tested In Sequence Number</th>
<th>Duty Cycle</th>
<th>Number of Poles</th>
<th>Maximum Voltage</th>
<th>Frame Rating (amperes)</th>
<th>Actual Test Current (rms symmetrical kA)</th>
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Chapter 3 - LVPCB Interrupting Ability

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Tested In Sequence Number</th>
<th>Duty Cycle</th>
<th>Number of Poles</th>
<th>Maximum Voltage</th>
<th>Frame Rating (amperes)</th>
<th>Actual Test Current (rms symmetrical kA)</th>
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</tbody>
</table>

† ANSI C37.50-1989 and ANSI C37.16-1988
Chapter 3 - Voltage Rating Considerations

MCCB/ICCB/LVPCB Circuit breakers
- Nominal system voltages of 600V, 480V, and 240V
- MCCB/ICCB also 120V, 120/240V, 277V, 347V, 480Y/277V, and 600Y/347V
- MCCB/ICCB – nominal voltage levels are maximum "not to exceed" voltages
- LVPCB – assigned maximum voltages of 254V, 508V, and 635V
- Slash marks
- Insulation testing - 2200V ac dielectric withstand voltage test (or equivalent dc) when new

Chapter 3 - Frequency and Temperature

Frequency
- Rated for 60 Hz operation
- Other frequency capabilities are marked
- May have to be de-rated

Temperature
- MCCB/ICCB: -5°C to +40°C
- LVPCB: -5°C to +40°C, but IEEE C37.20.1 permits temperature surrounding switchgear to be -30°C to +40°C

Chapter 3 - Enclosures and Conductors

Enclosures
- Fully rated for operation in free air
- LVPCBs are applied in enclosures and fully rated
- Some MCCBs are also 100% rated. They have a minimum enclosure size. Use 90°C conductors.
- MCCBs in enclosures 80% rated for continuous loads

Cable, wire, and conductor considerations
- Conductors serve as heat sinks – 75°C wire required
- Higher temperature wire must be used at the 75°C ampacity
- Welding cable should not be used
- 125A or less – marked for 60°C, 75°C, 60°/75°C

Chapter 3 - Ambient, Humidity, Altitude

Ambient
- Should be de-rated in ambients above maximum
- Consult the manufacturer for de-rating information

Altitude
- Reduced insulation and heat transfer properties of less dense air require de-rating of voltage withstand and current carrying capacity
- MCCB/ICCB – De-rated above 6000 feet. Consult the manufacturer.
- LVPCB – De-rated above 6600 feet
- IEEE C37.13: 8500 feet, .99 current and .95 voltage
- IEEE C37.13: 13000 feet, .96 current and .80 voltage
Chapter 3 - Other Considerations

- National Electrical Code
- Preferred current ratings
- Effect of non-linear loads
- High inrush loads
- Overload testing
- Safety factor for current loading
- Forced-air cooling of LV PCBs
- Short-circuit interrupting rating
- Fault current calculations
- Circuit breaker interrupting ratings
- Single-pole fault interruption testing

Chapter 3 - Other Considerations

- Testing
- Blow-open contact arms
- Circuit breaker useful life
- Interrupting duty and maintenance
- Integrally fused devices
- Series-connected rating
- Cascade arrangement
- Short-time rating
- X/R ratio – short-circuit power factor
- Power system design considerations

Chapter 3 - X/R Ratio
(Short-Circuit Power Factor)

<table>
<thead>
<tr>
<th>Type of Circuit Breaker</th>
<th>Interrupting Rating (kA)</th>
<th>Power Factor Test Range</th>
<th>X/R Test Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molded Case 10 or less</td>
<td>0.45 – 0.50</td>
<td>1.96 - 1.73</td>
<td></td>
</tr>
<tr>
<td>Molded Case over 10 to 20</td>
<td>0.25 – 0.30</td>
<td>3.87 - 3.18</td>
<td></td>
</tr>
<tr>
<td>Molded Case over 20</td>
<td>0.15 – 0.20</td>
<td>6.6 - 4.9</td>
<td></td>
</tr>
<tr>
<td>Low-Voltage Power all</td>
<td>0.15 max.</td>
<td>6.6 min.</td>
<td></td>
</tr>
</tbody>
</table>

Chapter 3 - Multiplying Factors

<table>
<thead>
<tr>
<th>% P.F.</th>
<th>X/R</th>
<th>Interrupting Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 10 kA</td>
<td>&gt; 10 kA</td>
</tr>
<tr>
<td>20</td>
<td>4.8990</td>
<td>0.762</td>
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<tr>
<td>15</td>
<td>6.9312</td>
<td>0.718</td>
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<tr>
<td>12</td>
<td>8.2731</td>
<td>0.691</td>
</tr>
<tr>
<td>10</td>
<td>9.9499</td>
<td>0.673</td>
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<tr>
<td>9</td>
<td>11.7251</td>
<td>0.659</td>
</tr>
<tr>
<td>7</td>
<td>14.2527</td>
<td>0.643</td>
</tr>
<tr>
<td>5</td>
<td>19.9750</td>
<td>0.627</td>
</tr>
</tbody>
</table>
Chapter 3 - Overload Performance

