Changes for the Better

MITSUBISHI
ELECTRIC

MOULDED CASE CIRCUIT BREAKERS

TECHNICAL NOTES

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We have the pleasure of providing all our customers with the technical information for Mitsubishi moulded case circuit breakers. This indicates the fundamental data of our circuit breakers regarding the applicable standards, constructional principles, and operational performances. Please refer to the catalogue of our circuit breakers for details of specifications.
Also please stand in need of the handling and maintenance manual for maintaning the circuit breakers in service continuously.
We do hope they are available for all our customers to built more efficient systems.

CONTENTS

1. INTRODUCTION

Mitsubishi Advancing Technology

Mitsubishi, the leading manufacturer of circuit breakers, has been providing customers with a wide range of highly reliable and safe moulded case circuit breakers (MCCB) and earth-leakage circuit breakers (ELCB), corresponding to the needs of the age.

Since production began in 1933 many millions of Mitsubishi ACBs, MCCBs and MCBs have been sold throughout many countries.

In 1985 a new design concept for controlling arc energies within MCCBs – vapour jet control (VJC) – was introduced and significantly improved performance. It is provided the technological advance for a new 'super series' range of MCCBs and is used in all present ratings from 3 to 1600 amps.

In 1995 PSS (Progressive Super Series) having four major features.

- Circuit-breaking technology ISTAC for a higher current-limiting performance.
- Electronic circuit breaker with the Digital ETR protecting the circuit accurately.
- One-frame, one-size design allowing efficient panel design.
- Cassette-type internal accessories that allow installation by the user.

In 2001 Mitsubishi present the WSS (World Super Series) breakers having rating from 3 to 250amps that concentrate the most advanced technologies.

- Polymer Ablation type Auto-Puffer
- Jet Pressure Trip Mechanism
- Advanced Impulsive Slot-type Accelerator
- Shunt-less Current Flow Technology

Targets one-class higher performance, in realizing superb breaking performance.

A Brief Chronology

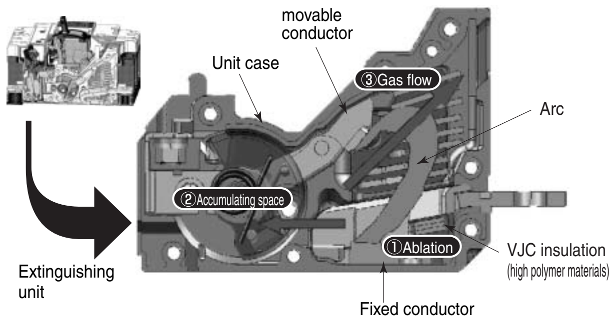
1933	Moulded case circuit breaker production begins.
1952	Miniature circuit breaker production begins.
1968	Manufacture commences of short-time-delayed breakers.
1969	Production and sale of first residual current circuit breakers.
1970	170kA breaking level 'permanent power fuse' integrated MCCBs is introduced.
1973	Introduction of first short-time delay and current-limiting selectable breakers go on sale.
1974	First MELNIC solid-state electronic trip unit MCCBs are introduced.
1975	ELCBs with solid-state integrated circuit sensing devices are introduced.
1977-1979	Four new ranges of MCCBs are introduced – economy, standard, current limiting, ultra current limiting and motor rated designs – a comprehensive coverage of most application requirements.
1982	Compact ACBs with solid-state trip devices and internally mounted accessories introduced.
1985-1989	Super series MCCBs with VJC and ETR are developed and launched – awarded the prestigious Japanese Minister of Construction Prize.
1990	New 200kA level U-series MCCBs super current limiting breakers are introduced.
1991	Super-NV ELCBs and Super-AE ACBs are introduced.
1995	Progressive Super Series from 30 to 250 amps are introduced.
1997	Progressive Super Series from 400 to 800 amps are introduced.
2001	World Super Series from 30 to 250amps are introduced.
2004	UL489 Listed MCCBs are introduced.
2004	World Super-AE ACBs are introduced.
2006	White & World Super Series are introduced.

2. FEATURES – Advanced MCCB Design Technology & Performance

2.1 [PA Auto-Puffer]

Polymer Ablation type Auto-Puffer [Adopted on SGW, HGW, RGW, UGW]

PA auto-Puffer is the technology to increase the interrupting performance by blowing out the gas to the arc by right angle. The gas pressure which is generated from high-polymer materials is accumulated in the accumulating space, and the gas is blown to the arc to extinguish. Especially this technology improves the high voltage breaking performance.



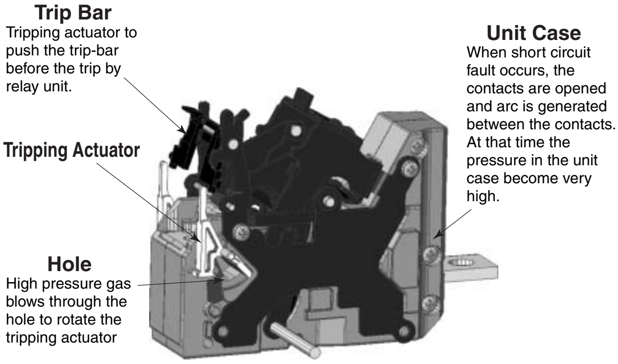
Arc Extinguishing Concept

①Ablation ⇒ ②Gas accumulating ⇒ ③Gas flow ⇒ Arc extinguishing

2.2 [JPT]

Jet Pressure Trip Mechanism [Adopted on SGW, HGW, RGW, UGW]

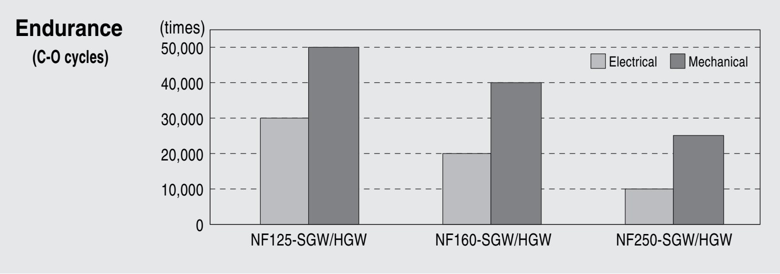
Ablation gas jet through the hole installed on the unit case directly activates the trip mechanism. This acts faster than the relay (magnet), and contributes to improved current-limiting performance and breaking reliability.

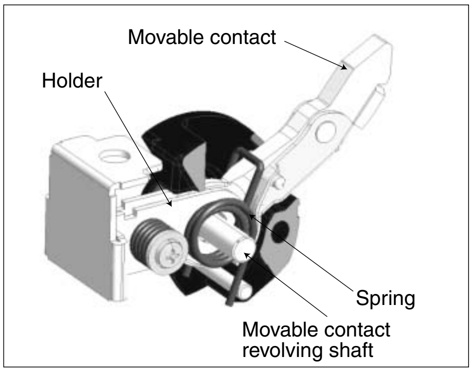


2.3 [Shunt-less]

Shunt-less Current Flow Technology [Adopted on SGW, HGW, RGW, UGW]

Double plates conductors hold the movable conductor without flexible wires. This shunt-less structure achieves the increased operating cycles.



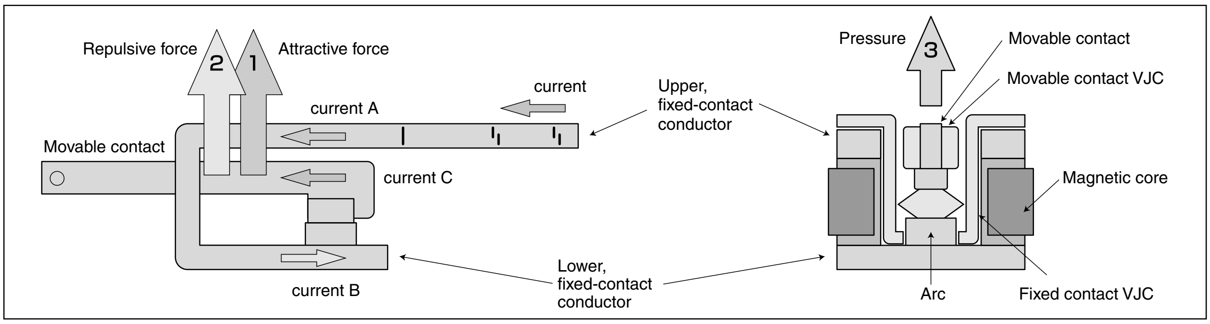


During revolution the movable contact is constantly in contact with the holder, maintaining current flow.

2.4 [Advanced ISTAC] Advanced Impulsive Slot-Type Accelerator [Adopted on SGW, HGW, RGW, UGW]

Further evolution in Mitsubishi original ISTAC breaking technology*. Optimization of the current path and the added magnetic core enhance driving electromagnetic forces. By the high-speed opening and the arc driving, the rising rate of arc voltage is increased and the peak current "Ip" is decreased.

*The triple forces which are the repulsive force, the attractive force, and the pressure accelerate the separating speed of the movable conductor.



(1) Electromagnetic attractive force between Current A and Current C
(2) Electromagnetic repulsive force between Current B and Current C
(3) Ablation gas pressure

These three forces generated high-speed drive

2.5 Equipment of High Technology

2.5.1 World Super Series

Series	Type		Advanced Technology					
			Advanced ISTAC	ISTAC	JPT	Shunt-less	PA-Auto-Puffer	Digital-ETR
NF-S	NF32-SW							
	NF63-SW							
	NF125-SW			●		●		
	NF125-SGW	RT	●		●	●	●	
		RE	●		●	●	●	●
	NF160-SW							
	NF160-SGW	RT	●		●	●	●	
		RE	●		●	●	●	●
	NF250-SW							
	NF250-SGW	RT	●		●	●	●	
		RE	●		●	●	●	●
NF-H	NF63-HW							
	NF125-HW			●				
	NF125-HGW	RT	●		●	●	●	
		RE	●		●	●	●	●
	NF160-HW			●				
	NF160-HGW	RT	●		●	●	●	
		RE	●		●	●	●	●
	NF250-HW			●				
	NF250-HGW	RT	●		●	●	●	
		RE	●		●	●	●	●
NF-C	NF63-CW							
	NF125-CW	125A	●	●	●	●	●	
		100 or less	●		●	●	●	
	NF250-CW							
NF-U	NF125-RGW	RT	●		●	●	●	
	NF125-UGW	RT	●		●	●	●	
	NF250-RGW	RT	●		●	●	●	
	NF250-UGW	RT	●		●	●	●	

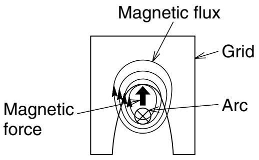
Series	Type	Advanced Technology					
		Advanced ISTAC	ISTAC	JPT	Shunt-less	PA-Auto-Puffer	Digital-ETR
NF-S	NF400-SW				●		
	NF400-SEW				●	●	●
	NF630-SW				●	●	
	NF630-SEW				●	●	●
	NF800-SEW				●		●
	NF800-SDW				●		
	NF1000-SEW						●
	NF1250-SEW						●
	NF1250-SDW						
	NF1600-SEW						●
	NF1600-SDW						
NF-H	NF400-HEW				●	●	●
	NF400-REW				●	●	●
	NF630-HEW				●	●	●
	NF630-REW				●	●	●
	NF800-HEW				●		●
	NF800-REW				●		●
NF-C	NF400-CW				●		
	NF630-CW				●	●	
	NF800-CEW				●		●
NF-U	NF400-UEW				●	●	●
	NF800-UEW				●		●

3. CONSTRUCTION AND OPERATION

3.1 General

The primary components are: a switching mechanism, an automatic tripping device (and manual trip button), contacts, an arc-extinguishing device, terminals and a molded case.

Arc-Extinguishing Device
Mitsubishi MCCBs feature excellent arc-extinguishing performance by virtue of the optimum combination of grid gap, shape, and material.

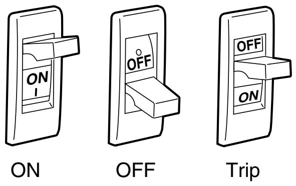


Arc extinction

Trip Button (Push to Trip)
Enables tripping mechanically from outside, for confirming the operation of the accessory switches and the manual resetting function.

Handle

1. Trip indication
   The automatically tripped condition is indicated by the handle in the center position between ON and OFF, the yellow (or white) line cannot be seen in this position.
2. Resetting
   Resetting after tripping is performed by first moving the handle to the OFF position to engage the mechanism, then returning the handle to ON to reclose the circuit.
3. Trip-Free
   Even if the handle is held at ON, the breaker will trip if an overcurrent flows.



Handle indication

4. Contact On Mechanism
   Even in the worst case in which welding occurs owing to an overcurrent, the breaker will trip and the handle will maintain to ON, indicating the energizing state.

Switching Mechanism
The contacts open and close rapidly, regardless of the moving speed of the handle, minimizing contact wear and ensuring safety.

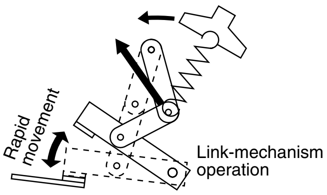


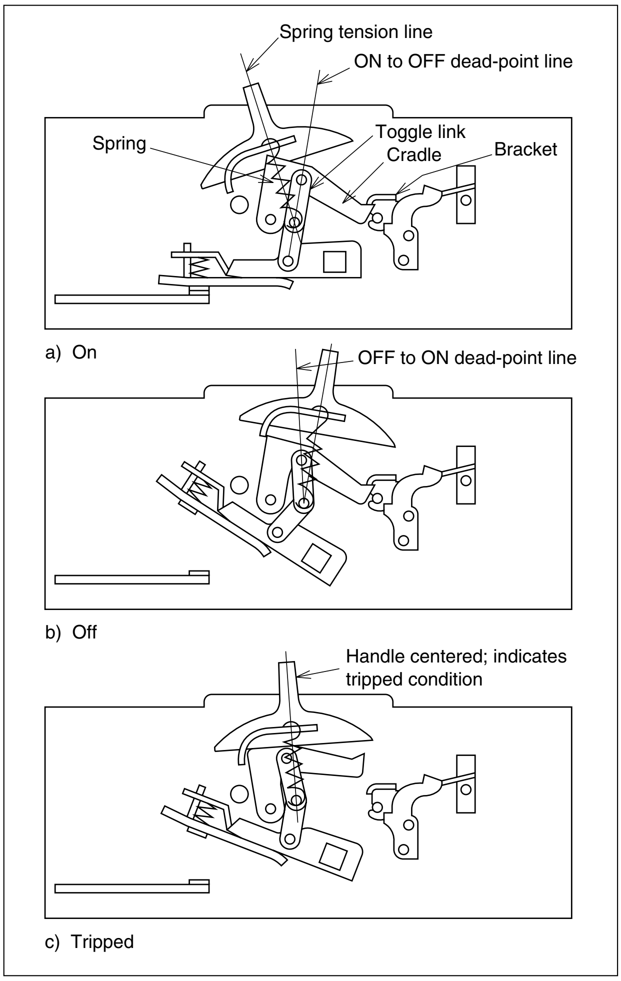
Fig. 3.1 Type NF125-HGW Construction

3.2 Switching Mechanism

The ON, OFF and TRIPPED conditions are shown in Fig. 3.2. In passing from ON to OFF, the handle tension spring passes through alignment with the toggle link (“dead point” condition). In so doing, a positive, rapid contact-opening action is produced; the OFF to ON contact closing acts in a similar way (“quick make” and “quick break” actions). In both cases the action of the contacts is always rapid and positive, and independent of the human element – i.e., the force or speed of the handle.

In auto tripping a rotation of the bracket releases the cradle and operates the toggle link to produce the contact-opening action described above. In the tripped condition the handle assumes the center position between on and off, providing a visual indication of the tripped condition. Also, auto trip is “trip free,” so that the handle cannot be used to hold the breaker in the ON condition. The protective contact-opening function cannot be defeated.

In multipole breakers the poles are separated by integral barriers in the molded case. The moving contacts of the poles are attached to the central toggle link by a common-trip bar, however, so that tripping, opening and closing of all poles is always simultaneous. This is the “common trip” feature, by which single phasing and similar unbalance malfunctions are effectively prevented.



a) On

b) Off

c) Tripped

Fig. 3.2 Switching Mechanism Action

3.3 Automatic Tripping Device

There are three types of device, the thermal-magnetic type, the hydraulic-magnetic type and the electronic trip relay type.

■Automatic Tripping Devices

●Thermal-Magnetic Type

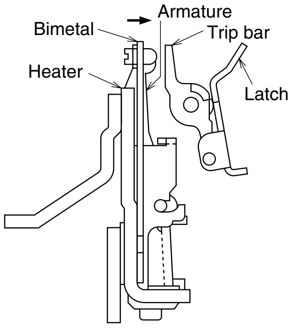


Fig. 3.3

1. Time-Delay Operation
   An overcurrent heats and warps the bimetal to actuate the trip bar.
2. Instantaneous Operation
   If the overcurrent is excessive, the amature is attracted and the trip bar actuated.

●Thermal-Magnetic Type

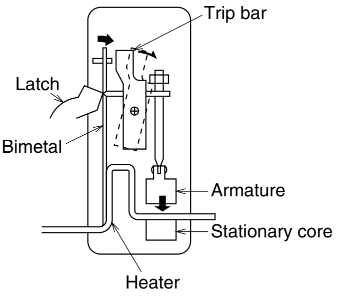


Fig. 3.4

1. Time-Delay Operation
   An overcurrent heats and warps the bimetal to actuate the trip bar.
2. Instantaneous Operation
   If the overcurrent is excessive, magnetization of the stationary core is strong enough to attract the armature and actuate the trip bar.

●Hydraulic-Magnetic Type

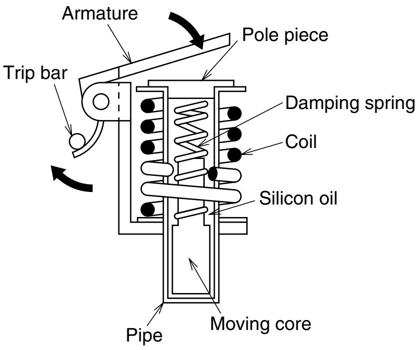


Fig. 3.5

1. Time-Delay Operation
   At an overcurrent flow, the magnetic force of the coil overcomes the spring, the core closes to the pole piece, attracts the armature, and actuates the trip bar. The delay is obtained by the viscosity of silicon oil.
2. Instantaneous Operation
   If the overcurrent is excessive, the armature is instantly attracted, without the influence of the moving core.

