Circuit Breaker Interrupting Capacity and Short-Time Current Ratings

IEEE Industry Applications Society
San Francisco Chapter
September 28, 2004

David D. Roybal, P.E.
Fellow Application Engineer
Eaton Electrical | Cutler-Hammer
IEEE Definition:

A device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined overload of current without injury to itself when properly applied within its ratings.
Low Voltage Circuit Breaker Types

Molded Case Circuit Breakers
- Tested in accordance with UL489
- Open Air Test - Rated @ 80%
- Over Toggle Mechanism
- Sealed Case - Not Maintainable
- Applied in Switchboards and Panelboards

Insulated Case Circuit Breakers
- Tested in accordance with UL489
- Open Air Test - Rated @ 80% or 100%
- 2-Step Stored Energy Mechanism
- Not Fully Maintainable
- Applied As Mains in Switchboards and MCCs

Power Circuit Breakers
- Tested in accordance with UL1066
- Tested in the Enclosure - Rated @ 100%
- 2-Step Stored Energy Mechanism
- Fully Maintainable
- Metal-Enclosed Draw-out Switchgear
Molded Case Circuit Breakers
Insulated Case Circuit Breakers

NEMA AB-1 – Molded Case Circuit Breakers and Molded Case Switches

UL489 – Molded-Case Circuit Breakers and Circuit-Breaker Enclosures
Low Voltage Power Circuit Breakers

ANSI C37.13 – IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures

ANSI C37.16 – Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors - Preferred Ratings, Related Requirements, and Application Recommendations

UL1066 – Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures
Interrupting Capacity

The Maximum Short Circuit Current that the Circuit Breaker Can Safely Interrupt at a Specific Voltage

- Expressed in rms symmetrical amperes
- Specified by current magnitude
The interrupting capacity for a circuit breaker provided with instantaneous trip elements is the maximum rating of the device with no intentional delay.

The interrupting capacity for a circuit breaker provided without instantaneous trip elements is the maximum rating of the device for the rated time interval.
Short-time Current Rating

*Defines the Ability of the Device to Remain Closed for a Time Interval Under High Fault Current Conditions*

- Performance of a circuit breaker over a specific current range for a period of time
- Specified by current magnitude and time magnitude
- Allows system selectivity
Low Voltage Circuit Breaker Types

**Molded Case Circuit Breaker (MCCB)**
- Tested in accordance with NEMA AB-1 and UL489

**Insulated Case Circuit Breaker (ICCB)**
- Tested in accordance with NEMA AB-1 and UL489

**Power Circuit Breaker (PCB)**
- Tested in accordance with ANSI C37.13 and UL1066
Instantaneous Trip Functions

- All MCCBs and ICCBs are provided with instantaneous trip functions (no intentional delay)
- PCBs can be provided with or without instantaneous trip functions
Vintage Low Voltage Circuit Breaker Trip Units

Thermal-magnetic trip elements

- Thermal element provided overload protection
- Magnetic (instantaneous) trip elements provided protection for high-magnitude faults
- Available in both MCCBs and PCBs

Thermal elements only (for PCBs)

- Thermal element provided overload protection
- 30 cycle short-time current rating
- No magnetic (instantaneous) trip elements provided
- Interrupting rating was equal to the rating with magnetic elements
- Must be applied within their short-time rating
Solid-state trip elements or microprocessor-based trip elements

- Long-time pickup and delay
- Short-time pickup and delay
- Instantaneous pickup
- Ground-fault pickup and delay
Instantaneous Pick-up

- Always provided in a molded case circuit breaker or an insulated case circuit breaker
- Sometimes called magnetic pick-up
- Instantaneous override
- Optional for power circuit breakers
Limited to the magnetic (instantaneous) pickup level of the device

• **MCCBs** – limited ratings which do not usually increase with higher interrupting capacity

• **ICCBs** – some extended ratings

• **PCBs** – highest extended ratings
ANSI C37 Test Standard

Low Voltage Power Circuit Breakers -

- **Interrupting Rating:** Shall safely interrupt a rated fault current expressed in rms symmetrical amperes as measured 1/2 cycle after short circuit initiation

- **Short-Time Current Rating:** Shall remain closed during a short delay fault test of 30 cycle duration - a 15 second zero current interval - followed by another 30 cycle fault duration

All ANSI C37 Tests are Performed at 15% Power Factor, or X/R Ratio of 6.6 or Less
Interrupting Capacity

MCCBs and ICCBs

- Highest interrupting capacity
- Trips immediately for faults exceeding instantaneous pickup
- Do not need to withstand high current for an extended time delay
- Economic advantages

PCBs

- High interrupting capacity available
- Highest extended short-time current ratings
## Typical 400-Ampere Frame Molded-Case Circuit Breakers

<table>
<thead>
<tr>
<th>MCCB Design</th>
<th>Low IC</th>
<th>High IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interrupting Capacity (kA @ 480 V)</td>
<td>35</td>
<td>100</td>
</tr>
<tr>
<td>Maximum Mag. Adjustment (kA)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Instantaneous Override (kA)</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

