

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
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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 - 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

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

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

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

Frame Size	Minimum Operation Rate (cycles/hour)		Number of Operating Cycles							
	ANSI C37.50		Between Servicing		With Current		Without Current		Total	
	UL489	ANSI C37.50	UL489*	ANSI C37.50	UL489	ANSI C37.50	UL489	ANSI C37.50	UL489	ANSI C37.50
225	300	30	-	2500	4000	4000	4000	10000	8000	14000
400	240	-	-	-	1000	-	5000	-	6000	-
600	240	30	-	1750	1000	2800	5000	9700	6000	12500
800	60	30	-	1750	500	2800	3000	9700	3500	12500
1200	60	-	-	-	500	-	2000	-	2500	-
1600	60	30	-	500	500	800	2000	3200	2500	4000
2000	60	30	-	500	500	800	2000	3200	2500	4000
2500	60	-	-	-	500	-	2000	-	2500	-
3000	60	30	-	250	400	400	1100	1100	1500	1500
4000	60	30	-	250	400	400	1100	1100	1500	1500

Chapter 3 - MCCB/ICCB Interrupting Ability

Test Number*	Tested In Sequence Number (Table 7.1.1.2)	Duty Cycle (Table 7.1.7.1)	Number of Poles (Table 7.1.7.1)	Maximum Rated Voltage (Table 7.1.7.1)	Actual Test Current (rms symmetrical kA) (Table 7.1.7.2)										
					Frame Rating (amperes)										
					225	600	800	1200	1600	2000	2500	3000	4000		
2	Z	O-CO	1	600	8.6	8.6	8.6	12.1	14	14	20	25	30		
3	Z	O-CO	1	600	8.6	8.6	8.6	12.1	14	14	20	25	30		
4	Z	O-CO	1	600	8.6	8.6	8.6	12.1	14	14	20	25	30		
6	Z	O	3	600	10	10	10	14	-	-	-	-	-		
7	Z	O	3	600	-	-	-	-	20	25	30	35	45		
9	Y	O-CO	3	600	3	6	10	14	20	25	30	35	45		
Test Number†	Duty Cycle	Number of Poles	Trip Rating	Actual Test Current (Tables 7.1.11.1.1 and 8.1)											
A	O-CO	3	Maximum	Same as maximum interrupting capacity rating											
B	O-CO	3	Maximum	I/C rating at maximum voltage rating											
C	O-CO	3	Maximum	I/C at maximum kVA rating											
D	O-CO	3	Minimum	Maximum I/C rating											

* Tests 1 through 9 are standard interrupting capacity tests.
† Tests A through D are high interrupting capacity tests.

Chapter 3 - LVPCB Interrupting Ability

Test Number	Tested In Sequence Number	Duty Cycle	Number of Poles	Maximum Rated Voltage	Actual Test Current (rms symmetrical kA)										
					Frame Rating (amperes)										
					225	600	800	1600	2000	3000	3200	4000			
1	I	O-CO	3	635	14	22	22	42	42	65	65	85			
2	II	O-CO	3	508	22	30	30	50	50	65	65	85			
3	II	O-CO	3	254	25	42	42	65	65	85	85	130			
4	II	O-CO	1	635	12.2	19.1	19.1	36.5	36.5	56.6	56.6	74			
5	II	O-CO	1	508	19.1	26.1	26.1	43.5	43.5	56.6	56.6	74			
6	II	O-CO	1	254	21.8	36.5	36.5	56.6	56.6	74	74	113.1			
7	III	O	3	635	14	22	22	42	42	65	65	85			
8	IV	O-CO	3	635	14	22	22	42	42	65	65	85			

* 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 LVPCBs*
- *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)

Type of Circuit Breaker	Interrupting Rating (kA)	Power Factor Test Range	X/R Test Range
Molded Case	10 or less	0.45 – 0.50	1.98 - 1.73
Molded Case	over 10 to 20	0.25 – 0.30	3.87 - 3.18
Molded Case	over 20	0.15 – 0.20	6.6 - 4.9
Low-Voltage Power	all	0.15 max.	6.6 min.