●Principle of Electronic Trip Relay (ETR) Operation

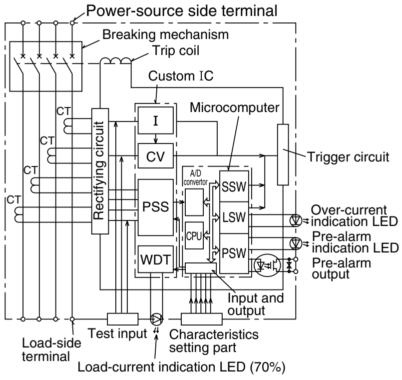
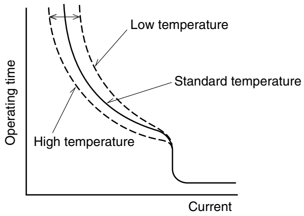
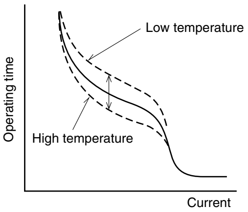
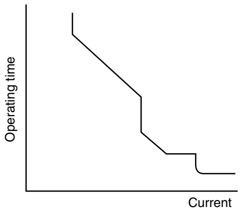
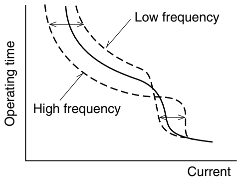
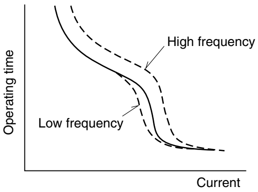
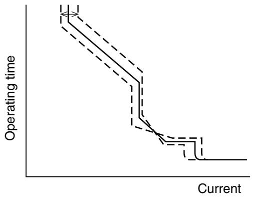
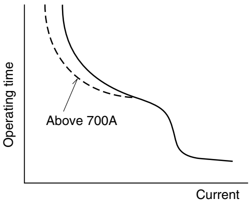
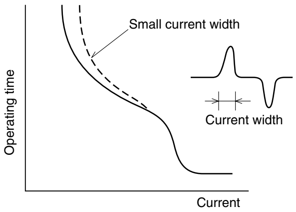
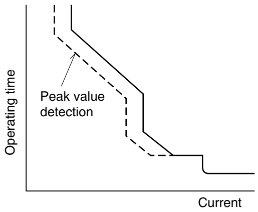
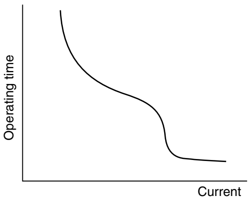
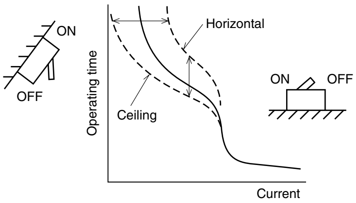
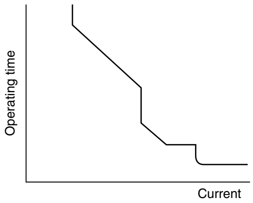
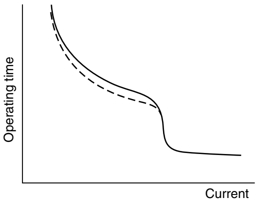
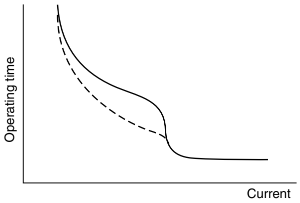
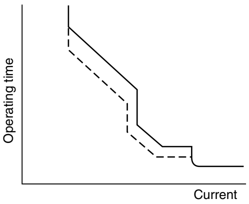


Fig. 3.6

1. The current flowing in each phase is monitored by a current transformer (CT).
2. Each phase of the transformed current undergoes full-phase rectification in the rectifier circuit.
3. After rectification, each of the currents are converted by a peak-conversion and an effective-value conversion circuit.
4. The largest phase is selected from the converted currents.
5. Each time-delay circuit generates a time delay corresponding to the largest phase.
6. The trigger circuit outputs a trigger signal.
7. The trip coil is excited, operating the switching mechanism.

Table 3.1 Comparison of Thermal-Magnetic, Hydraulic-Magnetic and Electronic Types

Item	Thermal-magnetic type	Hydraulic-magnetic type	Electronic type
Ambient temperature	Operating current is affected by ambient temperature (bimetal responds to absolute temperature not temperature rise). 	Affected only to the extent that the damping-oil viscosity is affected. 	Negligible effect 
Frequency	Negligible effect up to several hundred Hz; above that the instantaneous trip is affected due to increased iron losses. 	Trip current increases with frequency, due to increased iron losses. 	Tripping current of some types decrease due to CT or condition of operating circuit with high frequency, and others increase. 
Distorted wave	Negligible effect up to 630A; Above that operating current decreases due to increase of a fever. 	IF distortion is big, minimum operating current increases. 	For peak value detection, operating current drops. 
Mounting attitude	Negligible effect. 	Mounting attitude changes the effective weight of the magnetic core. 	Negligible effect 
Flexibility of operating characteristics	Bimetal must provide adequate deflection force and desired temperature characteristic. Operating time range is limited. 	Oil viscosity, cylinder, core and spring design, etc., allow a wide choice of operating times. 	Operating time can be easily shortened. To lengthen operating time is not. 
Flexibility of rated current	Units for small rated currents are physically impractical.	Coil winding can easily be designed to suit any ampere rating.	Within the range of 50(60)~100% of rated current, any ampere rating are practical. Also, to lower the value of short-time delay or instantaneous trip can be easily done comparatively.

3.4 Contacts

A pair of contacts comprises a moving contact and a fixed contact. The instants of opening and closing impose the most severe duty. Contact materials must be selected with consideration to three major criteria:

1. Minimum contact resistance
2. Maximum resistance to wear
3. Maximum resistance to welding

Silver or silver-alloy contacts are low in resistance, but wear rather easily. Tungsten, or majority-tungsten alloys are strong against wear due to arcing, but rather high in contact resistance. Where feasible, 60%+ silver alloy (with tungsten carbide) is used for contacts primarily intended for current carrying, and 60%+ tungsten alloy (with silver) is used for contacts primarily intended for arc interruption. Large-capacity MCCBs employ this arrangement, having multicontact pairs, with the current-carrying and arc-interruption duties separated.

3.5 Arc-Extinguishing Device

Arcing, an inevitable aspect of current interruption, must be extinguished rapidly and effectively, in normal switching as well as protective tripping, to minimize deterioration of contacts and adjacent insulating materials. In Mitsubishi MCCBs a simple, reliable, and highly effective “de-ion arc extinguisher,” consisting of shaped magnetic plates (grids) spaced apart in an insulating supporting frame, is used (Fig. 3.7). The arc (ionized-path current) induces a flux in the grids that attracts the arc, which tends to “lie down” on the grids, breaking up into a series of smaller arcs, and also being cooled by the grid heat conduction. The arc (being effectively longer) thus requires far more voltage to sustain it, and (being cooler) tends to lose ionization and extinguish. If these two effects do not extinguish the arc, as in a very large fault, the elevated temperature of the insulating frame will cause gassing-out of the frame material, to de-ionize the arc. Ac arcs are generally faster extinguishing due to the zero-voltage point at each half cycle.

3.6 Molded Case

The integral molded cases used in Mitsubishi MCCBs are constructed of the polyester resin containing glass fibers, the phenolic resin or glass reinforced nylon. They are designed to be suitably arc-, heat- and gas-resistant, and to provide the necessary insulating spacings and barriers, as well as the physical strength required for the purpose.

3.7 Terminals

These are constructed to assure electrical efficiency and reliability, with minimized possibility of localized heating. A wide variety of types are available for ease of mounting and connection. Compression-bonded types and bar types are most commonly used.

3.8 Trip Button

This is a pushbutton for external, mechanical tripping of the MCCB locally, without operating the external-accessory shunt trip or undervoltage trip, etc. It enables easy checking of breaker resetting, control-circuit devices associated with alarm contacts, etc., and resetting by external handle.

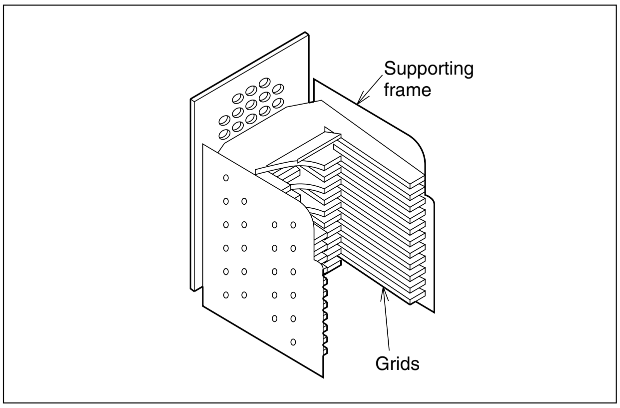


Fig. 3.7 The De-Ion Arc Extinguisher

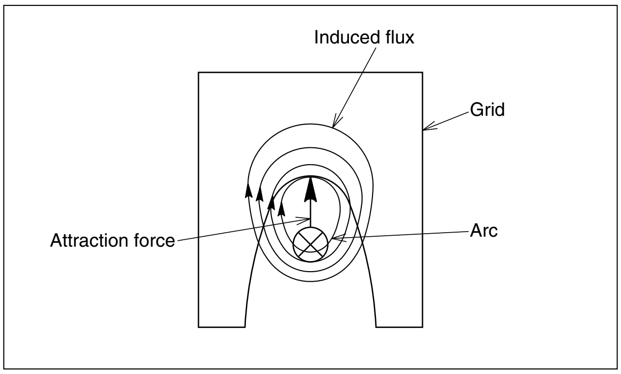


Fig. 3.8 The Induced-Flux Effect

4. CHARACTERISTICS AND PERFORMANCE

4.1 Overcurrent-Trip Characteristics (Delay Tripping)

Tripping times for overcurrents of 130 and 200% of rated current are given in Table 4.1, assuming ambient temperatures of 40°C, a typical condition inside of panelboards. The figures reflect all poles tested together for 130% tripping, and 105% non-tripping. Within the range of the long-delay-element (thermal or hydraulic) operation, tripping times are substantially linear, in inverse relationship to overcurrent magnitude.

The tripping times are established to prevent excessive conductor-temperature rise; although times may vary among MCCBs of different makers, the lower limit is restricted by the demands of typical loads: tungsten-lamp inrush, starting motor, mercury-arc lamps, etc. The tripping characteristics of Mitsubishi MCCBs are established to best ensure protection against abnormal currents, while avoiding nuisance tripping.

4.1.1 Ambient Temperature and Thermal Tripping

Fig. 4.1 is a typical ambient compensation curve (curves differ according to types and ratings), showing that an MCCB rated for 40°C ambient use must be derated to 90% if used in a 50°C environment. In an overcurrent condition, for the specified tripping time, tripping would occur at 180% rated current, not 200%. At 25°C, for the same tripping time, tripping would occur at 216%, not 200%.

4.1.2 Hot-State Tripping

The tripping characteristics described above reflect "cold-state tripping" – i.e., overloads increased from zero – and the MCCB stabilized at rated ambient. This is a practical parameter for most uses, but in intermittent operations, such as resistance welding, motor pulsing, etc., the "hot state" tripping characteristic must be specified, since over-loads are most likely to occur with the MCCB in a heated state, while a certain load current is already flowing.

Where the MCCB is assumed to be at 50% of rating when the overload occurs, the parameter is called the 50% hot-state characteristic; if no percentage is specified, 100% is assumed. Hot-state ratings of 50% and 75% are common.

4.2 Short-Circuit Trip Characteristics (Instantaneous Tripping)

For Mitsubishi MCCBs with thermal-magnetic trip units the instantaneous-trip current can be specified independently of the delay characteristic, and in many cases this parameter is adjustable offering considerable advantage in coordination with other protection and control devices. For example, in coordination with motor starters, it is important to set the MCCB instantaneous-trip element at a lower value than the fusing (destruction) current of the thermal overload relay (OLR) of the starter.

For selective tripping, it must be remembered that even though the branch-MCCB tripping time may be shorter than the total tripping time of the main MCCB, in a fault condition the latter may also be tripped because its latching curve overlaps the tripping curve of the former. The necessary data for establishing the required compatibility is provided in the Mitsubishi MCCB sales catalogues.

The total clearing time for the "instantaneous" tripping feature is shown in Fig. 4.3; actual values differ for each MCCB type.

Table 4.1 Overcurrent Tripping Times

Rated current (A)	Tripping time (minutes, max.)		Non-Tripping time (minutes, max.)
	200%	130%	105%
30 or less	8.5	60	60
31~63	4	60	60
64~100	8.5	120	120
101~250	8	120	120
251~400	10	120	120
401~630	12	120	120
631~800	14	120	120
801~1000	16	120	120
1001~1250	18	120	120
1251~1600	20	120	120
1601~2000	22	120	120
2001~4000	24	120	120

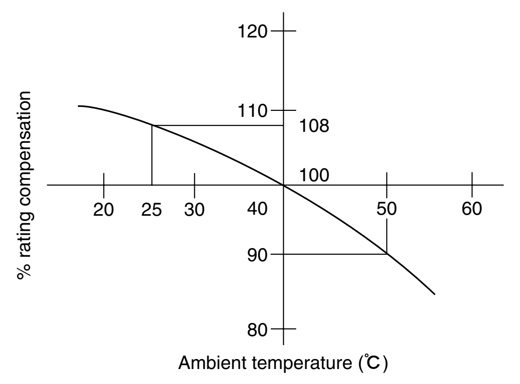


Fig. 4.1 Typical Temperature-Compensation Curve

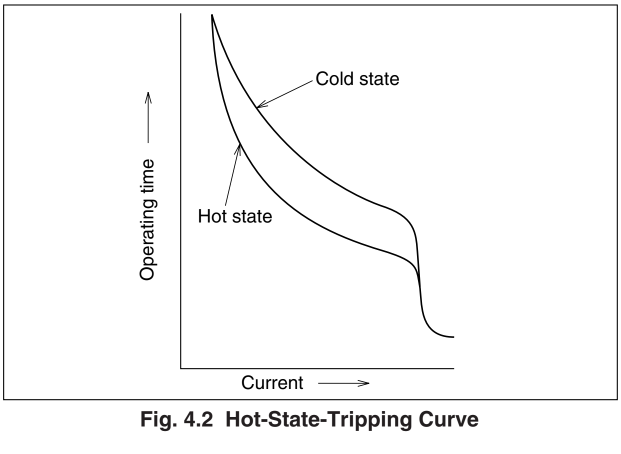


Fig. 4.2 Hot-State-Tripping Curve

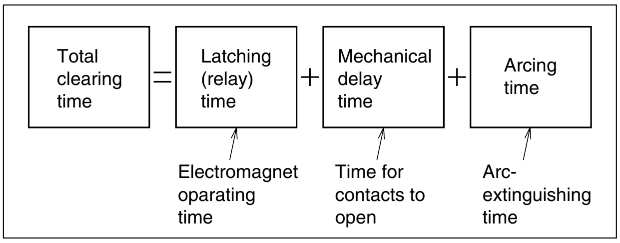


Fig. 4.3 Instantaneous Tripping Sequence

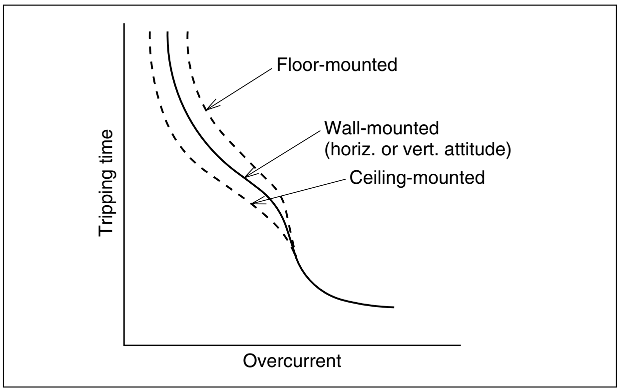


Fig. 4.4 Effect of Mounting Attitude on the Hydraulic-Magnetic MCCB Tripping Curves

4.3 Effects of Mounting Attitudes

Instantaneous tripping is negligibly affected by mounting attitude, for all types of MCCB. Delay tripping is also negligibly affected in the thermal types, but in the hydraulic-magnetic types the core-weight effect becomes a factor. Fig. 4.4 shows the effect, for vertical-surface mounting and for two styles of horizontal-surface mounting.

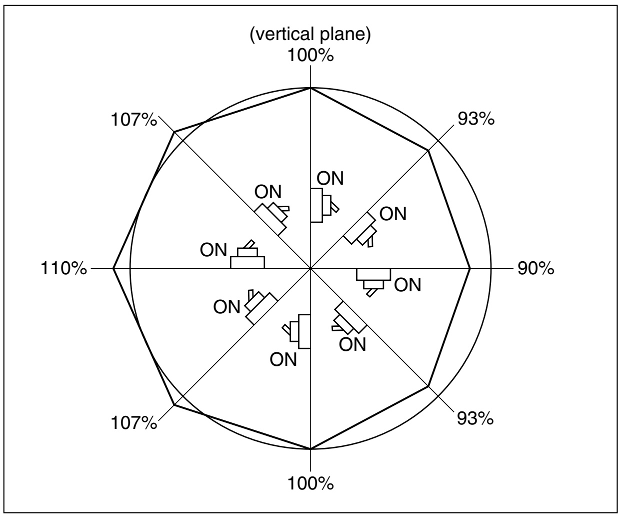
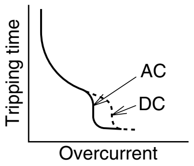
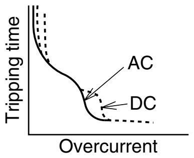


Fig. 4.5 Effects of Nonvertical-Plane Mounting on Current Rating

4.4 DC Tripping Characteristics of AC-Rated MCCBs

Table 4.2 DC Tripping Characteristics

Trip unit	Long delay	Instantaneous	Tripping curve
Thermal magnetic	No effect below 630A frame. Above this, AC types cannot be used for DC.	DC inst.-trip current is approx. 130% of AC value.	
Hydraulic magnetic	DC minimum-trip values are 110~140% of AC values.		

4.5 Frequency Characteristics

At commercial frequencies the characteristics of Mitsubishi MCCBs of below 630A frame size are virtually constant at both 50Hz and 60Hz (except for the E Line models, the characteristics of MCCBs of 2000A frame and above vary due to the CT used with the delay element).

At high frequencies (e.g., 400Hz), both the current capacity and delay tripping curves will be reduced by skin effect and increased iron losses.

Performance reduction will differ for different types; at 400Hz it will become 80% of the rating in breakers of maximum rated current for the frame size, and 90% of the rating in breakers of half of the maximum rating for the frame size.

The instantaneous trip current will gradually increase with frequency, due to reverse excitation by eddy currents. The rise rate is not consistent, but around 400Hz it becomes about twice the value at 60Hz. Mitsubishi makes available MCCBs especially designed for 400Hz use. Apart from operating characteristics they are identical to standard MCCBs (S Line).

4.6 Switching Characteristics

The MCCB, specifically designed for protective interruption rather than switching, and requiring high-contact pressure and efficient arc-extinguishing capability, is expected to demonstrate inferior capability to that of a magnetic switch in terms of the number of operations per minute and operation life span. The specifications given in Table 4.3 are applicable where the MCCB is used as a switch for making and breaking rated current.

Electrical tripping endurance in MCCBs with shunt or undervoltage tripping devices is specified as 10% of the mechanical-endurance number of operations quoted in IEC standards.

Shunt tripping or undervoltage tripping devices are intended as an emergency trip provision and should not be used for normal circuit-interruption purposes.

Table 4.3 MCCB Switching Endurance (IEC60947-2)

Frame size	Operations per hour	Number of operations		
		Without current	With current	Total
125 or less	120	8500	1500	10000
250	120	7000	1000	8000
400, 630	60	4000	1000	5000
800	20	2500	500	3000
1000~2000	20	2500	500	3000
2500, 3000	10	1500	500	2000
3200, 4000	10	1500	500	2000

4.7 Dielectric Strength

In addition to the requirements of the various international standards, Mitsubishi MCCBs also have the impulse-voltage withstand capabilities given below (Table 4.4). The impulse voltage is defined as substantially square-wave, with a crest length of 0.5~1.5μsec and a tail-length of 32~48μsec. The voltage is applied between line and load terminals (MCCB off), and between live parts and ground (MCCB on).

Table 4.4 MCCB Impulse Withstand Voltage (Uimp)

Line		Type	Impulse-voltage (kA)
MB		MB30-CS	4
		MB30-SW MB50-CW MB50-SW MB100-SW MB225-SW	6
NF	S	NF32-SW NF63-SW NF63-HW NF160-SW NF160-HW NF250-SW NF250-HW	6
		NF125-SW NF125-SGW NF125-HW NF125-HGW NF160-SGW NF160-HGW NF250-SGW NF250-HGW NF400-SW NF400-SEW NF400-HEW NF400-REW NF630-SW NF630-SEW NF630-HEW NF630-REW NF800-SEW NF800-HEW NF800-REW NF1000-SEW NF1250-SEW NF1600-SEW	8
	C	NF30-CS	4
		NF63-CW NF250-CW	6
		NF125-CW NF400-CW NF630-CW NF800-CEW	8
	U	NF125-RGW NF125-UGW NF250-RGW NF250-UGW	8
		NF400-UEW NF800-UEW	8

5. CIRCUIT BREAKER SELECTION

5.1 Circuit Breaker Selection Table

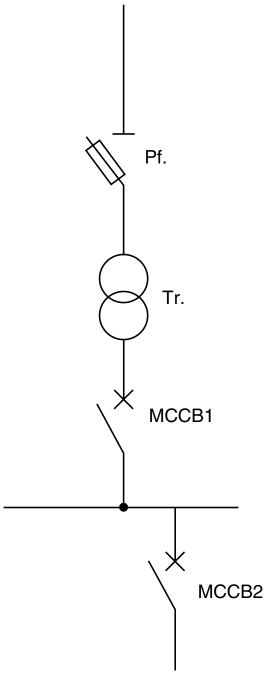
Following Table shows various characteristics of each breaker to consider selection and coordination with upstream devices or loads.

