Normal current flows for an alternating 60-hertz circuit. When an overload occurs, the magnitude of the current increases.

The fault is symmetrical when the current has a wave shape that has equal magnitudes above and below the zero current axis.
The fault is asymmetrical when the current has a wave shape that has unequal magnitudes above and below the zero current axis.

Bolted fault condition represents solid connection.

Three-phase bolted faults typically result in the highest level of fault current.

Arcing faults – Three Phase
THREE-PHASE ARCING FAULT

A three-phase arcing fault 0.02 seconds after a screwdriver touched phase-to-ground.

TIME CURRENT CHARACTERISTIC CURVES

- Understanding how OCPDs respond to various levels of overcurrent (from light overloads to high level short-circuit currents).
- How to read time-current curves (TCCs) of an OCPD.

TIME CURRENT CHARACTERISTIC CURVES

- For 100A fuse, different overcurrent scenarios.
- The following slides will illustrate each scenario on a time-current curve.
Understanding the TCC
- TCC for 100A Class J fuse (dark solid line labeled)
- Logarithmic scales, not linear
- Horizontal axis: current axis (amperes)
- Vertical axis: time axis (seconds)

Scenario A

Scenario B
TIME CURRENT CHARACTERISTIC CURVES

Scenario C

Threshold of current-limiting range ≈ 1500A

Scenario D

Scenario E

Current-limiting
Considerations for Fuse Clearing Times

- Maintenance generally not an issue
- Can vary by fuse UL class
- Can vary by amp rating
- Can vary by vintage

**Typical Clearing Times for LV Fuses**

**Branch Circuit Breakers**

- Three Types Branch Circuit CBs
  - MCCBs
  - ICCBs
  - LVPCBs

**MCCB Frame Sizes and Amperes Ratings**

<table>
<thead>
<tr>
<th>Frame</th>
<th>18 mA rms</th>
<th>30</th>
<th>65</th>
<th>100</th>
<th>200</th>
<th>600</th>
<th>1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>15-250</td>
<td>70</td>
<td>100</td>
<td>200</td>
<td>400</td>
<td>800</td>
<td>1600</td>
</tr>
<tr>
<td>L</td>
<td>35</td>
<td>65</td>
<td>65</td>
<td>100</td>
<td>200</td>
<td>600</td>
<td>1200</td>
</tr>
<tr>
<td>N</td>
<td>35</td>
<td>65</td>
<td>65</td>
<td>100</td>
<td>200</td>
<td>600</td>
<td>1200</td>
</tr>
<tr>
<td>E</td>
<td>35</td>
<td>65</td>
<td>65</td>
<td>100</td>
<td>200</td>
<td>600</td>
<td>1200</td>
</tr>
</tbody>
</table>

- Molded Case Circuit Breakers

- Trip Unit: Electronic, Electronic
- Frame: Electronic, Electronic
TYPICAL CB OPENING TIMES

2002 IEEE 1584 Guide for Calculating Arc Flash Hazard

Table 1—Power circuit breaker operating times

<table>
<thead>
<tr>
<th>Circuit breaker rating and type</th>
<th>Opening time at 60 Hz</th>
<th>Opening time (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low voltage (in stalled case)</td>
<td>1.5</td>
<td>0.025</td>
</tr>
<tr>
<td>Low voltage (unstalled case)</td>
<td>3.0</td>
<td>0.650</td>
</tr>
<tr>
<td>Medium voltage (1-35 kV)</td>
<td>5.0</td>
<td>0.080</td>
</tr>
<tr>
<td>Some high voltage (20 kV)</td>
<td>8.0</td>
<td>0.130</td>
</tr>
</tbody>
</table>

*This table does not include the external relay trip times.

Qualifiers: LV CBs with instantaneous trip.

EXAMPLE: 200A THERMAL MAGNETIC MCCB

Carry Current Continuously

160A

EXAMPLE: 200A THERMAL MAGNETIC MCCB

190 s

600A

This is for IT = 10X.
**EXAMPLE: 200A THERMAL MAGNETIC MCCB**

- [Diagram showing current and time relationship]
- Example: 200A thermal magnetic MCCB
  - This is for IT = 10X
  - 0.018s
  - 10,000A

**TYPES OF OCPDs – CIRCUIT BREAKERS**

- 2000A CB with:
  - Short-time delay
  - Instantaneous override set at 12X
- When MCCBs and ICCBs have short-time delays, an instantaneous override is necessary to protect the CB.
  - Time in Second: 0.23s

**DIFFERENT TYPES OF CBs**

- CB curve on the right is a low voltage power circuit breaker equipped with a short-time delay and no instantaneous trip.
- CB curve on left has an instantaneous trip.
  - Time in Second: 0.18s
When there is a fault on the load side of CB3, CB3 opens instantaneously and sends a signal to CB2 and CB1 to hold off (short time delay).

**Typical Opening Times for Some Circuit Breakers**

- 150A (F Frame, Thermal Mag): 0.02 sec or less in instantaneous range
- 400A (J & K Frame, Thermal Mag or Elect Trip): 0.02 sec or less in instantaneous range
- Zone selective interlocking available 400A frame and above (0.04 sec.)
- 600A (L Frame, Thermal Mag, Elect Trip or Optimum Trip Unit): 0.02 sec or less in instantaneous range (typically 10X max)
- Zone selective interlocking available 400A frame and above (0.04 sec.)
- 1200A (N Frame, Elect Trip): 0.03 sec or less in instantaneous range (typically 8X max)
- Zone selective interlocking available 400A frame and above (0.04 sec.)
- 2500A (R Frame, Elect Trip): 0.05 sec or less in instantaneous range (typically 10X max)
- Zone selective interlocking available 400A frame and above (0.04 sec.)

**Current Limiting Circuit Breaker (Both Types):**

- 100A Current-R-Limiter (Slot motor design): 0.03 cycles or less
- 1/2 cycle or less about 20,000A or more
- 400A Current-R-Limiter (Slot motor design): 0.03 cycles or less
- 1/2 cycle or less about 30,000A or more
- 100A Tri-Pac (fused limiter design): 0.017 cycles or less
- 1/2 cycle or less about 7000A or more
- 400A Tri-Pac (fused limiter design): 0.017 cycles or less
- 1/2 cycle or less about 10,000A or more
### Typical Opening Times for Some Circuit Breakers

#### Insulated Case Circuit Breaker (SPB w/Digitrip Unit):
- w/short time delay - Up to 30 Cycles, until to instantaneous override.
- w/instantaneous override - 0.05 sec (3 cycles)

<table>
<thead>
<tr>
<th>Current Range</th>
<th>Breaking Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>400-800</td>
<td>25kA</td>
</tr>
<tr>
<td>1200</td>
<td>35kA</td>
</tr>
<tr>
<td>1600-3000</td>
<td>35-51kA</td>
</tr>
<tr>
<td>4000-5000</td>
<td>65-85kA</td>
</tr>
</tbody>
</table>

#### Low Voltage Drawout Circuit Breaker (DS w/Digitrip Trip Unit):
- w/out Instantaneous Trip - Up to 30 Cycles, depending upon the short time delay setting.
- w/Instantaneous Trip (no short time delay): 0.07 sec (between 4-5 cycles)
- w/fused limiter (DSL): half cycle or less (in current limiting range, fault would need to be approx 12-15 times limiter rating)

#### Considerations for CB Opening Times
- Depends on condition of maintenance
- Can vary by manufacturer
- Can vary by type
- Can vary by frame size
- Can vary on options and settings
- Can vary by vintage
  - Older circuit breakers may be slower operating designs (even if CB is in original operation condition)