Chapter 3 - Multiplying Factors

% P.F.	X/R	Interrupting Rating			
		≤ 10 kA	> 10 kA ≤ 20 kA	> 20 kA	All LV PCB
20	4.8990	0.762	0.899	1.000	1.000
15	6.5912	0.718	0.847	0.942	1.000
12	8.2731	0.691	0.815	0.907	0.962
10	9.9499	0.673	0.794	0.883	0.937
9	11.7221	0.659	0.778	0.865	0.918
7	14.2507	0.645	0.761	0.847	0.899
5	19.9750	0.627	0.740	0.823	0.874

Chapter 3 - Overload Performance

Frame Size (amps)	Minimum Operation Rate (cycles/hour)		Number of Operating Cycles	
	UL489	ANSI C37.50*	UL489	ANSI C37.50*
225	300	60	50	50
400	240	-	50	-
600	240	60	50	50
800	60	60	50	50
1200	60	-	50	-
1600	60	60	50	38
2000	60	60	25	38
2500	60	-	25	-
3000	60	N/A	28	N/A
4000	60	N/A	28	N/A

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 MCCBs*
- *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

Chapter 4 - Comparison of Features

LVPCB	ICCB	MCCB
Selective trip over full range of fault currents up to interrupting rating.	Selective trip over partial range of fault currents within interrupting rating.	Selective trip over a smaller range of fault currents within interrupting rating.
Types of operators: mechanically operated, two-step, stored energy, and electrical two-step stored energy.	Types of operators: mechanically operated, two-step, stored energy, and electrical two-step stored energy.	Types of operators: mechanically operated over-center toggle or motor operator.
Available in draw-out construction permitting racking to a distinct "test position" and removal for maintenance.	Available in draw-out construction permitting racking to a distinct "test position" and removal for maintenance.	Some are available in plug-in design allowing removal for inspection and maintenance. Large frame sizes may be available in draw-out construction.
Operation counter is available.	Operation counter is available.	Operation counter is available.
Interrupting duty at 480 Vac; 22-100 kA without fuses and up to 200 kA with fuses.	Interrupting duty at 480 Vac; 22-100 kA	Interrupting duty at 480 Vac; 22-65 kA without fuses and up to 200 kA with integral fuses or for current-limiting type.

Chapter 4 - Comparison of Features

LVPCB	ICCB	MCCB
Current limiting available only with fuses.	Current limiting not available.	Current limiting available with and without fuses.
Usually most costly.	Usually mid-range cost, but depends on the enclosure selected.	Usually least costly.
Small number of frame sizes available.	Small number of frame sizes available.	Large number of frame sizes available.
Extensive maintenance possible on all frame sizes.	Limited maintenance possible on larger frame sizes.	Limited maintenance possible on larger frame sizes.
Used in enclosures, switchboards, and switchgear.	Used in enclosures, switchboards, and switchgear.	Used in enclosures, panelboards, and switchboards.
Not available in series ratings.	Not available in series ratings.	Available in series ratings.
100% continuous current rated in its enclosure	80% continuous-current rated, unless specifically stated to be rated 100% in an enclosure.	80% continuous-current rated, unless specifically stated to be rated 100% in an enclosure.
IEEE Standard C37.13	UL 489	UL 489

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*

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

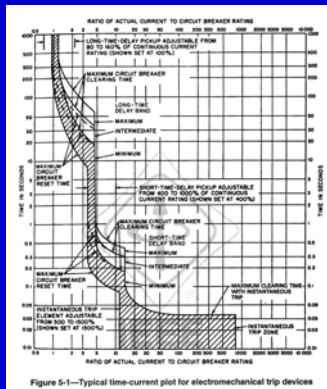
LVPCBs

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

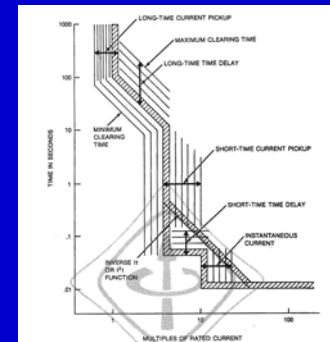
MCCBs and ICCBs

- *Thermal-magnetic circuit breakers*
- *Electronic trip devices*
- *Long-time and short-time delay protection*
- *Instantaneous protection*
- *Ground-fault protection*

Chapter 5 - Selective Coordination



Chapter 5 - Selective Coordination



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

**Overview of IEEE Standard 1015-1997
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Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems

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