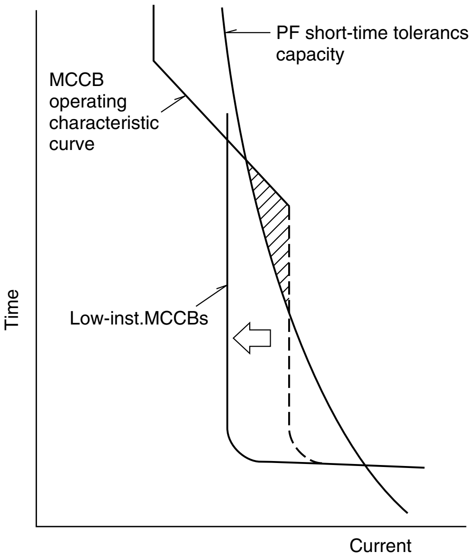
Characteristics

Standard : Standard characteristics MCCBs

Low-inst : Low-inst. MCCBs for Discrimination

When a power fuse (PF) is used as a high-voltage protector, it must be coordinated with an MCCBs on the secondary side.





Generator : Generator-Protection MCCBs

These MCCBs have long-time-delay operation shorter than standard type and low instantaneous operation.

Mag-Only : Magnetic trip only MCCBs

These are standard MCCBs minus the thermal tripping device. They have no time-delay tripping characteristic, providing protection only against large-magnitude short-circuit faults.

CIRCUIT BREAKER SELECTION TABLE

Frame (A)		30	32
Type		NF30-CS	NF32-SW
Rated current In (A)		3, 5, 10, 15, 20, 30	3, 4, 6, 10, 16, 20, 25, 32
Rated insulation voltage Ui (V) AC		500	600
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	–
	525V	–	–
	500V	–	2.5/1
	440V	–	2.5/1
	415V	1.5/1.5	2.5/1
	400V	–	5/2
	380V	1.5/1.5	5/2
	230V	2.5/2 (240V)	7.5/4
Standard	Number of poles	2 3	2 3
	Automatic tripping device	Hydraulic-magnetic Fixed ampere rating and fixed instantaneous	Hydraulic-magnetic Fixed ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	3 39 ± 17 5 66 ± 28 10 132 ± 57 15 198 ± 86 20 265 ± 115 30 397 ± 172	3 33 ± 12 4 44 ± 16 6 66 ± 24 10 110 ± 39 16 176 ± 62 20 220 ± 77 25 275 ± 97 32 352 ± 124
Low-inst	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Generator	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Mag-Only	Number of poles	–	2 3
	Automatic tripping device	–	Magnetic Fixed ampere rating fixed instantaneous
	Rating (A) and Inst. (A)	–	3 30 ± 6 4 40 ± 8 6 60 ± 12 10 100 ± 20 16 160 ± 32 20 200 ± 40 25 250 ± 50 32 320 ± 64

Frame (A)		63		
Type		NF63-CW	NF63-SW	NF63-HW
Rated current In (A)		3, 4, 6, 10, 16, 20, 25, 32, 40, 50, 63	3, 4, 6, 10, 16, 20, 25, 32, 40, 50, 63	10, 16, 20, 25, 32, 40, 50, 63
Rated insulation voltage Ui (V) AC		600	600	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	–	2.5/1
	525V	–	–	–
	500V	2.5/1	7.5/4	7.5/4
	440V	2.5/1	7.5/4	10/5
	415V	2.5/1	7.5/4	10/5
	400V	5/2	7.5/4	10/5
	380V	5/2	7.5/4	10/5
	230V	7.5/4	15/8	25/13
Standard	Number of poles	2 3	2 3 4	2 3 4
	Automatic tripping device	Hydraulic-magnetic Fixed ampere rating and fixed instantaneous	Hydraulic-magnetic Fixed ampere rating and fixed instantaneous	Hydraulic-magnetic Fixed ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	3 33 ± 12 4 44 ± 16 6 66 ± 24 10 110 ± 39 16 176 ± 62 20 220 ± 77 25 275 ± 97 32 352 ± 124 40 440 ± 154 50 550 ± 193 63 693 ± 224	3 33 ± 12 4 44 ± 16 6 66 ± 24 10 110 ± 39 16 176 ± 62 20 220 ± 77 25 275 ± 97 32 352 ± 124 40 440 ± 154 50 550 ± 193 63 693 ± 224	10 110 ± 39 16 176 ± 62 20 220 ± 77 25 275 ± 97 32 352 ± 124 40 440 ± 154 50 550 ± 193 63 693 ± 224
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only	Number of poles	2 3	2 3 4	2 3 4
	Automatic tripping device	Magnetic Fixed ampere rating and fixed instantaneous	Magnetic Fixed ampere rating and fixed instantaneous	Magnetic Fixed ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	3 30 ± 6 4 40 ± 8 6 60 ± 12 10 100 ± 20 16 160 ± 32 20 200 ± 40 25 250 ± 50 32 320 ± 64 40 400 ± 80 50 500 ± 100 63 630 ± 126	3 30 ± 6 4 40 ± 8 6 60 ± 12 10 100 ± 20 16 160 ± 32 20 200 ± 40 25 250 ± 50 32 320 ± 64 40 400 ± 80 50 500 ± 100 63 630 ± 126	10 100 ± 20 16 160 ± 32 20 200 ± 40 25 250 ± 50 32 320 ± 64 40 400 ± 80 50 500 ± 100 63 630 ± 126

Frame (A)		125		
Type		NF125-CW	NF125-SW	NF125-HW
Rated current In (A)		50, 63, 80, 100, 125	16, 20, 32, 40, 50, 63, 80, 100, 125	16, 20, 32, 40, 50, 63, 80, 100
Rated insulation voltage Ui (V) AC		600	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	8/4	10/5
	525V	–	18/5	22/11
	500V	7.5/4	18/9	30/15
	440V	10/5	23/13	50/25
	415V	10/5	30/15	50/25
	400V	10/5	30/15	50/25
	380V	10/5	30/15	50/25
	230V	30/15	50/25	100/50
Standard	Number of poles	2 3	2 3 4	2 3 4
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Fixed ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	50 750 ± 150 63 945 ± 189 80 1200 ± 240 100 1500 ± 300 125 1500 ± 300	16 600 ± 120 20 600 ± 120 32 600 ± 120 40 600 ± 120 50 750 ± 150 63 945 ± 189 80 1200 ± 240 100 1500 ± 300 125 1500 ± 300	16 600 ± 120 20 600 ± 120 32 600 ± 120 40 600 ± 120 50 750 ± 150 63 945 ± 189 80 1200 ± 240 100 1500 ± 300
Low-inst	Number of poles	2 3	2 3 4	–
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Fixed ampere rating and fixed instantaneous	–
	Rating (A) and Inst. (A)	50 300 ± 60 63 378 ± 76 80 480 ± 96 100 600 ± 120 125 750 ± 150	16 96 ± 20 20 120 ± 24 32 192 ± 39 40 240 ± 48 50 300 ± 60 63 378 ± 76 80 480 ± 96 100 600 ± 120 125 750 ± 150	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only	Number of poles	2 3	2 3 4	2 3 4
	Automatic tripping device	Magnetic Fixed ampere rating and fixed instantaneous	Magnetic Fixed ampere rating and fixed instantaneous	Magnetic Fixed ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	50 500 ± 100 63 630 ± 126 80 800 ± 160 100 1000 ± 200 125 1250 ± 250	16 160 ± 32 20 200 ± 40 32 320 ± 64 40 400 ± 80 50 500 ± 100 63 630 ± 126 80 800 ± 160 100 1000 ± 200 125 1250 ± 250	16 160 ± 32 20 200 ± 40 32 320 ± 64 40 400 ± 80 50 500 ± 100 63 630 ± 126 80 800 ± 160 100 1000 ± 200 125 1250 ± 250

Frame (A)		125		
Type		NF125-SGW RT	NF125-SGW RE	NF125-SGW RM
Rated current In (A)		16-25, 25-40, 40-63, 63-100, 80-125	16-32, 32-63, 63-100, 75-125	125
Rated insulation voltage Ui (V) AC		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	8/8	8/8	8/8
	525V	22/22	22/22	22/22
	500V	30/30	30/30	30/30
	440V	36/36	36/36	36/36
	415V	36/36	36/36	36/36
	400V	36/36	36/36	36/36
	380V	36/36	36/36	36/36
	230V	85/85	85/85	85/85
Standard	Number of poles	2 3 4	3 4	–
	Automatic tripping device	Thermal, magnetic • Adjustable ampere rating and fixed instantaneous (up to 63-100A) • Adjustable ampere rating and adjustable instantaneous (80-125A only)	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	16- 25 250 ± 50 25- 40 400 ± 80 40- 63 630 ± 126 63-100 1000 ± 200 Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 80-125 500-1250	Instantaneous pick up current Variation is within ±15% of setting current 16- 32 128- 448 32- 63 252-1134 63-100 400-1400 75-125 500-1750	–
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	3	–
	Automatic tripping device	–	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	–	Rating: 16-32A, 32-63A, 63-100A, 75-125A Inst. : Operating characteristics must be adjusted as follows. STD ≦ 3 (Is setting) LTD : minimum setting (T_L=12sec setting)	–
Mag-Only	Number of poles	–	–	2 3 4
	Automatic tripping device	–	–	Magnetic Fixed ampere rating and Adjustable instantaneous
	Rating (A) and Inst. (A)	–	–	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125 500-1250

Frame (A)		125		
Type		NF125-HGW RT	NF125-HGW RE	NF125-HGW RM
Rated current In (A)		16-25, 25-40, 40-63, 63-100, 80-125	16-32, 32-63, 63-100, 75-125	125
Rated insulation voltage Ui (V) AC		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	20/20	20/20	20/20
	525V	35/35	35/35	35/35
	500V	50/50	50/50	50/50
	440V	65/65	65/65	65/65
	415V	70/70	70/70	70/70
	400V	75/75	75/75	75/75
	380V	75/75	75/75	75/75
	230V	100/100	100/100	100/100
Standard	Number of poles	2 3 4	3 4	–
	Automatic tripping device	Thermal, magnetic • Adjustable ampere rating and fixed instantaneous (up to 80-125A) • Adjustable ampere rating and adjustable instantaneous (80-125A only)	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	16- 25 250 ± 50 25- 40 400 ± 80 40- 63 630 ± 126 63-100 1000 ± 200 Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 80-125 500-1250	Instantaneous pick up current Variation is within ±15% of setting current 16- 32 128- 448 32- 63 252-1134 63-100 400-1400 75-125 500-1750	–
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	3	–
	Automatic tripping device	–	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	–	Rating: 16-32A, 32-63A, 63-100A, 75-125A Inst. : Operating characteristics must be adjusted as follows. STD ≦ 3 (Is setting) LTD : minimum setting (T_L=12sec setting)	–
Mag-Only	Number of poles	–	–	2 3 4
	Automatic tripping device	–	–	Magnetic Fixed ampere rating and Adjustable instantaneous
	Rating (A) and Inst. (A)	–	–	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125 500-1250

Frame (A)		125	
Type		NF125-RGW RT	NF125-UGW RT
Rated current In (A)		16-25, 25-40, 40-63, 63-100	16-25, 25-40, 40-63, 63-100
Rated insulation voltage Ui (V) AC		690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	25/25	30/30
	525V	125/125	200/200
	500V	125/125	200/200
	440V	125/125	200/200
	415V	125/125	200/200
	400V	125/125	200/200
	380V	125/125	200/200
	230V	125/125	200/200
Standard	Number of poles	2 3	2 3 4
	Automatic tripping device	Thermal, magnetic Adjustable ampere rating and fixed instantaneous	Thermal, magnetic Adjustable ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	16- 25 250 ± 50 25- 40 400 ± 80 40- 63 630 ± 126 63-100 1000 ± 200	16- 25 250 ± 50 25- 40 400 ± 80 40- 63 630 ± 126 63-100 1000 ± 200
Low-inst	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Generator	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Mag-Only	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–

Frame (A)		160			
Type		NF160-SW	NF160-SGW RT	NF160-SGW RE	NF160-SGW RM
Rated current In (A)		125, 150, 160	125-160	80-160	160
Rated insulation voltage Ui (V) AC		690	690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	8/8	8/8	8/8
	525V	–	22/22	22/22	22/22
	500V	15/8	30/30	30/30	30/30
	440V	25/13	36/36	36/36	36/36
	415V	30/15	36/36	36/36	36/36
	400V	30/15	36/36	36/36	36/36
	380V	30/15	36/36	36/36	36/36
	230V	50/25	85/85	85/85	85/85
Standard	Number of poles	2 3 4	2 3 4	3 4	–
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Adjustable ampere rating and adjustable instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	125 1750 ± 350 150 2100 ± 420 160 2240 ± 448	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125-160 640-1600	Instantaneous pick up current Variation is within ±15% of setting current 4 In-14 In 80-160 640-2240	–
Low-inst	Number of poles	–	–	–	–
	Automatic tripping device	–	–	–	–
	Rating (A) and Inst. (A)	–	–	–	–
Generator	Number of poles	–	–	–	–
	Automatic tripping device	–	–	–	–
	Rating (A) and Inst. (A)	–	–	–	–
Mag-Only	Number of poles	2 3 4	–	–	2 3 4
	Automatic tripping device	Magnetic Fixed ampere rating and fixed instantaneous	–	–	Magnetic Fixed ampere rating and Adjustable instantaneous
	Rating (A) and Inst. (A)	125 1250 ± 250 150 1500 ± 300 160 1600 ± 320	–	–	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 160 640-1600

Frame (A)		160			
Type		NF160-HW	NF160-HGW RT	NF160-HGW RE	NF160-HGW RM
Rated current In (A)		125, 150, 160	125-160	80-160	160
Rated insulation voltage Ui (V) AC		690	690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	5/3	20/20	20/20	20/20
	525V	–	35/35	35/35	35/35
	500V	30/8	50/50	50/50	50/50
	440V	50/13	65/65	65/65	65/65
	415V	50/13	70/70	70/70	70/70
	400V	50/13	75/75	75/75	75/75
	380V	50/13	75/75	75/75	75/75
	230V	100/25	100/100	100/100	100/100
Standard	Number of poles	2 3 4	2 3 4	3 4	–
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Adjustable ampere rating and adjustable instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	125 1750 ± 350 150 2100 ± 420 160 2240 ± 448	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125-160 640-1600	Instantaneous pick up current Variation is within ±15% of setting current 4 In-14 In 80-160 640-2240	–
Low-inst	Number of poles	–	–	–	–
	Automatic tripping device	–	–	–	–
	Rating (A) and Inst. (A)	–	–	–	–
Generator	Number of poles	–	–	–	–
	Automatic tripping device	–	–	–	–
	Rating (A) and Inst. (A)	–	–	–	–
Mag-Only	Number of poles	2 3 4	–	–	–
	Automatic tripping device	Magnetic Fixed ampere rating and fixed instantaneous	–	–	Magnetic Fixed ampere rating and Adjustable instantaneous
	Rating (A) and Inst. (A)	125 1250 ± 250 150 1500 ± 300 160 1600 ± 320	–	–	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 160 640-1600

Frame (A)		250		
Type		NF250-CW	NF250-SW	NF250-HW
Rated current In (A)		125, 150, 175, 200, 225, 250	125, 150, 175, 200, 225, 250	125, 150, 175, 200, 225, 250
Rated insulation voltage Ui (V) AC		600	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	–	5/3
	525V	–	–	–
	500V	10/5	15/8	30/8
	440V	15/8	25/13	50/13
	415V	18/9	30/15	50/13
	400V	18/9	30/15	50/13
	380V	18/9	30/15	50/13
	230V	35/18	50/25	100/25
Standard	Number of poles	2 3	2 3 4	2 3 4
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Fixed ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	125 1750 ± 350 150 2100 ± 420 175 2450 ± 490 200 2800 ± 560 225 3150 ± 630 250 2500 ± 500	125 1750 ± 350 150 2100 ± 420 175 2450 ± 490 200 2800 ± 560 225 3150 ± 630 250 2500 ± 500	125 1750 ± 350 150 2100 ± 420 175 2450 ± 490 200 2800 ± 560 225 3150 ± 630 250 2500 ± 500
Low-inst	Number of poles	2 3	2 3 4	–
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and fixed instantaneous	Thermal, magnetic Fixed ampere rating and fixed instantaneous	–
	Rating (A) and Inst. (A)	6 In 4 In 125 750 ± 150 500 ± 100 150 900 ± 180 600 ± 120 175 1050 ± 210 700 ± 140 200 1200 ± 240 800 ± 160 225 1350 ± 270 900 ± 180 250 1500 ± 300 1000 ± 200	6 In 4 In 125 750 ± 150 500 ± 100 150 900 ± 180 600 ± 120 175 1050 ± 210 700 ± 140 200 1200 ± 240 800 ± 160 225 1350 ± 270 900 ± 180 250 1500 ± 300 1000 ± 200	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only	Number of poles	2 3	2 3 4	2 3 4
	Automatic tripping device	Magnetic Fixed ampere rating and fixed instantaneous	Magnetic Fixed ampere rating and fixed instantaneous	Magnetic Fixed ampere rating and fixed instantaneous
	Rating (A) and Inst. (A)	125 1250 ± 250 150 1500 ± 300 175 1750 ± 350 200 2000 ± 400 225 2250 ± 450 250 2500 ± 500	125 1250 ± 250 150 1500 ± 300 175 1750 ± 350 200 2000 ± 400 225 2250 ± 450 250 2500 ± 500	125 1250 ± 250 150 1500 ± 300 175 1750 ± 350 200 2000 ± 400 225 2250 ± 450 250 2500 ± 500

Frame (A)		250		
Type		NF250-SGW RT	NF250-SGW RE	NF250-SGW RM
Rated current In (A)		125-160, 160-250	125-250	250
Rated insulation voltage Ui (V) AC		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	8/8	8/8	8/8
	525V	22/22	22/22	22/22
	500V	30/30	30/30	30/30
	440V	36/36	36/36	36/36
	415V	36/36	36/36	36/36
	400V	36/36	36/36	36/36
	380V	36/36	36/36	36/36
	230V	85/85	85/85	85/85
Standard	Number of poles	2 3 4	3 4	–
	Automatic tripping device	Thermal, magnetic Adjustable ampere rating and adjustable instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125-160 640-1600 160-250 1000-2500	Instantaneous pick up current Variation is within ±15% of setting current 4 In-14 In 125-250 1000-3500	–
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only	Number of poles	–	–	2 3 4
	Automatic tripping device	–	–	Magnetic Fixed ampere rating and Adjustable instantaneous
	Rating (A) and Inst. (A)	–	–	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 250 1000-2500