<table>
<thead>
<tr>
<th>Frame Size (amps)</th>
<th>Minimum Operation Rate (cycles/hour)</th>
<th>Number of Operating Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UL 489</td>
<td>ANSI C37.50*</td>
</tr>
<tr>
<td>200</td>
<td>300</td>
<td>60</td>
</tr>
<tr>
<td>400</td>
<td>240</td>
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<td>600</td>
<td>240</td>
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<tr>
<td>800</td>
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<tr>
<td>1200</td>
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<tr>
<td>1600</td>
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<tr>
<td>3000</td>
<td>80</td>
<td>N/A</td>
</tr>
<tr>
<td>4000</td>
<td>80</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Chapter 4 - Selection Considerations

- System Voltage
- System Grounding
- System Frequency
- Continuous Current Rating
- Ambient Temperature and Altitude
- Harmonics
- Interrupting Rating
- Series Connected Rating
- Fully-Rated Versus Series-Connected Rated
- Arcing Ground Fault Protection

Chapter 4 - Modifications and Accessories

- Shunt trip device
- Undervoltage release
- Auxiliary switches
- Mechanism operated cell (MOC) switch
- Truck operated cell (TOC) switch
- Alarm switches
- Motor operators on MCBs
- Electrical close mechanism on LVPCBs and ICCBs
- Mechanical interlocks
- Moisture, Fungus, and corrosion treatment
- Terminal shields
- Handle locks and handle ties
- Shutters

Chapter 4 - Specific Applications

Normal Environmental and Operating Conditions

- Ambient temperature between 0°C and 40°C
- Altitude does not exceed 6600 ft (2000 m)
- Seismic zone 0
- Frequency of 60 Hz
Chapter 4 - Specific Applications

Abnormal Environmental and Operating Conditions

• Operation at ambient temperatures below 0°C or above 40°C
• Operation at altitudes above 6600 ft (2000 m)
• Exposure to corrosive materials
• Exposure to explosive fumes or dust
• Exposure to dust or moisture
• Seismic zones 1, 2, 3, or 4
• Abnormal vibrations
• Unusual operating duties
• Harmonics
• Repetitive duty cycle
• Capacitor bank switching
• Frequent switching
• Circuits with high X/R ratios
• Single pole interruption with three-pole breakers
• Frequencies other than 60 Hz
• Occurrence of frequent and/or severe faults

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Chapter 4 - Comparison of Features

<table>
<thead>
<tr>
<th>LVPCB</th>
<th>ICCB</th>
<th>MCCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selective trip over full range of fault currents up to interrupting rating.</td>
<td>Selective trip over partial range of fault currents within interrupting rating.</td>
<td>Selective trip over a smaller range of fault currents within interrupting rating.</td>
</tr>
<tr>
<td>Types of operations: mechanically operated, two-step, stored energy, and electrical two-step stored energy.</td>
<td>Types of operations: mechanically operated, two-step, stored energy, and electrical two-step stored energy.</td>
<td>Types of operations: mechanically operated over-center toggle or rotary operator.</td>
</tr>
<tr>
<td>Available in draw-out construction permitting racking to a distinct “test position” and removal for maintenance.</td>
<td>Available in draw-out construction permitting racking to a distinct “test position” and removal for maintenance.</td>
<td>Some are available in plug-in type allowing removal for inspection and maintenance.</td>
</tr>
<tr>
<td>Operation counter is available.</td>
<td>Operation counter is available.</td>
<td>Operation counter is available.</td>
</tr>
<tr>
<td>Interrupting duty at 480 Vac: 22-100 kA without fuses and up to 200 kA with fuses.</td>
<td>Interrupting duty at 480 Vac: 22-100 kA.</td>
<td>Interrupting duty at 480 Vac: 22-65 kA without fuses and up to 200 kA with integral fuses or for current-limiting type.</td>
</tr>
</tbody>
</table>

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Chapter 4 - Service Requirements and Protection

Main circuit breakers

• Disconnecting means
• Overload, short-circuit, and GF protection
• General application considerations

Tie circuit breakers

• Disconnecting means
• Overload, short-circuit, and GF protection
• General application considerations

IEEE Standard C37.13

UL 489

UL 489
Chapter 4 - Service Requirements and Protection

Feeder protection
- Overload protection of cables
- Short-circuit and GF protection
- Protection of busway
- Protection of switchgear bus
- Protection of switchboard bus
- Protection of motor feeders and motors
- Feeder and branch-circuit protection
- Protection of generators
- Protection of capacitors
- Protection of transformers

Chapter 5 - Selective Coordination

LVPCBs
- Electromechanical trip devices
- Electronic trip devices
- Long-time delay protection
- Short-time delay protection
- Instantaneous protection
- Ground-fault protection

MCCBs and ICCBs
- Thermal-magnetic circuit breakers
- Electronic trip devices
- Long-time and short-time delay protection
- Instantaneous protection
- Ground-fault protection
Chapter 5 - Other Coordinating Devices

- Low-voltage fuses
- Medium-voltage fuses
- Overcurrent relays
- Coordination Examples

Chapter 6 - Special-Purpose Circuit Breakers

- Instantaneous-trip circuit breakers (MCPs)
  - Ratings
  - Current-limiting attachments
  - Code considerations
  - Setting of instantaneous-trip breakers
  - Energy-efficient motors
- Mine-duty circuit breakers
- Current-limiting circuit breakers
- Molded-case switches
- Integrally fused circuit breakers

Chapter 7 - Acceptance and Maintenance

- Maintenance program
- Maintenance of MCCBs
- Maintenance of LVPCBs
- Documenting maintenance results
- Testing program
- Failures detected

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