*The minimum frame size for most ICCBs and LVPCBs is 800 amperes.*
## Typical 800-Ampere Frame Circuit Breakers

<table>
<thead>
<tr>
<th>Type of Device</th>
<th>MCCBs</th>
<th>ICCBs</th>
<th>LVPCBs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low IC</td>
<td>High IC</td>
<td>Low IC</td>
</tr>
<tr>
<td>Interrupting Capacity (kA @ 480 V)</td>
<td>50</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Instantaneous Override or Max. Short-time Current Rating (kA)</td>
<td>6 – 9</td>
<td>6 – 9</td>
<td>25</td>
</tr>
<tr>
<td>Short-time Delay (cycles)</td>
<td>18</td>
<td>18</td>
<td>30</td>
</tr>
</tbody>
</table>
## Typical 1600-Ampere Frame Circuit Breakers

<table>
<thead>
<tr>
<th>Type of Device</th>
<th>MCCBs</th>
<th>ICCBs</th>
<th>LVPCBs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interrupting Capacity (kA @ 480 V)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low IC</td>
<td>65</td>
<td>65</td>
<td>50</td>
</tr>
<tr>
<td>High IC</td>
<td>100</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td><strong>Instantaneous Override or Max. Short-time Current Rating (kA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low IC (Internal Inst. Trip)</td>
<td>17</td>
<td>35</td>
<td>42</td>
</tr>
<tr>
<td>High IC (Internal Inst. Trip)</td>
<td>17</td>
<td>51</td>
<td>85</td>
</tr>
<tr>
<td><strong>Short-time Delay (cycles)</strong></td>
<td>18</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

---

IEEE San Francisco IAS
Externally adjustable designs

- Typical adjustment range of 5 – 10 times the frame continuous ampere rating
- Inhibits the use of a higher instantaneous pickup that may be available

Internally fixed designs

- MCCBs set at about 13 times the frame rating
- ICCB setting may be higher
- May be deleted for PCBs

Both externally adjustable and internally fixed instantaneous trip elements inhibit the use of short-time current ratings
X/R Ratio - Impedance Diagram

Utility Impedance

Ru
Xu

Transformer Impedance

Rbx
Xtx

Facility Feeder Impedance

Rf
Xf

Infinite Bus

Utility Service

Secondary Service

Distribution Panel

Fault A

Fault B

X/R for Utility Service = Xu / Ru

X/R for Point A = (Xu+Xbx) / (Ru+Rbx)

X/R for Point B = (Xu+Xbx+Xf) / (Ru+Rbx+Rf)
X/R Ratio Effect on Symmetry

X/R = 0, PF = 1.0 (symmetry)   X/R = 6.6, PF = 0.15 (asymmetry)

Current in Per Unit

Time in Cycles

September 28, 2004
IEEE San Francisco IAS
Asymmetrical Current Wave

- Total Current - A Wholly Offset Asymmetrical Alternating Wave
- Rms Value of Total Current
- Alternating Component - A Symmetrical Wave
- Rms Value of Alternating Component
- Direct Component - The Axis of Asymmetrical Wave
- Time in Cycles of a 60 Cps Wave
# Circuit Breaker

## Asymmetrical Ratings

<table>
<thead>
<tr>
<th>Type of Device</th>
<th>MCCB</th>
<th>ICCB</th>
<th>LVPCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test PF (%)</td>
<td>20</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>X/R</td>
<td>4.9</td>
<td>4.9</td>
<td>6.6</td>
</tr>
<tr>
<td>Peak Mult. Factor</td>
<td>2.2</td>
<td>2.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>
Peak Multiplication Factor

\[ \text{Rms Asym} = \sqrt{\text{Dc}^2 + \text{Rms Sym}^2} \]

With Dc Value
Taken at Current Peak
Protection and coordination are often competing objectives.

Selective tripping is necessary for continuity of service.

Coordination is achieved through the use of short-time current ratings.

Selective coordination may be sacrificed with:

- Series ratings – instantaneous trips
- Current limiting circuit breakers
Time-Current Curves for a Non-Coordinated System
Time-Current Curves for a Coordinated System

Coordinated Systems

Summary

- All circuit breakers provide overcurrent protection
- Performance based on design standards and features
- Interrupting capacity, short-time current ratings, test power factor (X/R) determine ability to provide system protection, coordination, and selectivity
Conclusions

**MCCBs and ICCBs**
- Excellent interrupting ratings but limited short-time current ratings
- For improved selectivity choose a MCCB or an ICCB with a fixed internal instantaneous trip unit rather than an externally adjustable trip unit

**LVPCBs**
- Available without instantaneous trip elements and with high short-time current ratings
- Some lower short-time current rating models are being introduced

*High interrupting capacity does not necessarily mean high short time current rating*