Frame (A)		250		
Type		NF250-HGW RT	NF250-HGW RE	NF250-HGW RM
Rated current In (A)		125-160, 160-250	125-250	250
Rated insulation voltage Ui (V) AC		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	20/20	20/20	20/20
	525V	35/35	35/35	35/35
	500V	50/50	50/50	50/50
	440V	65/65	65/65	65/65
	415V	70/70	70/70	70/70
	400V	75/75	75/75	75/75
	380V	75/75	75/75	75/75
	230V	100/100	100/100	100/100
Standard	Number of poles	2 3 4	3 4	–
	Automatic tripping device	Thermal, magnetic Adjustable ampere rating and adjustable instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up, and instantaneous	–
	Rating (A) and Inst. (A)	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125-160 640-1600 160-250 1000-2500	Instantaneous pick up current Variation is within ±15% of setting current 4 In-14 In 125-250 1000-3500	–
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only	Number of poles	–	–	2 3 4
	Automatic tripping device	–	–	Magnetic Fixed ampere rating and Adjustable instantaneous
	Rating (A) and Inst. (A)	–	–	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 250 1000-2500

Frame (A)		250	
Type		NF250-RGW RT	NF250-UGW RT
Rated current In (A)		125-160, 160-225	125-160, 160-225
Rated insulation voltage Ui (V) AC		690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	25/25	30/30
	525V	125/125	–
	500V	125/125	200/200
	440V	125/125	200/200
	415V	125/125	200/200
	400V	125/125	200/200
	380V	125/125	200/200
	230V	125/125	200/200
Standard	Number of poles	2 3	2 3 4
	Automatic tripping device	Thermal, magnetic Adjustable ampere rating and adjustable instantaneous	Thermal, magnetic Adjustable ampere rating and adjustable instantaneous
	Rating (A) and Inst. (A)	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125-160 640-1600 160-225 900-2250	Instantaneous pick up current Variation is within ±20% of setting current 4 In-10 In 125-160 640-1600 160-225 900-2250
Low-inst	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Generator	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Mag-Only	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–

Frame (A)		400A		
Type		NF400-CW	NF400-SW	NF400-SEW
Rated current In (A)		250, 300, 350, 400	250, 300, 350, 400	200-400 adjustable
Rated insulation voltage Ui (V)		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	10/10	10/10
	500V	15/8	30/30	30/30
	440V	25/13	42/42	42/42
	400V	36/18	45/45	50/50
	230V	50/25	85/85	85/85
Standard	Number of poles	2 3	2 3 4	3 4
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and instantaneous	Thermal, magnetic Fixed ampere rating and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous
	Rating (A) and Inst. (A)	250 2500 ± 500 300 3000 ± 600 350 3500 ± 700 400 4000 ± 800	250 3500 ± 700 300 4200 ± 840 350 4900 ± 980 400 5600 ± 1120	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 200 400-500-600-700-800-1000-1200-1400-1600-2000 225 450-562.5-675-787.5-900-1125-1350-1575-1800-2250 250 500-625-750-875-1000-1250-1500-1750-2000-2500 300 600-750-900-1050-1200-1500-1800-2100-2400-3000 350 700-875-1050-1225-1400-1750-2100-2450-2800-3500 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-16 In 1600-6400
Low-inst	Number of poles	2 3	–	–
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and instantaneous	–	–
	Rating (A) and Inst. (A)	6 In 4 In 250 1500 ± 300 1000 ± 200 300 1800 ± 360 1200 ± 240 350 2100 ± 420 1400 ± 280 400 2400 ± 480 1600 ± 320	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only (Inst trip only)	Number of poles	2 3	2 3 4	–
	Automatic tripping device	Magnetic Fixed ampere rating and instantaneous	Magnetic Fixed ampere rating and instantaneous	–
	Rating (A) and Inst. (A)	250 2500 ± 500 300 3000 ± 600 350 3500 ± 700 400 4000 ± 800	250 2500 ± 500 300 3000 ± 600 350 3500 ± 700 400 4000 ± 800	–

Frame (A)		400A		
Type		NF400-HEW	NF400-REW	NF400-UEW
Rated current In (A)		200-400 adjustable	200-400 adjustable	200-400 adjustable
Rated insulation voltage Ui (V)		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	35/18	–	–
	500V	50/50	70/35	170/170
	440V	65/65	125/63	200/200
	400V	70/70	125/63	200/200
	230V	100/100	150/75	200/200
Standard	Number of poles	3 4	3	3 4
	Automatic tripping device	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous
	Rating (A) and Inst. (A)	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 200 400-500-600-700-800-1000-1200-1400-1600-2000 225 450-562.5-675-787.5-900-1125-1350-1575-1800-2250 250 500-625-750-875-1000-1250-1500-1750-2000-2500 300 600-750-900-1050-1200-1500-1800-2100-2400-3000 350 700-875-1050-1225-1400-1750-2100-2450-2800-3500 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-16 In 1600-6400	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 200 400-500-600-700-800-1000-1200-1400-1600-2000 225 450-562.5-675-787.5-900-1125-1350-1575-1800-2250 250 500-625-750-875-1000-1250-1500-1750-2000-2500 300 600-750-900-1050-1200-1500-1800-2100-2400-3000 350 700-875-1050-1225-1400-1750-2100-2450-2800-3500 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-16 In 1600-6400	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 200 400-500-600-700-800-1000-1200-1400-1600-2000 225 450-562.5-675-787.5-900-1125-1350-1575-1800-2250 250 500-625-750-875-1000-1250-1500-1750-2000-2500 300 600-750-900-1050-1200-1500-1800-2100-2400-3000 350 700-875-1050-1225-1400-1750-2100-2450-2800-3500 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-16 In 1600-6400
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only (Inst trip only)	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–

Frame (A)		630A		
Type		NF630-CW	NF630-SW	NF630-SEW
Rated current In (A)		500, 600, 630	500, 600, 630	300-630 adjustable
Rated insulation voltage Ui (V)		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	10/10	10/10
	500V	18/9	30/30	30/30
	440V	36/18	42/42	42/42
	400V	36/18	50/50	50/50
	230V	50/25	85/85	85/85
Standard	Number of poles	2 3	2 3 4	3 4
	Automatic tripping device	Thermal, magnetic Fixed ampere rating and instantaneous	Thermal, magnetic Fixed ampere rating and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous
	Rating (A) and Inst. (A)	500 5000 ± 1000 600 6000 ± 1200 630 6300 ± 1260	500 7000 ± 1400 600 8400 ± 1680 630 8820 ± 1764	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 300 600-750-900-1050-1200-1500-1800-2100-2400-3000 350 700-875-1050-1225-1400-1750-2100-2450-2800-3500 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 630 1260-1575-1890-2205-2520-3150-3780-4410-5040-6300 Instantaneous pick up current Variation is within ±15% of setting current 4 In-15 In 2520-9450
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only (Inst trip only)	Number of poles	2 3	2 3 4	–
	Automatic tripping device	Magnetic Fixed ampere rating and instantaneous	Magnetic Fixed ampere rating and instantaneous	–
	Rating (A) and Inst. (A)	500 5000 ± 1000 600 6000 ± 1200 630 6300 ± 1260	500 5000 ± 1000 600 6000 ± 1200 630 6300 ± 1260	–

Frame (A)		630A	
Type		NF630-HEW	NF630-REW
Rated current In (A)		300-630 adjustable	300-630 adjustable
Rated insulation voltage Ui (V)		690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	35/18	–
	500V	50/50	70/35
	440V	65/65	125/63
	400V	70/70	125/63
	230V	100/100	150/75
Standard	Number of poles	3 4	3
	Automatic tripping device	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous
	Rating (A) and Inst. (A)	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 300 600-750-900-1050-1200-1500-1800-2100-2400-3000 350 700-875-1050-1225-1400-1750-2100-2450-2800-3500 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 630 1260-1575-1890-2205-2520-3150-3780-4410-5040-6300 Instantaneous pick up current Variation is within ±15% of setting current 4 In-15 In 2520-9450	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 300 600-750-900-1050-1200-1500-1800-2100-2400-3000 350 700-875-1050-1225-1400-1750-2100-2450-2800-3500 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 630 1260-1575-1890-2205-2520-3150-3780-4410-5040-6300 Instantaneous pick up current Variation is within ±15% of setting current 4 In-15 In 2520-9450
Low-inst	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Generator	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Mag-Only (Inst trip only)	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–

Frame (A)		800A		
Type		NF800-CEW	NF800-SEW	NF800-HEW
Rated current In (A)		400-800 adjustable	400-800 adjustable	400-800 adjustable
Rated insulation voltage Ui (V)		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	—	10/10	15/15
	500V	18/9	30/30	50/50
	440V	36/18	42/42	65/65
	400V	36/18	50/50	70/70
	230V	50/25	85/85	100/100
Standard	Number of poles	3	3 4	3 4
	Automatic tripping device	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous
	Rating (A) and Inst. (A)	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 450 900-1125-1350-1575-1800-2250-2700-3150-3600-4500 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 700 1400-1750-2100-2450-2800-3500-4200-4900-5600-7000 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 3200-9600	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 450 900-1125-1350-1575-1800-2250-2700-3150-3600-4500 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 700 1400-1750-2100-2450-2800-3500-4200-4900-5600-7000 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 3200-9600	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 450 900-1125-1350-1575-1800-2250-2700-3150-3600-4500 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 700 1400-1750-2100-2450-2800-3500-4200-4900-5600-7000 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 3200-9600
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only (Inst trip only)	Number of poles	–	3 4	–
	Automatic tripping device	–	Electronic trip relay Adjustable ampere rating, instantaneous pick up current	–
	Rating (A) and Inst. (A)	–	Instantaneous pick up current Variation is within ±15% of setting current 2 to 10 Ir	–

Frame (A)		800A	
Type		NF800-REW	NF800-UEW
Rated current In (A)		400-800 adjustable	400-800 adjustable
Rated insulation voltage Ui (V)		690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	–	35/35
	500V	70/35	170/170
	440V	125/63	200/200
	400V	125/63	200/200
	230V	150/75	200/200
Standard	Number of poles	3	3 4
	Automatic tripping device	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous
	Rating (A) and Inst. (A)	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 450 900-1125-1350-1575-1800-2250-2700-3150-3600-4500 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 700 1400-1750-2100-2450-2800-3500-4200-4900-5600-7000 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 3200-9600	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 400 800-1000-1200-1400-1600-2000-2400-2800-3200-4000 450 900-1125-1350-1575-1800-2250-2700-3150-3600-4500 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 700 1400-1750-2100-2450-2800-3500-4200-4900-5600-7000 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 3200-9600
Low-inst	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Generator	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–
Mag-Only (Inst trip only)	Number of poles	–	–
	Automatic tripping device	–	–
	Rating (A) and Inst. (A)	–	–

Frame (A)		1000A	1250A	1600A
Type		NF1000-SEW	NF1250-SEW	NF1600-SEW
Rated current In (A)		500-1000 adjustable	600-1250 adjustable	800-1600 adjustable
Rated insulation voltage Ui (V)		690	690	690
AC Breaking capacity (kA rms) IEC 60947-2 Icu/Ics	690V	25/13	25/13	25/13
	500V	65/33	65/33	65/33
	440V	85/43	85/43	85/43
	400V	85/43	85/43	85/43
	230V	125/63	125/63	125/63
Standard	Number of poles	3 4	3 4	3 4
	Automatic tripping device	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous	Electronic trip relay Adjustable ampere rating Adjustable long time delay operating time, short time delay pick up and instantaneous
	Rating (A) and Inst. (A)	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 500 1000-1250-1500-1750-2000-2500-3000-3500-4000-5000 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 700 1400-1750-2100-2450-2800-3500-4200-4900-5600-7000 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 900 1800-2250-2700-3150-3600-4500-5400-6300-7200-9000 1000 2000-2500-3000-3500-4000-5000-6000-7000-8000-10000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 4000-12000	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 600 1200-1500-1800-2100-2400-3000-3600-4200-4800-6000 700 1400-1750-2100-2450-2800-3500-4200-4900-5600-7000 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 1000 2000-2500-3000-3500-4000-5000-6000-7000-8000-10000 1200 2400-3000-3600-4200-4800-6000-7200-8400-9600-12000 1250 2500-3125-3750-4375-5000-6250-7500-8750-10000-12500 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 5000-15000	Short time delay pick up current Variation is within ±15% of setting current 2 to 10 Ir 800 1600-2000-2400-2800-3200-4000-4800-5600-6400-8000 1000 2000-2500-3000-3500-4000-5000-6000-7000-8000-10000 1200 2400-3000-3600-4200-4800-6000-7200-8400-9600-12000 1400 2800-3500-4200-4900-5600-7000-8400-9800-11200-14000 1500 3000-3750-4500-5250-6000-7500-9000-10500-12000-15000 1600 3200-4000-4800-5600-6400-8000-9600-11200-12800-16000 Instantaneous pick up current Variation is within ±15% of setting current 4 In-12 In 6400-19200
Low-inst	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Generator	Number of poles	–	–	–
	Automatic tripping device	–	–	–
	Rating (A) and Inst. (A)	–	–	–
Mag-Only (Inst trip only)	Number of poles	3 4	3 4	3 4
	Automatic tripping device	Electronic trip relay Adjustable ampere rating, instantaneous pick up current	Electronic trip relay Adjustable ampere rating, instantaneous pick up current	Electronic trip relay Adjustable ampere rating, instantaneous pick up current
	Rating (A) and Inst. (A)	Instantaneous pick up current Variation is within ±15% of setting current 2 to 10 Ir	Instantaneous pick up current Variation is within ±15% of setting current 2 to 10 Ir	Instantaneous pick up current Variation is within ±15% of setting current 2 to 10 Ir

6. PROTECTIVE CO-ORDINATION

6.1 General

Type of System

The primary purpose of a circuit protection system is to prevent damage to series connected equipment and to minimise the area and duration of power loss. The first consideration is whether an air circuit breaker or moulded case circuit breaker is most suitable.
The next is the type of system to be used. The three major types are:
Fully Rated, Selective and Cascade Back-Up.

Fully Rated

This system is highly reliable, as all of the breakers are rated for the maximum fault level at the point of their installation. Discrimination (selective interruption) can be incorporated in some cases. The disadvantage is that high cost branch breakers may be necessary.

Selective-Interruption(Discrimination)

Selective Interruption requires that in the event of a fault, only the device directly before the fault will trip, and that other branch circuits of the same or higher level will not be affected. The range of selective Interruption of the main breaker varies considerably depending on the breaker used.

Cascade Back-Up Protection

This is an economical approach to the use of circuit breakers, whereby only the main (upstream) breaker has adequate interrupting capacity for the maximum available fault current. The MCCBs downstream cannot handle this maximum fault current and rely on the opening of the upstream breaker for protection.

The advantage of the cascade back-up approach is that it facilitates the use of low cost, low fault level breakers downstream, thereby offering savings in both the cost and size of equipment.

As Mitsubishi MCCBs have a very considerable current limiting effect, they can be used to provide this ‘cascade back-up’ protection for downstream circuit breakers.

6.2 Interrupting Capacity Consideration

Table 1 230VAC

<table>
<tr><td colspan="2">3ph trans. capacity (kVA)</td><td colspan="2">30 or less</td><td colspan="2">50~75</td><td>100</td><td colspan="3">150~300</td><td colspan="2">500~1500</td><td colspan="4">2000~3000</td></tr>
<tr><td colspan="2">1ph trans. capacity (kVA)</td><td colspan="2">20 or less</td><td colspan="2">30~50</td><td>75</td><td>100~150</td><td colspan="3">200~500</td><td colspan="5">–</td></tr>
<tr><td colspan="2">Interrupting capacity (kA)(sym)</td><td>2.5</td><td>5</td><td>7.5</td><td>10</td><td>15</td><td>25</td><td>30</td><td>35</td><td>50</td><td>85</td><td>100</td><td>125</td><td>170</td><td>200</td></tr>
<tr><td rowspan="8">Frame (A)</td><td>30·32</td><td>NF30-CS</td><td colspan="2">NF32-SW</td><td colspan="11"></td></tr>
<tr><td>63</td><td colspan="3">NF63-CW</td><td colspan="2">NF63-SW</td><td>NF63-HW</td><td colspan="8"></td></tr>
<tr><td>125</td><td colspan="7">NF125-CW</td><td colspan="2">NF125-SW</td><td>NF125-SW
NF125-SGW</td><td>NF125-HW
NF125-HGW</td><td>NF125-RGW</td><td colspan="2">NF125-UGW</td></tr>
<tr><td>160
≀
250</td><td colspan="8">NF250-CW</td><td>NF160-SW
NF250-SW</td><td>NF160-SGW
NF250-SGW</td><td>NF160-HW
NF160-HGW
NF250-HW
NF250-HGW</td><td>NF250-RGW</td><td colspan="2">NF250-UGW</td></tr>
<tr><td>400</td><td colspan="8">NF400-CW</td><td colspan="2">NF400-SW, NF400-SEW</td><td>NF400-HEW</td><td>NF400-REW</td><td colspan="2">NF400-UEW</td></tr>
<tr><td>630</td><td colspan="9">NF630-CW</td><td>NF630-SW, NF630-SEW</td><td>NF630-HEW</td><td>NF630-REW</td><td colspan="2"></td></tr>
<tr><td>800</td><td colspan="9">NF800-CEW</td><td>NF800-SEW</td><td>NF800-HEW</td><td>NF800-REW</td><td colspan="2">NF800-UEW</td></tr>
<tr><td>1000
≀
1600</td><td colspan="12">NF1000-SEW~NF1600-SEW</td><td colspan="2"></td></tr>
</table>

░ C Series ▓ S·H Series

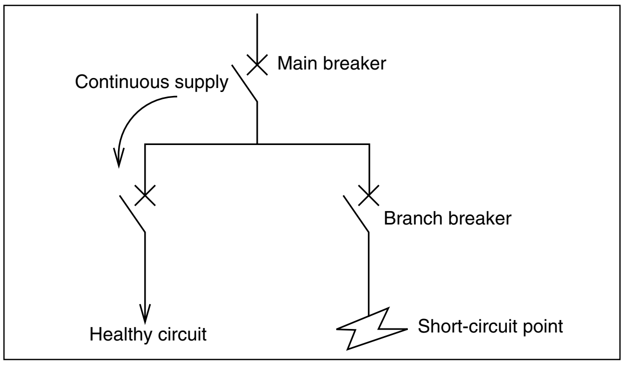
Table 2 440VAC

<table>
<tr><td colspan="2">Trans. capacity (kVA)</td><td colspan="2">30 or less</td><td>50~100</td><td colspan="3">150~300</td><td colspan="2">500~1000</td><td colspan="5">1500~2000</td><td colspan="2">2500~5000</td></tr>
<tr><td colspan="2">Interrupting capacity (kA)(sym)</td><td>1.5</td><td>2.5</td><td>7.5</td><td>10</td><td>15</td><td>18</td><td>25</td><td>30</td><td>36</td><td>42</td><td>50</td><td>65</td><td>85</td><td>125</td><td>200</td></tr>
<tr><td rowspan="8">Frame (A)</td><td>30·32</td><td>NF30-CS</td><td>NF32-SW</td><td colspan="13"></td></tr>
<tr><td>63</td><td colspan="2">NF63-CW</td><td>NF63-SW</td><td>NF63-HW</td><td colspan="11"></td></tr>
<tr><td>125</td><td colspan="4">NF125-CW</td><td colspan="3">NF125-SW</td><td colspan="2">NF125-SGW</td><td colspan="2">NF125-HW</td><td>NF125-HGW</td><td colspan="2">NF125-RGW</td><td>NF125-UGW</td></tr>
<tr><td>160
≀
250</td><td colspan="5">NF250-CW</td><td colspan="2">NF160-SW
NF250-SW</td><td colspan="2">NF160-SGW
NF250-SGW</td><td colspan="2">NF160-HW
NF250-HW</td><td>NF160-HGW
NF250-HGW</td><td colspan="2">NF250-RGW</td><td>NF250-UGW</td></tr>
<tr><td>400</td><td colspan="7">NF400-CW</td><td colspan="3">NF400-SW, NF400-SEW</td><td colspan="2">NF400-HEW</td><td colspan="2">NF400-REW</td><td>NF400-UEW</td></tr>
<tr><td>630</td><td colspan="9">NF630-CW</td><td>NF630-SW, NF630-SEW</td><td colspan="2">NF630-HEW</td><td colspan="2">NF630-REW</td><td></td></tr>
<tr><td>800</td><td colspan="9">NF800-CEW</td><td>NF800-SEW</td><td colspan="2">NF800-HEW</td><td colspan="2">NF800-REW</td><td>NF800-UEW</td></tr>
<tr><td>1000
≀
1600</td><td colspan="13">NF1000-SEW~NF1600-SEW</td><td colspan="2"></td></tr>
</table>

6.3 Selective-Interruption (Discrimination)

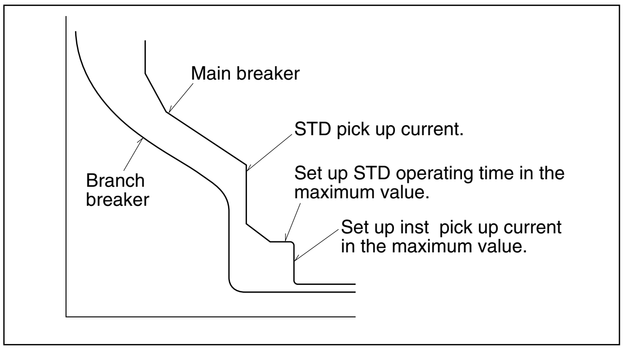
6.3.1 Selective-Interruption Combination

Following tables show combinations of main-circuit selective coordination breakers and branch breakers and the available selective tripping current at the setting points at the branch-circuits.



Selection Conditions

1. The main breaker rated current, STD operating time and INST pickup current are to be set to the maximum values.
2. When selecting the over-current range, also check the conformity using the other characteristic curves.



Selective interruption combinations (MCB-MCCB)

230VAC (Sym. kA)

Branch Breaker	Main Breaker Note 1	NF125-SGW RE	NF250-SGW RE
	Icu(kA)	50	50
BH-D6 TYPE B	6	1.6 Note2	3.5
BH-D6 TYPE C	6	1.6 Note2	3.5

Icu : Rated breaking capacity
Note1 : Reted currents of main breakers are maximum values.
Note2 : Reted currents of branch breakers are 50A or less.

Selective interruption combinations (MCCB-MCCB)

440VAC (Sym. kA)

Branch Breaker		Main Breaker	NF125-SGW RE	NF125-HGW RE	NF160-SGW RE	NF160-HGW RE	NF250-SGW RE	NF250-HGW RE	NF400-SEW	NF400-HEW	NF630-SEW	NF630-HEW	NF800-CEW	NF800-SEW	NF800-HEW	NF1000-SEW NF1250-SEW NF1600-SEW
		Icu(kA)	36	65	36	65	36	65	42	65	42	65	36	42	65	85
S · H	NF32-SW MB30-SW	2.5	1.6	1.6	1.6	1.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	NV32-SW	5	1.6	1.6	1.6	1.6	3.5	3.5	5	5	5	5	5	5	5	5
	NF63-SW MB50-SW NV63-SW	7.5	1.6	1.6	1.6	1.6	3.5	3.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	NF63-HW NV63-HW	10	1.6	1.6	1.6	1.6	3.5	3.5	7.5	7.5	10	10	10	10	10	10
	NF125-SW MB100-SW NV125-SW	25	–	–	–	–	3.5	3.5	5	5	10	10	10	10	10	22
	NF125-SGW RT NF125-SGW RE	36	–	–	–	–	3.5	3.5	7.5	7.5	15	15	15	15	15	36
	NF125-HW NV125-HW	50	–	–	–	–	3.5	3.5	7.5	7.5	18	18	18	18	18	50
	NF125-HGW RT NF125-HGW RE	65	–	–	–	–	3.5	3.5	7.5	7.5	15	15	15	15	15	42
	NF160-SW	25	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	22
	NF160-SGW RT NF160-SGW RE	36	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	25
	NF160-HW	50	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	22
	NF160-HGW RT NF160-HGW RE	65	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	25
	NF250-SW MB225-SW NV250-SW	25	–	–	–	–	–	–	–	–	10	10	10	10	10	22
	NV250-SEW	25	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	22
	NF250-SGW RT	36	–	–	–	–	–	–	–	–	10	10	10	10	10	25
	NF250-SGW RE	36	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	25
	NF250-HW NV250-HW	50	–	–	–	–	–	–	–	–	10	10	10	10	10	22
	NV250-HEW	50	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	22
	NF250-HGW RT	65	–	–	–	–	–	–	–	–	10	10	10	10	10	25
	NF250-HGW RE	65	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	25
	NF400-SW NV400-SW	42	–	–	–	–	–	–	–	–	–	–	10	10	10	20
	NF400-SEW NV400-SEW	42	–	–	–	–	–	–	–	–	9.5	9.5	10	10	10	20
	NF400-HEW NV400-HEW	65	–	–	–	–	–	–	–	–	9.5	9.5	10	10	10	20
	NF400-REW NV400-REW	125	–	–	–	–	–	–	–	–	9.5	9.5	10	10	10	20
	NF630-SW NF630-SEW NV630-SW NV630-SEW	42	–	–	–	–	–	–	–	–	–	–	–	–	–	20
	NF630-HEW NV630-HEW	65	–	–	–	–	–	–	–	–	–	–	–	–	–	20
	NF630-REW	125	–	–	–	–	–	–	–	–	–	–	–	–	–	20
C	MB50-CW NF63-CW NV63-CW	2.5	1.6	1.6	1.6	1.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	NF125-CW NV125-CW	10	–	–	–	–	3.5	3.5	5	5	10	10	10	10	10	10
	NF250-CW NV250-CW	15	–	–	–	–	–	–	–	–	7.5	7.5	7.5	7.5	7.5	15
	NF400-CW NV400-CW	25	–	–	–	–	–	–	–	–	–	–	10	10	10	20
	NF630-CW NV630-CW	36	–	–	–	–	–	–	–	–	–	–	–	–	–	20
U	NF125-RGW NV125-RW	125	–	–	–	–	3.5	3.5	15	15	30	30	30	42	50	85
	NF125-UGW	200	–	–	–	–	3.5	3.5	15	15	30	30	30	42	50	85
	NF250-RGW NV250-RW	125	–	–	–	–	–	–	–	–	15	15	15	25	25	85
	NF250-UGW	200	–	–	–	–	–	–	–	–	15	15	15	25	25	85
	NF400-UEW	200	–	–	–	–	–	–	–	–	9.5	9.5	15	15	15	25
	NF800-UEW	200	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Icu : Rated ultimate breaking capacity
Note : Rated currents of main breakers are maximum values.

Selective interruption combinations (MCCB-MCCB)

230VAC (Sym. kA)

Main Breaker / Branch Breaker			NF125-SGW RE	NF125-HGW RE	NF160-SGW RE	NF160-HGW RE	NF250-SGW RE	NF250-HGW RE	NF400-SEW	NF400-HEW	NF630-SEW	NF630-HEW	NF800-CEW	NF800-SEW	NF800-HEW	NF1000-SEW NF1250-SEW NF1600-SEW
		Icu(kA)	85	100	85	100	85	100	85	100	85	100	50	85	100	125
S·H	NF32-SW MB30-SW	7.5	1.6	1.6	1.6	1.6	3.5	3.5	5	5	7.5	7.5	7.5	7.5	7.5	7.5
	NV32-SW	10	1.6	1.6	1.6	1.6	3.5	3.5	10	10	10	10	10	10	10	10
	NF63-SW MB50-SW NV63-SW	15	1.6	1.6	1.6	1.6	3.5	3.5	10	10	15	15	15	15	15	15
	NF63-HW NV63-HW	25	1.6	1.6	1.6	1.6	3.5	3.5	10	10	20	20	20	20	20	25
	NF125-SW MB100-SW NV125-SW	50	–	–	–	–	3.5	3.5	7.5	7.5	15	15	15	15	15	50
	NF125-SGW RT NF125-SGW RE	85	–	–	–	–	3.5	3.5	7.5	7.5	15	15	15	15	15	85
	NF125-HW NV125-HW	100	–	–	–	–	3.5	3.5	10	10	25	25	25	25	25	100
	NF125-HGW RT NF125-HGW RE	100	–	–	–	–	3.5	3.5	7.5	7.5	15	15	15	15	15	85
	NF160-SW	50	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF160-SGW RT NF160-SGW RE	85	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF160-HW	100	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF160-HGW RT NF160-HGW RE	100	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF250-SW MB225-SW NV250-SW	50	–	–	–	–	–	–	–	–	10	10	10	10	10	50
	NV250-SEW	50	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF250-SGW RT	85	–	–	–	–	–	–	–	–	10	10	10	10	10	50
	NF250-SGW RE	85	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF250-HW NV250-HW	100	–	–	–	–	–	–	–	–	10	10	10	10	10	50
	NV250-HEW	100	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF250-HGW RT	100	–	–	–	–	–	–	–	–	10	10	10	10	10	50
	NF250-HGW RE	100	–	–	–	–	–	–	6.4	6.4	10	10	10	10	10	50
	NF400-SW NV400-SW	85	–	–	–	–	–	–	–	–	–	–	10	10	10	20
	NF400-SEW NV400-SEW	85	–	–	–	–	–	–	–	–	9.5	9.5	10	10	10	20
	NF400-HEW NV400-HEW	100	–	–	–	–	–	–	–	–	9.5	9.5	10	10	10	20
	NF400-REW NV400-REW	150	–	–	–	–	–	–	–	–	9.5	9.5	10	10	10	20
	NF630-SW NF630-SEW NV630-SW NV630-SEW	85	–	–	–	–	–	–	–	–	–	–	–	–	–	20
	NF630-HEW NV630-HEW	100	–	–	–	–	–	–	–	–	–	–	–	–	–	20
	NF630-REW	150	–	–	–	–	–	–	–	–	–	–	–	–	–	20
C	MB50-CW NF63-CW NV63-CW	7.5	1.6	1.6	3.5	3.5	5	5	5	5	7.5	7.5	7.5	7.5	7.5	7.5
	NF125-CW NV125-CW	30	–	–	–	–	3.5	3.5	7.5	7.5	10	10	10	10	15	25
	NF250-CW NV250-CW	35	–	–	–	–	–	–	–	–	7.5	7.5	7.5	7.5	7.5	25
	NF400-CW NV400-CW	50	–	–	–	–	–	–	–	–	–	–	10	10	10	20
	NF630-CW NV630-CW	50	–	–	–	–	–	–	–	–	–	–	–	–	–	20
U	NF125-RGW NV125-RW	125	–	–	–	–	3.5	3.5	22	22	65	65	50	85	85	125
	NF125-UGW	200	–	–	–	–	3.5	3.5	22	22	65	65	50	85	85	125
	NF250-RGW NV250-RW	125	–	–	–	–	–	–	–	–	–	–	18	50	50	125
	NF250-UGW	200	–	–	–	–	–	–	–	–	–	–	18	50	50	125
	NF400-UEW	200	–	–	–	–	–	–	–	–	–	–	15	15	15	25
	NF800-UEW	200	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Icu : Rated ultimate breaking capacity

Note : Rated currents of main breakers are maximum values.

Selective interruption combinations (ACB-MCCB)

440VAC (Sym. kA)

Branch Circuit Breaker		Single Unit Breaking Capacity / Main Circuit Breaker	Low-Voltage Air Circuit Breaker AE-SW								
			AE 630-SW	AE 1000-SW	AE 1250-SW	AE 1600-SW	AE 2000-SWA	AE 2000-SW	AE 2500-SW	AE 3200-SW	AE 4000-SWA
			65	65	65	65	65	85	85	85	85
NF-S · NV-S · MB · MN	NF32-SW MB30-SW MB50-CW	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	NV32-SW	5	5	5	5	5	5	5	5	5	5
	NF63-SW NV63-SW MB50-SW	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	NF63-HW NV63-HW	10	9(10)	10	10	10	10	10	10	10	10
	NF125-SW NV125-SW MB100-SW	25	7(30)	20(30)	25(30)	30	30	30	30	30	30
	NF125-SGW RT NF125-SGW RE	36	9(36)	20(36)	36	36	36	36	36	36	36
	NF125-HW NV125-HW	50	9(50)	30(50)	50	50	50	50	50	50	50
	NF125-HGW RT NF125-HGW RE	65	9(65)	20(65)	36(65)	65	65	65	65	65	65
	NF160-SW	25	7(25)	14(25)	19(25)	25	25	25	25	25	25
	NF160-SGW RT NF160-SGW RE	36	9(36)	15(36)	25(36)	36	36	36	36	36	36
	NF160-HW	50	9(50)	15(50)	25(50)	42(50)	42(50)	50	50	50	50
	NF160-HGW RT NF160-HGW RE	65	9(65)	15(65)	25(65)	42(65)	42(65)	65	65	65	65
	NF250-SW NV250-SW NV250-SEW MB225-SW	25	7(30)	14(30)	19(30)	25(30)	25(30)	30	30	30	30
	NF250-SGW RT NF250-SGW RE	36	7(36)	15(36)	25(36)	36	36	36	36	36	36
	NF250-HW NV250-HW NV250-HEW	50	7(50)	15(50)	25(50)	42(50)	42(50)	50	50	50	50
	NF250-HGW RT NF250-HGW RE	65	7(65)	15(65)	25(65)	42(65)	42(65)	65	65	65	65
	NF400-SW NV400-SW	45	–	–	18(45)	24(45)	24(45)	33(45)	45(45)	45	45
	NF400-SEW NV400-SEW	50	9(50)	15(50)	18(50)	24(50)	24(50)	30(50)	39(50)	50	50
	NF400-HEW NV400-HEW	70	9(65)	15(65)	18(65)	24(65)	24(65)	30(70)	39(70)	70	70
	NF400-REW NV400-REW	125	9(65)	15(65)	18(65)	24(65)	24(65)	30(75)	39(75)	80	80
	NF630-SW NV630-SW	50	–	–	–	24(50)	24(50)	30(50)	37(50)	50	50
	NF630-SEW NV630-SEW	50	–	15(50)	18(50)	24(50)	24(50)	30(50)	37(50)	50	50
	NF630-HEW NV630-HEW	70	–	15(65)	18(65)	24(65)	24(65)	30(70)	37(70)	48(70)	48(70)
	NF630-REW	125	–	15(65)	18(65)	24(65)	24(65)	30(75)	37(75)	48(75)	48(75)
	NF800-SEW NV800-SEW	50	–	–	18(50)	24(50)	24(50)	30(50)	37(50)	48(50)	48(50)
	NF800-HEW NV800-HEW	70	–	–	18(65)	24(65)	24(65)	30(70)	37(70)	48(70)	48(70)
	NF800-REW	125	–	–	18(65)	24(65)	24(65)	30(75)	37(75)	48(75)	48(75)
NF-C · NV-C	NF63-CW NV63-CW	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	NF125-CW NV125-CW	10	9(10)	10	10	10	10	10	10	10	10
	NF250-CW NV250-CW	15	9(18)	15(18)	18	18	18	18	18	18	18
	NF400-CW NV400-CW	36	–	15(36)	18(36)	24(36)	24(36)	25(36)	36	36	36
	NF630-CW NV630-CW	36	–	–	–	24(36)	24(36)	30(36)	36	36	36
	NF800-CEW	36	–	–	18(36)	24(36)	24(36)	30(36)	36	36	36
NF-U	NF125-RGW NV125-RW	125	35(65)	65	65	65	65	85	85	85	85
	NF125-UGW	200	50(65)	65	65	65	65	85	85	85	85
	NF250-RGW NV250-RW	125	9(65)	50(65)	65	65	65	85	85	85	85
	NF250-UGW	200	9(65)	65	65	65	65	85	85	85	85
	NF400-UEW	200	9(65)	15(65)	18(65)	29(65)	29(65)	48(75)	85	85	85
	NF800-UEW	200	–	–	18(65)	24(65)	24(65)	30(75)	37(75)	68(75)	68(75)

Note1 : The values in the table represent the max. rated current for both Series AE-SW air circuit breakers and branch breakers, and the selective co-ordination applies when the AE-SW siries air circuit breakers instantaneous pick up is set to maximum.

Note2 : The numerals shown in parentheses are for AE-SW with MCR. (When set MCR.)

Selective interruption combinations (ACB-MCCB)

230VAC (Sym. kA)

Branch Circuit Breaker		Single Unit Breaking Capacity / Main Circuit Breaker	Low-Voltage Air Circuit Breaker AE-SW								
			AE 630-SW	AE 1000-SW	AE 1250-SW	AE 1600-SW	AE 2000-SWA	AE 2000-SW	AE 2500-SW	AE 3200-SW	AE 4000-SWA
			65	65	65	65	65	85	85	85	85
NF-S · NV-S · MB · MN	NF32-SW MB30-SW MB50-CW	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	NV32-SW	10	9(10)	10	10	10	10	10	10	10	10
	NF63-SW NV63-SW MB50-SW	15	9(10)	15	15	15	15	15	15	15	15
	NF63-HW NV63-HW	25	9(25)	25	25	25	25	25	25	25	25
	NF125-SW NV125-SW MB100-SW	50	9(50)	45(50)	50	50	50	50	50	50	50
	NF125-SGW RT NF125-SGW RE	85	16(65)	45(65)	65	65	65	85	85	85	85
	NF125-HW NV125-HW	100	9(65)	50(65)	65	65	65	85	85	85	85
	NF125-HGW RT NF125-HGW RE	100	16(65)	45(65)	65	65	65	85	85	85	85
	NF160-SW	50	15(50)	24(50)	30(50)	42(50)	50	50	50	50	50
	NF160-SGW RT NF160-SGW RE	85	9.4(65)	25(65)	40(65)	65	65	85	85	85	85
	NF160-HW	100	9.4(65)	25(65)	40(65)	65	65	85	85	85	85
	NF160-HGW RT NF160-HGW RE	100	9.4(65)	25(65)	40(65)	65	65	85	85	85	85
	NF250-SW NV250-SW NV250-SEW MB225-SW	50	9(50)	20(50)	22(50)	42(50)	42(50)	50	50	50	50
	NF250-SGW RT NF250-SGW RE	85	9.4(65)	25(65)	40(65)	65	65	85	85	85	85
	NF250-HW NV250-HW	100	9(65)	25(65)	40(65)	65	65	85	85	85	85
	NV250-HEW	100	9.4(65)	25(65)	40(65)	65	65	85	85	85	85
	NF250-HGW RT NF250-HGW RE	100	9.4(65)	25(65)	40(65)	65	65	85	85	85	85
	NF400-SW NV400-SW	85	–	–	20(65)	30(65)	30(65)	48(75)	70(75)	85	85
	NF400-SEW NV400-SEW	85	9(65)	15(65)	20(65)	30(65)	30(65)	48(75)	70(75)	85	85
	NF400-HEW NV400-HEW	100	9(65)	15(65)	20(65)	30(65)	30(65)	48(75)	70(75)	85	85
	NF400-REW NV400-REW	150	9(65)	15(65)	20(65)	30(65)	30(65)	48(75)	70(75)	85	85
	NF630-SW NV630-SW	85	–	–	–	24(65)	24(65)	30(75)	40(75)	60(75)	60(75)
	NF630-SEW NV630-SEW	85	–	15(65)	18(65)	24(65)	24(65)	30(75)	40(75)	60(75)	60(75)
	NF630-HEW NV630-HEW	100	–	15(65)	18(65)	24(65)	24(65)	30(75)	40(75)	60(75)	60(75)
	NF630-REW	150	–	15(65)	18(65)	24(65)	24(65)	30(75)	40(75)	60(75)	60(75)
	NF800-SEW NV800-SEW	85	–	–	18(65)	24(65)	24(65)	30(75)	40(75)	60(75)	60(75)
	NF800-HEW NV800-HEW	100	–	–	18(65)	24(65)	24(65)	30(75)	40(75)	60(75)	60(75)
	NF800-REW	150	–	–	18(65)	24(65)	24(65)	30(75)	40(75)	60(75)	60(75)
NF-C · NV-C	NF63-CW NV63-CW	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	NF125-CW NV125-CW	30	9(30)	15(30)	18(30)	24(30)	24(30)	30	30	30	30
	NF250-CW NV250-CW	35	9(35)	15(35)	18(35)	24(35)	24(35)	35	35	35	35
	NF400-CW NV400-CW	50	–	15(50)	20(50)	27(50)	27(50)	42(50)	50	50	50
	NF630-CW NV630-CW	50	–	–	–	24(50)	24(50)	30(50)	40(50)	50	50
	NF800-CEW	50	–	–	18(50)	24(50)	24(50)	30(50)	40(50)	50	50
NF-U	NF125-RGW NV125-RW	125	65	65	65	65	65	85	85	85	85
	NF125-UGW	200	65	65	65	65	65	85	85	85	85
	NF250-RGW NV250-RW	125	9(65)	65	65	65	65	85	85	85	85
	NF250-UGW	200	9(65)	65	65	65	65	85	85	85	85
	NF400-UEW	200	9(65)	15(65)	18(65)	29(65)	29(65)	48(75)	85	85	85
	NF800-UEW	200	–	–	18(65)	24(65)	24(65)	30(75)	37(75)	68(75)	68(75)

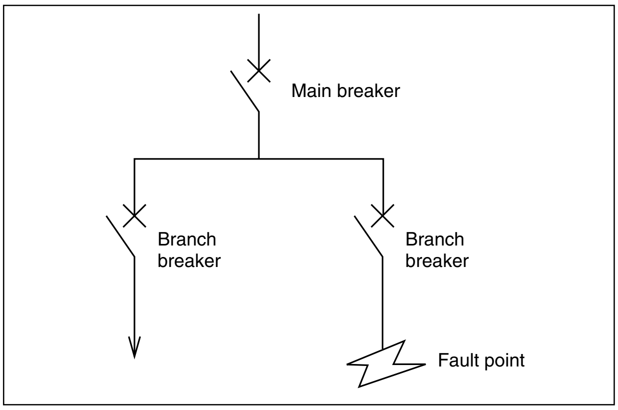
Note1 : The values in the table represent the max. rated current for both Series AE-SW air circuit breakers and branch breakers, and the selective co-ordination applies when the AE-SW siries air circuit breakers instantaneous pick up is set to maximum.

Note2 : The numerals shown in parentheses are for AE-SW with MCR. (When set MCR.)

6.4 Cascade Back-up Protection

6.4.1 Cascade Back-up Combinations

Following tables show the available MCCB combinations for cascade interruption and their interrupting capacity.



440VAC (sym. kA)

	Main Circuit Breaker	Interrupting Capacity (kA)	S·H																						C				U					
	Branch Circuit Breaker		NF125-SW, NV125-SW	NF125-SGW	NF125-HW, NV125-HW	NF125-HGW	NF160-SW	NF160-SGW	NF160-HW	NF160-HGW	NF250-SW, NV250-SW	NF250-SGW	NF250-HW, NV250-HW	NF250-HGW	NF400-SW, NV400-SW	NF400-HEW, NV400-HEW	NF400-REW, NV400-REW	NF630-SW, NV630-SW	NF630-HEW, NV630-HEW	NF630-REW	NF800-SEW, NV800-SEW	NF800-HEW, NV800-HEW	NF800-REW	NF1000-SEW, NF1250-SEW, NF1600-SEW	NF250-CW, NV250-CW	NF400-CW, NV400-CW	NF630-CW, NV630-CW	NF800-CEW	NF125-RGW, NV125-RW	NF125-UGW	NF250-RGW, NV250-RW	NF250-UGW	NF400-UEW	NF800-UEW
			25	36	50	65	25	36	50	65	25	36	50	65	42	65	125	42	65	125	42	65	125	85	15	25	36	36	125	200	125	200	200	200
S·H	NF32-SW MB30-SW	2.5	10	14	14	14	5	5	5	5	5	5	5	5	–	–	–	–	–	–	–	–	–	–	5	–	–	–	35	125	35	50	–	–
	NV32-SW	5	14	14	14	14	10	10	10	10	10	10	10	10	7.5	7.5	7.5	7.5	7.5	7.5	–	–	–	–	–	–	–	–	50	125	35	50	–	–
	NF63-SW MB50-SW	7.5	14	20	20	20	15	15	10	15	15	15	10	15	15	10	10	10	10	10	10	10	10	–	–	10	10	–	50	125	50	50	10	10
	NV63-SW	7.5	14	20	20	20	10	10	10	10	10	10	10	10	–	–	–	–	–	–	–	–	–	–	–	10	10	–	50	125	50	50	–	–
	NF63-HW NV63-HW	10	20	30	30	30	18	18	–	18	18	18	–	18	15	15	15	14	14	14	–	–	–	–	–	–	–	–	125	125	50	50	–	–
	NF125-SW MB100-SW NV125-SW	25	–	36	50	50	–	36	42	50	–	36	42	50	35	35	35	35	35	35	30	35	35	30	–	–	–	–	125	200	125	200	50	35
	NF125-SGW	36	–	–	50	50	–	–	42	50	–	–	42	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	125	200	50	–
	NF125-HW NV125-HW	50	–	–	–	65	–	–	–	65	–	–	–	65	–	65	65	–	65	65	–	65	65	–	–	–	–	–	125	200	125	200	200	85
	NF125-HGW	65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	125	200	200	85
	NF160-SW	25	–	–	–	–	–	–	–	–	–	–	–	–	35	50	50	35	50	50	35	50	50	50	–	–	–	–	–	–	125	200	85	85
	NF160-SGW	36	–	–	–	–	–	–	–	–	–	–	–	–	–	50	50	–	50	50	–	50	50	50	–	–	–	–	–	–	125	200	85	85
	NF160-HW	50	–	–	–	–	–	–	–	65	–	–	–	65	–	65	65	–	65	65	–	65	65	65	–	–	–	–	–	–	125	200	200	200
	NF160-HGW	65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	200
	NF250-SW MB225-SW NV250-SW NV250-SEW	25	–	–	–	–	–	–	–	–	–	–	–	–	35	50	50	35	50	50	35	50	50	–	–	–	–	–	–	–	125	200	85	85
	NF250-SGW	36	–	–	–	–	–	–	–	–	–	–	–	–	–	50	50	–	50	50	–	50	50	–	–	–	–	–	–	–	125	200	85	85
	NF250-HW NV250-HW NV250-HEW	50	–	–	–	–	–	–	–	–	–	–	–	65	–	65	65	–	65	65	–	65	65	–	–	–	–	–	–	–	125	200	200	200
	NF250-HGW	65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	200
	NF400-SW NF400-SEW NV400-SW NV400-SEW	42	–	–	–	–	–	–	–	–	–	–	–	–	–	65	65	–	65	65	–	65	65	–	–	–	–	–	–	–	–	–	200	200
	NF630-SW NF630-SEW NV630-SW NV630-SEW	42	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	65	65	–	65	65	–	–	–	–	–	–	–	–	–	–	200
C	MB50-CW NF63-CW NV63-CW	2.5	10	14	14	14	5	5	5	5	5	5	5	5	–	–	–	–	–	–	–	–	–	–	5	–	–	–	35	125	35	50	5	–
	NF125-CW NV125-CW	10	20	30	30	30	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	–	–	14	14	14	125	200	50	125	14	14
	NF250-CW NV250-CW	15	–	–	–	–	–	–	–	–	25	25	25	25	30	30	30	25	25	25	20	20	20	–	–	18	18	18	–	–	125	200	50	25
	NF400-CW NV400-CW	25	–	–	–	–	–	–	–	–	–	–	–	–	35	35	35	35	35	35	35	35	35	30	–	–	–	–	–	–	–	–	50	50
	NF630-CW NV630-CW	36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	42	50	50	42	50	50	42	–	–	–	–	–	–	–	–	–	200

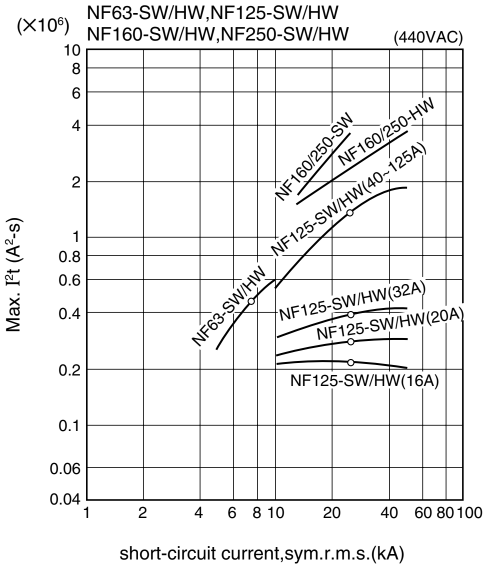
Cascade Back-up Combinations

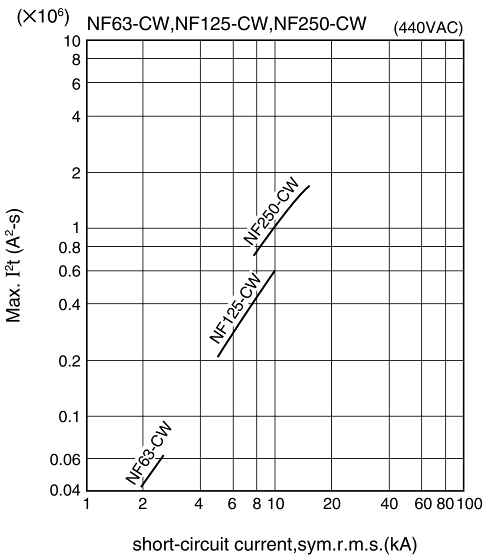
230VAC (sym. kA)

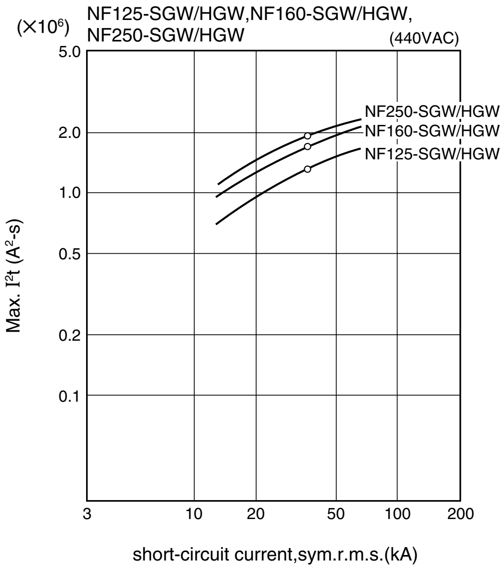
Main Circuit Breaker Interrupting Capacity (kA) Branch Circuit Breaker			S·H																						C				U					
			NF125-SW, NV125-SW	NF125-SGW	NF125-HW, NV125-HW	NF125-HGW	NF160-SW	NF160-SGW	NF160-HW	NF160-HGW	NF250-SW, NV250-SW	NF250-SGW	NF250-HW, NV250-HW	NF250-HGW	NF400-SW, NV400-SW	NF400-HEW, NV400-HEW	NF400-REW, NV400-REW	NF630-SW, NV630-SW	NF630-HEW, NV630-HEW	NF630-REW	NF800-SEW, NV800-SEW	NF800-HEW, NV800-HEW	NF800-REW	NF1000-SEW, NF1250-SEW, NF1600-SEW	NF250-CW, NV250-CW	NF400-CW, NV400-CW	NF630-CW, NV630-CW	NF800-CEW	NF125-RGW, NV125-RW	NF125-UGW	NF250-RGW, NV250-RW	NF250-UGW	NF400-UEW	NF800-UEW
			50	85	100	100	50	85	100	100	50	85	100	100	85	100	150	85	100	150	85	100	150	125	35	50	50	50	125	200	125	200	200	200
S·H	NF32-SW MB30-SW	7.5	42	50	50	50	10	10	10	10	10	10	10	10	–	–	–	–	–	–	–	–	–	–	7.5	–	–	–	125	200	35	50	–	–
	NV32-SW	10	42	50	50	50	35	35	35	35	35	35	35	35	14	14	14	14	14	14	–	–	–	–	25	14	14	–	125	200	35	50	–	–
	NF63-SW MB50-SW	15	42	85	85	85	35	35	35	35	35	35	35	35	30	30	30	30	30	30	–	–	–	–	25	–	–	–	125	200	85	125	–	–
	NV63-SW	15	42	85	85	85	35	35	35	35	35	35	35	35	–	–	–	–	–	–	–	–	–	–	25	–	–	–	125	200	85	125	–	–
	NF63-HW NV63-HW	25	50	85	100	100	50	50	50	50	50	50	50	50	50	50	50	50	50	50	–	–	–	–	–	30	30	–	125	200	85	125	–	–
	NF125-SW MB100-SW NV125-SW	50	–	85	100	100	–	85	85	85	–	85	85	85	85	85	85	85	85	85	–	–	–	–	–	–	–	–	125	200	125	200	200	125
	NF125-SGW	85	–	–	100	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	125	200	200	125
	NF125-HW NV125-HW	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	125	200	200	125
	NF125-HGW	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	125	200	200	125
	NF160-SW	50	–	–	–	–	–	85	85	85	–	85	85	85	85	85	85	85	85	85	70	70	70	70	–	–	–	–	–	–	125	200	200	125
	NF160-SGW	85	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	125
	NF160-HW	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	200
	NF160-HGW	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	200
	NF250-SW MB225-SW NV250-SW NV250-SEW	50	–	–	–	–	–	–	–	–	–	85	85	85	85	85	85	85	85	85	70	70	70	70	–	–	–	–	–	–	125	200	200	125
	NF250-SGW	85	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	125
	NF250-HW NV250-HW NV250-HEW	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	200
	NF250-HGW	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	200	200
	NF400-SW NF400-SEW NV400-SW NV400-SEW	85	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	100	–	–	–	–	–	–	–	–	200	200
	NF630-SW NF630-SEW NV630-SW NV630-SEW	85	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	100	–	–	–	–	–	–	–	–	–	200
C	MB50-CW NF63-CW NV63-CW	7.5	35	50	50	50	10	10	10	10	10	10	10	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	125	200	35	50	–	–
	NF125-CW NV125-CW	30	35	85	85	85	50	50	50	50	50	50	50	50	50	50	50	50	50	50	–	–	–	–	–	–	–	–	125	200	85	125	50	–
	NF250-CW NV250-CW	35	–	–	–	–	–	–	–	–	50	50	50	50	50	50	50	50	50	50	–	–	–	–	–	–	–	–	–	–	125	200	200	50
	NF400-CW NV400-CW	50	–	–	–	–	–	–	–	–	–	–	–	–	85	85	85	85	85	85	85	85	85	85	–	–	–	–	–	–	–	–	200	200
	NF630-CW NV630-CW	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	85	85	85	85	85	85	85	–	–	–	–	–	–	–	–	–	200
BH	BH BH-P	2.5	30	42	42	42	5	7.5	7.5	7.5	5	7.5	7.5	7.5	–	–	–	–	–	–	–	–	–	–	5	–	–	–	125	200	–	–	–	–

6.5 I^2t Let-Through and Current Limiting Characteristics (440 VAC)

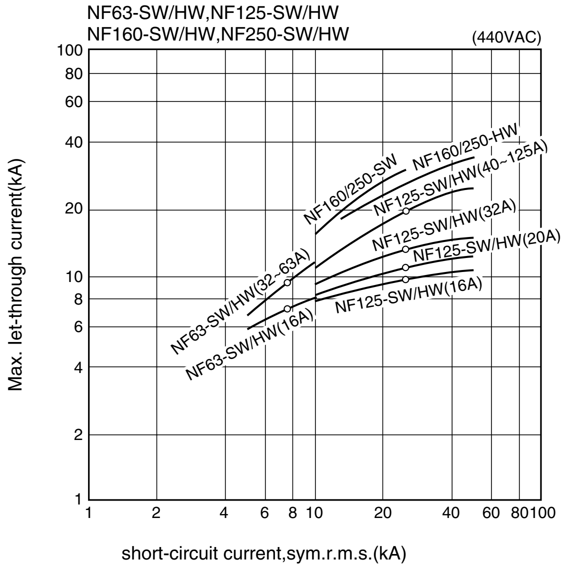
I^2t let-through characteristics

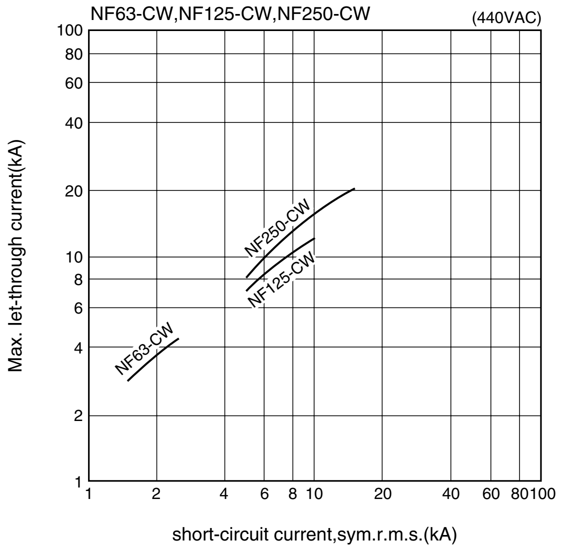


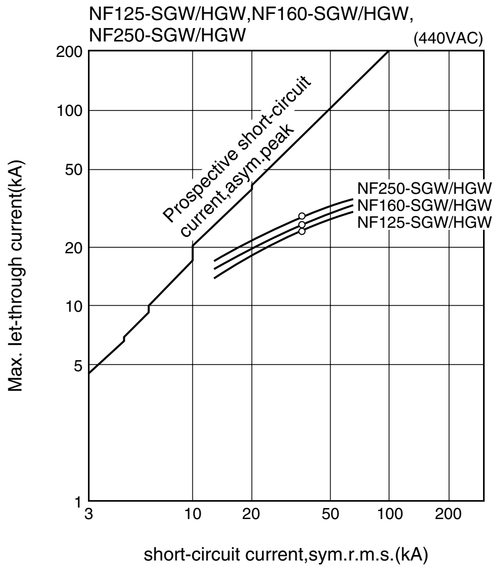


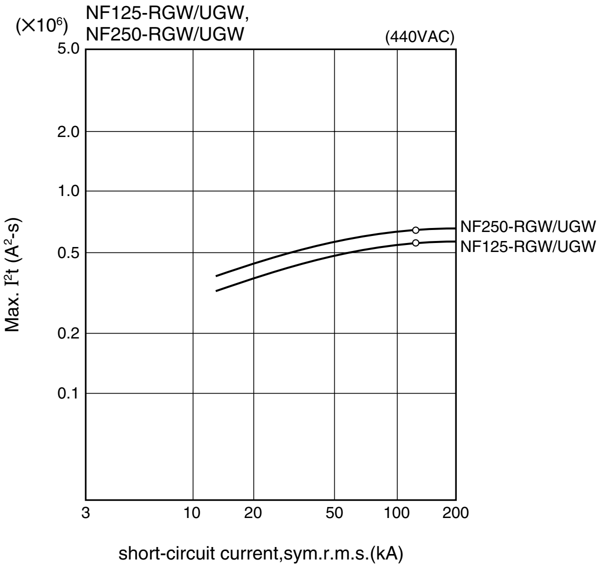


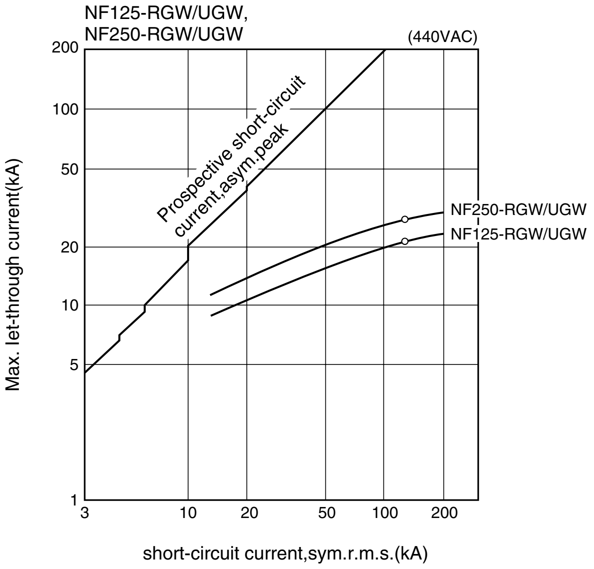
Current limiting characteristics

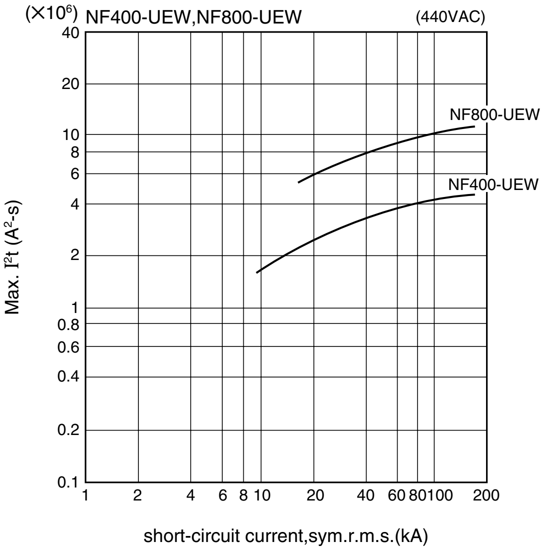


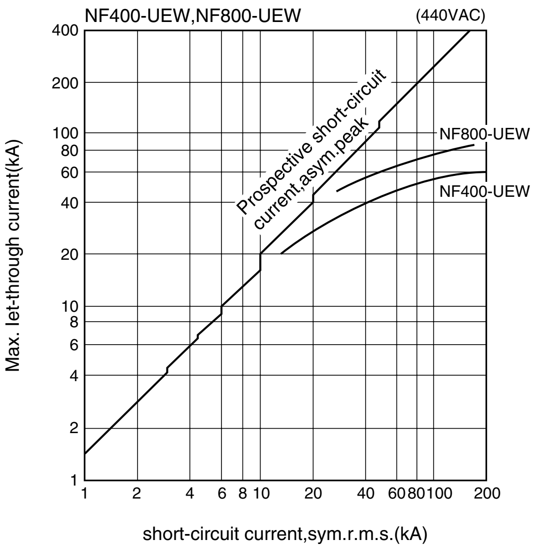





(×10^6)
NF125-RGW/UGW,
NF250-RGW/UGW
(440VAC)
5.0
2.0
1.0
0.5
0.2
0.1
Max. I²t (A²-s)
NF250-RGW/UGW
NF125-RGW/UGW
3
10
20
50
100
200
short-circuit current,sym.r.m.s.(kA)


NF125-RGW/UGW,
NF250-RGW/UGW
(440VAC)
200
100
50
20
10
5
1
Max. let-through current(kA)
Prospective short-circuit
current,asym.peak
NF250-RGW/UGW
NF125-RGW/UGW
3
10
20
50
100
200
short-circuit current,sym.r.m.s.(kA)


(×10^6)
NF400-UEW,NF800-UEW
(440VAC)
40
20
10
8
6
4
2
1
0.8
0.6
0.4
0.2
0.1
Max. I²t (A²-s)
NF800-UEW
NF400-UEW
1
2
4
6
8
10
20
40
60
80
100
200
short-circuit current,sym.r.m.s.(kA)


NF400-UEW,NF800-UEW
(440VAC)
400
200
100
80
60
40
20
10
8
6
4
2
1
Max. let-through current(kA)
Prospective short-circuit
current,asym.peak
NF800-UEW
NF400-UEW
1
2
4
6
8
10
20
40
60
80
100
200
short-circuit current,sym.r.m.s.(kA)

6.6 Protective Coordination with Wiring

6.6.1 General Considerations

If it is assumed that the heat generated by a large current passing through a wire is entirely dissipated within the wire, the following expression is applicable (for copper wires):

$$\left(\frac{I}{S}\right)^2 t=5.05\times10^4 \log_e \frac{234+T}{234+To}$$

I : Current(A, rms)
S : Wire cross-sectional area(mm²)
t : Current let-through time(s)
T : Wire temperature due to short circuit(°C)
To : Wire temperature before short circuit(°C)

Assume that short-circuit current occurs in a wire carrying its rated current (hot state To=60°C). If 150°C is the allowable temperature T, the following expression is applicable (see also Fig. 6.13):

$$\text{Allowable } I^2t=14000S^2$$

Table 6.4 Allowable Fault Conditions in Conductors

S Wire size	Allowable I^2t	I_S Allowable short-circuit current accoeding to I^2t
mm²	$A^2\times s$	kA, sym. (PF)
1	0.014×10^6	1.17 (0.9)
1.5	0.032×10^6	1.76 (0.9)
2.5	0.088×10^6	2.93 (0.9)
4	0.224×10^6	4.68 (0.9)
6	0.504×10^6	6.79 (0.8)
10	1.40×10^6	10.5 (0.6)
16	3.58×10^6	16.0 (0.5)
25	8.75×10^6	17.3 (0.3)
35	17.2×10^6	24.2 (0.3)
50	35.0×10^6	34.5 (0.3)
70	68.6×10^6	48.3 (0.3)
95	126×10^6	65.6 (0.3)
120	202×10^6	82.8 (0.3)
150	315×10^6	103 (0.3)
185	479×10^6	128 (0.3)
240	806×10^6	166 (0.3)

Notes: 1. Allowable I^2t is calculated assuming that all heat energy is dissipated in the conductor, conductor allowable maximum temperature exceeds 150°C, and hot start is applied, at 60°C.

2. I_S is an asym. value of allowable short-circuit current reduced to below the allowable I^2t, assuming half cycle interruption for 16mm² or less and one cycle interruption for 25mm² or more.

Considering let-through energy ($\int i^2dt$) in a fault where the protector has no current-limiting capability, if short-circuit occurs when let-through current is max., $\int i^2dt$ is:

Approx. $\frac{Ie^2}{71}$ ($A^2\cdot s$) in $\frac{1}{2}$ cycle interruption
(Power factor is 0.5.)
Approx. $\frac{Ie^2}{34}$ ($A^2\cdot s$) in 1 cycle interruption
(Power factor is 0.3.)

where current Ie is the effective value of the AC component. Half-cycle interruption is applied to wire of up to 14mm², and one-cycle interruption to larger wires. Table 6.4 is restrictive in that, e.g., in a circuit of fault capacity of 5000A or more, 2.5mm² wires would not be permitted. In practice, the impedance of the conductor itself presents a limiting factor, as does the inherent impedance of the MCCB, giving finite let-through I^2t and Ip values that determine the actual fault-current flow.

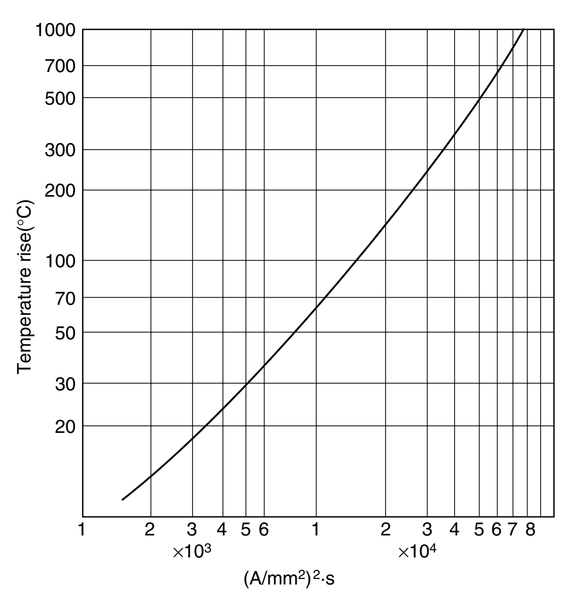


Fig. 6.13 Temperature Rises Due to Current Flow in Copper Wires

6.6.2 600V Vinyl-Insulated Wire (Overcurrent)

Japanese Electrical Installations Technical Standards (domestic) specify vinyl-insulated wire operating temperature as 60°C max., being a 30°C rise over a 30°C ambient temperature. This is to offset aging deterioration attendant on elevated temperatures over long periods. Criteria for elevated temperatures over short periods have been presented in a study by B. W. Jones and J. A. Scott ("Short-Time Current Ratings for Aircraft Wire and Cable," AIEE Transactions), which proposes 150°C for periods of up to 2 seconds, and 100°C for periods in the order of 20 seconds. These criteria can be transposed to currents for different wire sizes by the curves given in Fig. 6.14. Such figures, however, must be further compensated for the difference between vinyl materials used for aircraft and for

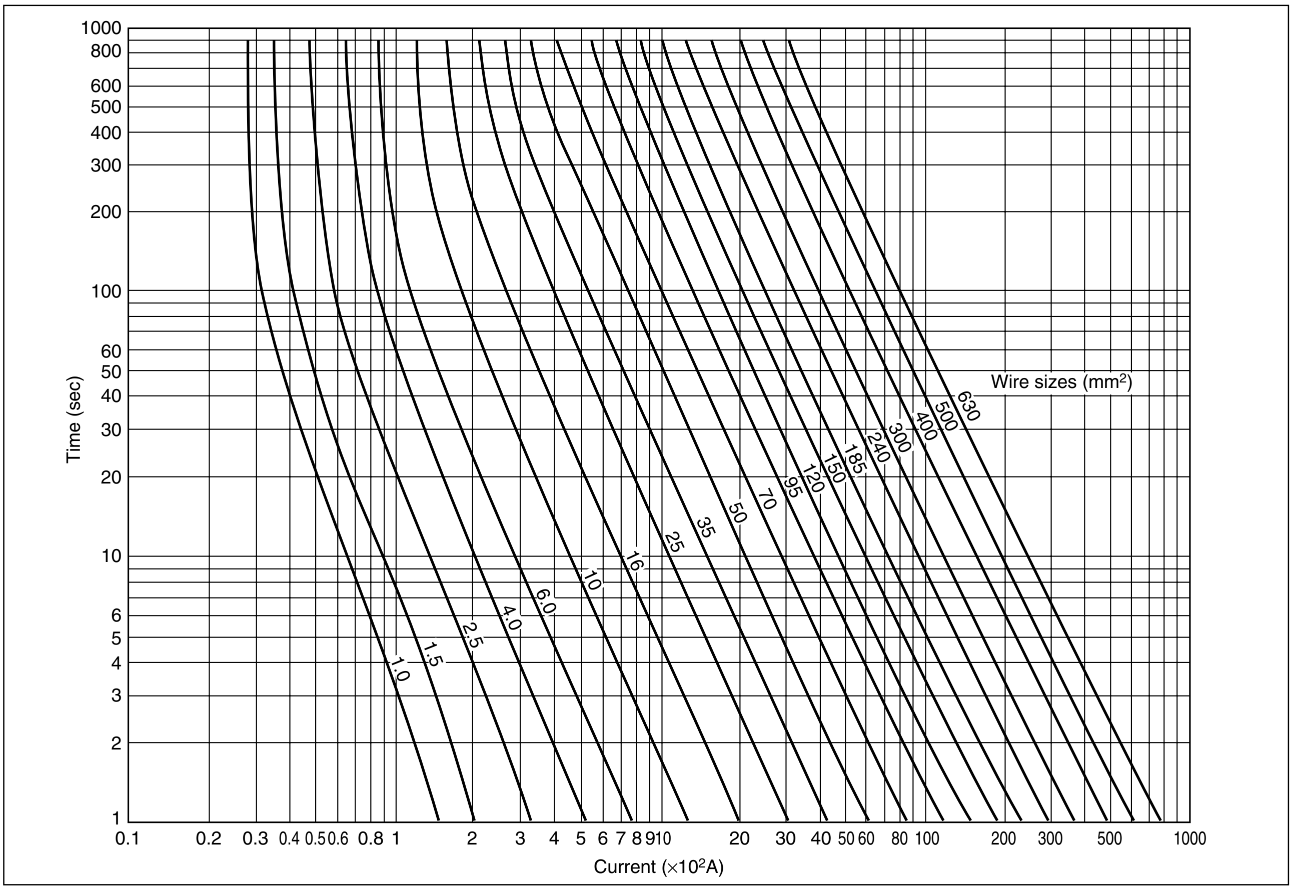


Fig. 6.14 Relation of Let-through Current to Time until 600V Vinyl-Insulated Wire Reaches a 70°C Temperature Rise. (In a Start from No Load State at Ambient Temperature of 30°C)

ground use; ultimately, the temperature figure of 75°C is derived (100°C per Jones and Scott, compensated) as a suitable short-time limitation for wiring with heat-proof vinyl or styrene-butadene-rubber insulation. Current transpositions for the range of wire sizes are not presented, being non-standard ; however, Fig. 6.15 gives MCCB ratings for temperature limitations of 30°C in normal operation, and 75°C for periods of up to 20 seconds.

The apparent disparity of the ambient ratings of 30°C for wiring against 40°C for MCCBs, is reconcilable in that wiring, for the most part, is externally routed, while MCCBs are housed in panelboards or the like. The two figures can be used compatibly, without modification. It is further noted that, where MCCBs with long-delay elements of the thermal type are employed, the effect of increased ambient, which would normally derate the wiring, is adequately compensated by the attendant decrease in thermal-region tripping time of the MCCB.

The curves in Fig. 6.17 show the comparison of the delay regions of MCCB tripping with allowable currents in open-routed wiring. Fig. 6.16 shows the method required by the Japanese standards referred to above, for derating wiring to be routed in conduit.

Wire size (mm²) / MCCB rating(A)	1	1.5	2.5	4	6	10	16	25	35	50	70	95	120	185	240
15	▨														
20	▨	▨													
32	▨	▨	▨												
40	▨	▨	▨							Protected region					
50	▨	▨	▨	▨											
63	▨	▨	▨	▨	▨	▨									
80	▨	▨	▨	▨	▨	▨									
100	▨	▨	▨	▨	▨	▨	▨								
125	▨	▨	▨	▨	▨	▨	▨								
150	▨	▨	▨	▨	▨	▨	▨	▨							
175	▨	▨	▨	▨	▨	▨	▨	▨	▨						
200	▨	▨	▨	▨	▨	▨	▨	▨	▨						
225	▨	▨	▨	Unprotected region	▨	▨	▨	▨	▨	▨					
250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨					
300	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
350	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
400	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		

Fig. 6.15 MCCBs and Wiring Sizes

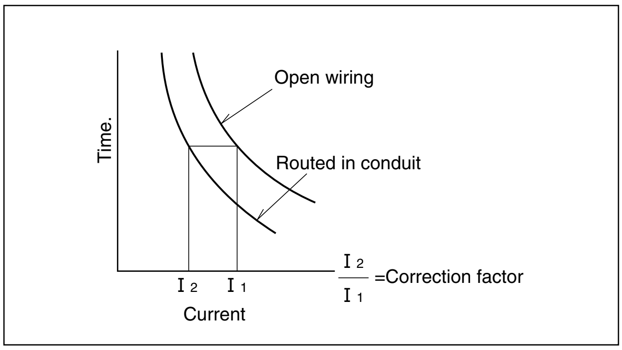
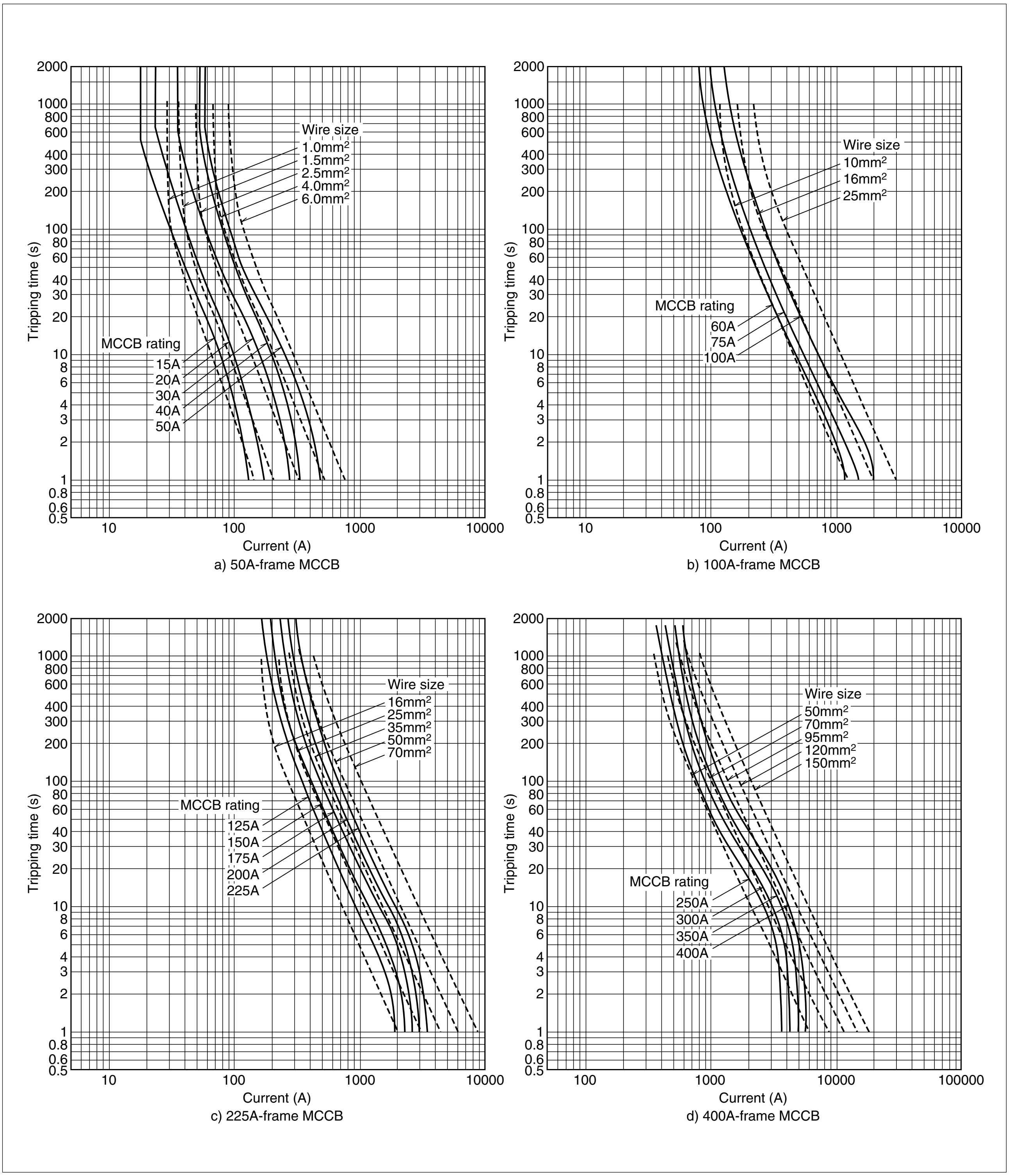


Fig. 6.16 Wire Derating Method, for Conduit Routing



a) 50A-frame MCCB

b) 100A-frame MCCB

c) 225A-frame MCCB

d) 400A-frame MCCB

Fig. 6.17 600V Wire and MCCB Protection Compatibility

6.7 Protective Coordination with Motor Starters

Motor starters comprise a magnetic contactor and a thermal overload relay, providing the nesessary switching function for control of the motor, plus an automatic cutout function for overload protection. Mitsubishi Electric's excellent line of motor starters are available for a wide range of motor applications and are compatible with Mitsubishi MCCBs.

Magnetic contactors are rugged switching devices required to perform under severe load conditions without adverse affect. They are divided into Classes A through D (by capacity); Class A, e.g., must be able to perform 5 cycles of closing and opening of 10 times rated current, followed by 100 closing operations of the same current after grinding off 3/4 of the contact thickness.

Current ratings of contactors usually differ according to the circuit rated voltage, since voltage determines arc energy, which limits current-handling capability.

Thermal overload relays (OLRs) employ bimetal elements (adjustable) similar to those of MCCBs.

For compatibility with the magnetic contactor, the OLR must be capable of interrupting 10 times the motor full-load current without destruction of its heater element. Mitsubishi Type TH OLRs are normally capable of handing 12 to 20 times rated current; in addition there is available a unique saturable reactor for parallel connection to the heaters of some types, giving a fusion-proofing effect of 40~50 times.

6.7.1 Basic Criteria for Coordination

It is necessary to ensure that the MCCB does not trip due to the normal starting current, but that the OLR cutout curve intersects the MCCB thermal delay-tripping curve between normal starting current and 10 times full-load current. The MCCB instantaneous-tripping setting should be low enough to protect the OLR heater element from fusion, in a short-circuit condition.

The above criteria should ensure that either the MCCB or the OLR will interrupt an overload, to protect the motor and circuit wiring, etc. In practice it is desirable for the MCCB instantaneous tripping to be set for about 15 times full-load current as a margin against transients, such as in reclosing after power failure, **Y**-delta switching, inching, etc.

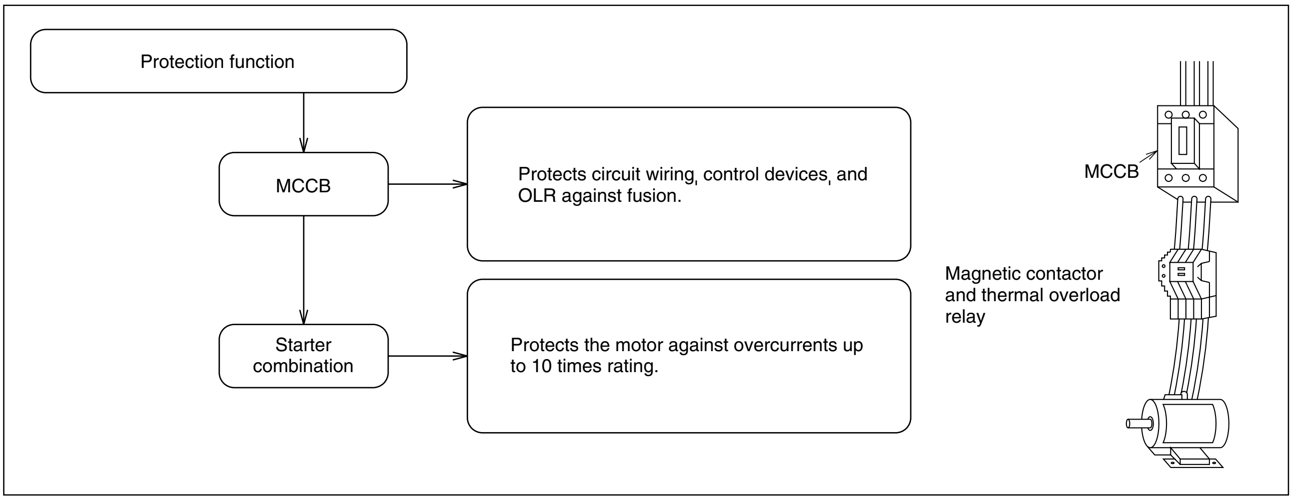


Fig. 6.18 Protective Coordination; MCCBs and Motor Starters

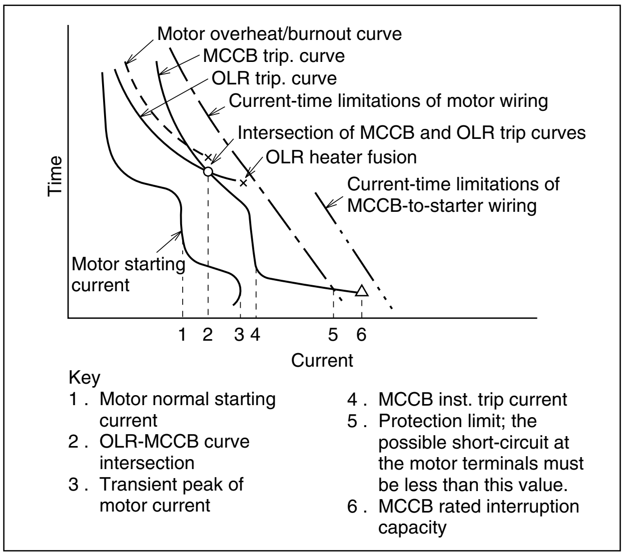


Fig. 6.19 Protection Coordination Criteria for MCCBs and Motor Starters

6.7.2 Levels of Protection (Short Circuit)

In some cases it may be advantageous to allow the starter to be damaged in the event of a short circuit, provided that the fault is interrupted and the load side is properly protected.

IEC standards defines 2 types of coordination, summarized as:

1. Type "1" coordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and may not be suitable for further service without repair and replacement of parts.
2. Type "2" coordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and shall be suitable for further use. The risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken as regards the maintenance of the equipment.

6.7.3 Motors with Long Starting Times

The usual approach is to select a starter with a larger current rating, but this method, of course, involves a degree of sacrifice of protection. Mitsubishi provides a unique solution to this problem in the form of a saturable reactor added to the OLR heater element. The effect is to change the high-current characteristics, so that nuisance tripping in starting is eliminated, without loss of overload protection. Mitsubishi saturable reactors are adjusted to allow around 25~30 seconds of continuous starting current.

6.7.4 Motor Breakers (M Line MCCBs) and Magnetic Contactors

M Line MCCBs are provided with trip curves especially suitable for motor protection, with ratings based on motor full-load currents. They provide overcurrent and short-circuit protection, and are normally used with magnetic contactors. The need for protective coordination (as with a regular MCCB plus a starter) is eliminated, and the reliability of protection in a short-circuit condition is far higher than that of the heater of a starter OLR. Where the motor starting time is long, the MCCB tripping curve must be checked carefully, since tripping times are rather short in the delay-trip range. Care must also be taken with respect to surge conditions such as inching, reversing, restart, **Y**-delta starting, etc.

6.7.5 Motor Thermal Characteristics

Overload currents in motors can lead to burnout, or insulation damage resulting in shock or fire hazard; the basic approaches to protection are (summarized from Japanese standards):

1. MCCB + magnetic contactor + OLR
2. Motor breaker + magnetic contactor
3. Motor breaker alone

In 1, the OLR is the primary interrupter of overload, and being adjustable, can be set for the true load requirement. Large overcurrent or short-circuit fault conditions are interrupted by the MCCB instantaneous trip. In 2, the motor breaker is the protector for both overload and short-circuit, and not being adjustable must be selected carefully, for best coordination with the load concerned. In 3, since the MCCB is relied on not only for all protective functions but also for switching, this arrangement should be reserved for applications requiring infrequent motor starting and stopping.

6.7.6 Motor Starting Current

Motor starting times of up to 15 seconds are generally considered safe; more than this is considered undesirable; more than 30 seconds is considered dangerous and should be avoided wherever possible. For instantaneous tripping considerations, the MCCB is normally set to 600% of the motor full-load current, for trouble-free line-starting of an induction motor.

More detailed consideration is required where short-time inrush effects (current magnification) are involved, such as in **Y**-delta switching, running restart, etc. Two basic causations are as follows:

1. Superimposed DC Transient (Low Power-Factor Effect) Fig. 6.20 shows that the power factor is about 0.3 at starting, causing a significant DC component, so that the total transient inrush current may reach about twice the value of the AC component, even though the latter is of constant amplitude. Peak inrush current (I_t) of 1.4 x normal starting current (I_o) must be allowed for, in selecting the MCCB instantaneous-trip setting.

2. Residual Voltage (Running Restart)

If residual (regenerative) voltages appearing at the motor terminals are out of phase with the supply voltage (at the time of reclosing after being interrupted, before the motor speed is substantially reduced), the cumulative effect of the line voltage and the residual voltage is equivalent to the motor being directly subjected to a large line overvoltage, with a resulting abnormal inrush current of:

$$\frac{\text{Residual+source V}}{\text{Source V}} \times \text{Normal starting inrush current}$$

This is a current magnification effect, which may be as much as 2 x in direct restarting, and $\left(1+\frac{1}{\sqrt{3}}\right)$ x in **Y**-delta-switching restarting. When the DC-transient factor (§1 above) is added, the magnification becomes 2.4 in the case of direct restarting, and 1.9 for **Y**-delta restarting.

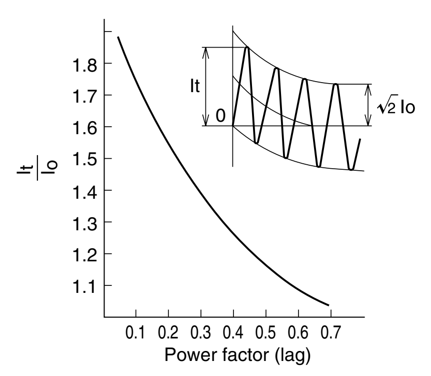
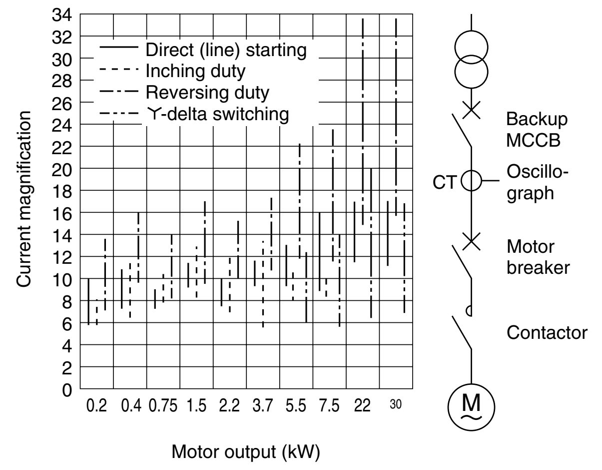


Fig. 6.20 Transient DC Component



b) Test results a) Test connections

Fig. 6.21 Peak Inrush-Current Measurements

Thus, if normal starting current is assumed as 600% of full-load current, the peak inrush becomes 1200% in **Y**-delta restarting and 1600% in direct restarting. The MCCB instantaneous-trip setting must be selected at larger than these values.

Fig. 6.21 shows test date with respect to four conditions of transient inrush current, expressed as magnifications of full-load current, measured on motors rated from 0.2~30kW. The MCCB was used for line-starting switching, and the contactor for the other switching duties. Phase matching between the line and residual voltages was uncontrolled.

The oscillographs taken showed that the peak inrush currents persist for about one-half cycle, followed by a rapid decrease to normal starting-current level. From the curves it can be concluded that peak inrush magnifications vary greatly depending on the duty involved; for reversing duty, the MCCB instantaneous trip settings must be selected from 1600 ~ 3400% of full-load current. For line starting and **Y**-delta starting, the range spans from 1000~2000%.

6.8 Coordination with Devices on the High-Voltage Circuit.

6.8.1 High-Voltage Power Fuse

The MCCB on the secondary (low-voltage) side of a power transformer must have tripping characteristics that provide protective coordination with the power fuse (PF) on the high-voltage side (Fig. 6.22). The MCCB must always trip in response to overcurrent, to ensure that the PF does not fuse or deteriorate by elevated temperature aging.

Fig. 6.23 shows the MCCB curve in relationship to the deteriorated PF curve (if this is unavailable, the average fusing curve reduced by 20% can usually be assumed). The PF characteristic can be converted to the secondary side, or the MCCB characteristic to the primary side; the curves must not overlap in the overcurrent region.

Where the MCCB instantaneous-tripping current of the MCCB is adjustable, difficulties in matching the curves can be overcome as shown, but a 10% margin must be included to allow for the tolerance of the MCCB tripping setting.

The shaded area in Fig. 6.23 belong to overcurrent region, the overcurrent generally occur at the lower circuit of MCCB$_2$.

Thus, it may in some cases be better to accept a coordination between the PF and MCCB$_2$, permitting a mismatch between the PF and MCCB$_1$.

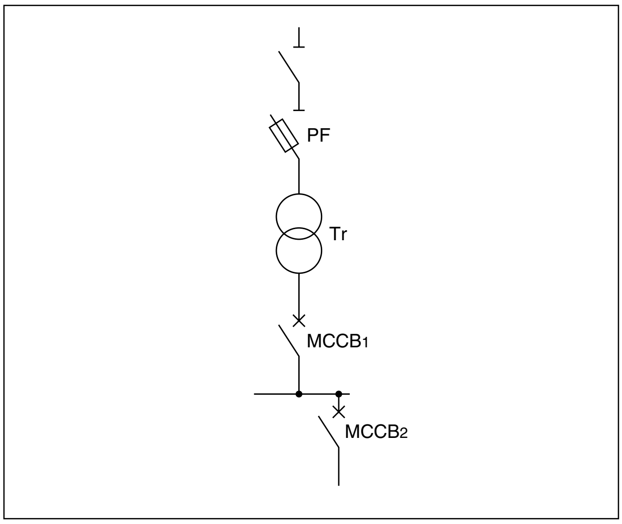


Fig. 6.22 Protective Coordination of MCCBs and HV-Side PF

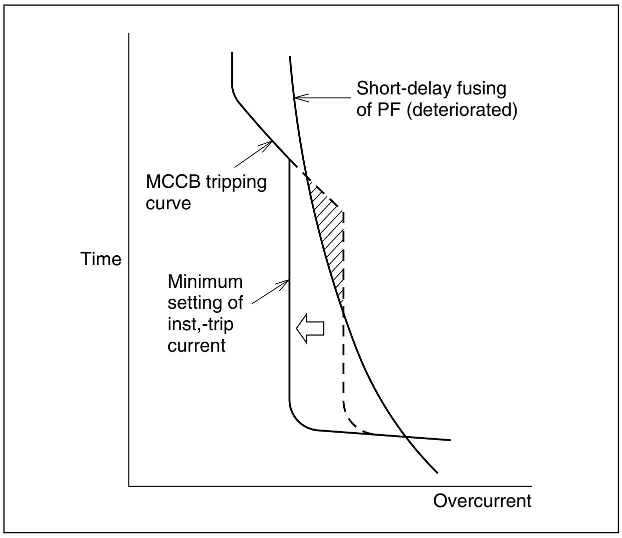


Fig. 6.23 Coordinated PF and MCCB Characteristics

6.8.2 Electronic MCCBs and HV PF

A basic requirement is that the deteriorated short-delay curve of the PF, and the short-delay trip curve of Electronic MCCB, which is shifted +10% along the current axis, do not overlap.

To facilitate matching, the rated current of the PF should be as large as possible; however, there is an upper limit, as seen from the following criteria:

1. The rated current should be 1.5~2 times the load current.
2. To ensure protection in the event of a short circuit, the PF must interrupt a current of 25 times the transformer rating within 2 seconds.
3. To ensure that the PF neither deteriorates nor fuses as a result of the transformer excitation surge current, the short-delay deterioration curve of the PF must be more than 0.1 seconds, at a current of 10 times the transformer rating. The “10 times” factor becomes “15 times” in the case of a single-phase transformer.

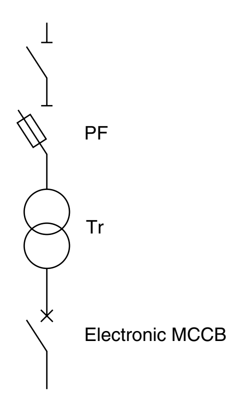


Fig. 6.24 Protective Coordination of Electorinic MCCBs and PF

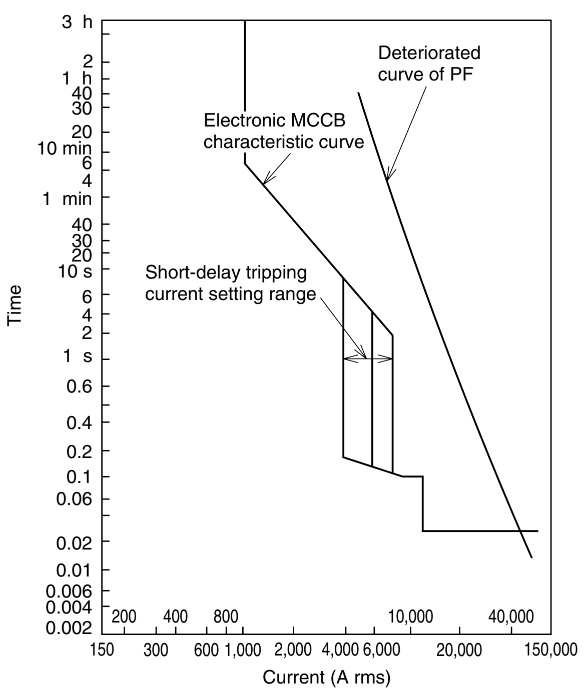


Fig. 6.25 Coordinated PF and Electronic MCCB Characteristics

6.8.3 MCCBs and HV-Side OCR

An overcurrent-relay remote tripping device (OCR) on the HV side of the circuit must be coordinated with the MCCBs on the LV side. The OCR setting must take into consideration the coordination with the OCR at the power-utility substation and, at the same time, the following:

1. The setting of an OCR with an instantaneous-trip element must be at least 10 times the transformer current rating, to ensure that the excitation surge of the latter does not trip the OCR.
2. To ensure short-circuit protection, the OCR must operate within 2 seconds, at 25 times the transformer rated current.

Figs. 6.26 and 6.27 show the setup, and the coordinated characteristics converted to the low-voltage side. The turns ratio of the CT is 150:5, to match the rated primary current of 87.5A. Considering cooperation of the OCR with the upper-ranking substation OCR, the OCR dial is normally set to 0.2 or less, or 1 second max. if it has an instantaneous trip element. On the Mitsubishi Type MOC-E general-purpose relay this is equivalent to dial setting No. 2. Latching-curve overlap, shown by the broken lines in Fig. 6.27, must be allowed for. The instantaneous trip is set to 30A, in accordance with §1, above.

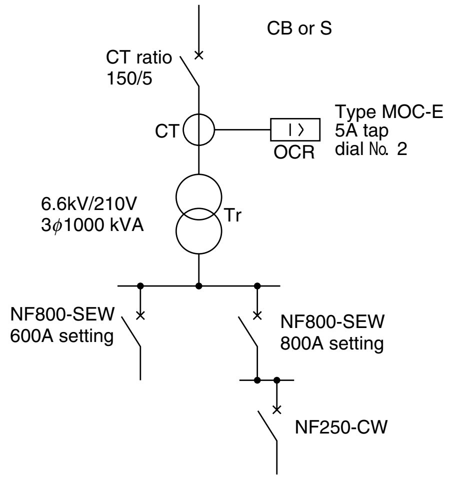


Fig. 6.26 Electronic MCCBs in Coordination with an HV-Side OCR

For setting the Electronic MCCBs (800 and 600A versions of Type NF800-SEW), the short-delay tripping currents of both are set to MIN. NF800-SEW have negligible latching inertia, so that the reset characteristics (except in the instantaneous-trip region) can be regarded as the same as the tripping characteristics. Further, there is very little tolerance variation between units; thus, the tripping characteristics can be shown as a single line.

If the NF800-SEW short-delay trip current is set at MAX (where MIN and MAX respectively correspond to 2 and 10 times rated current), a 600A rating setting will correspond to 6000A tripping, and an 800A setting will correspond to 8000A tripping. In this case (at MAX setting), short-delay latching of the NF800-SEP will overlap the OCR latching (4710A, secondary conversion). But if the NF800-SEW and the OCR are all set to MIN, so that the latching values do not exceed 4710A, good coordination will be achieved.

As the OCR has an instantaneous-trip element, set at 30A (secondary conversion 28.3kA), the region of selective interruption between the OCR and the NF800-SEW will extend to this value.

Considering the coordination of the Electronic MCCBs with the lower-level MCCBs (NF250-CW), it can be seen from Fig. 6.27 that the maximum trip curve (tolerance) of the C Line units matches well with the NF800-SEW curves, with no danger of overlap.

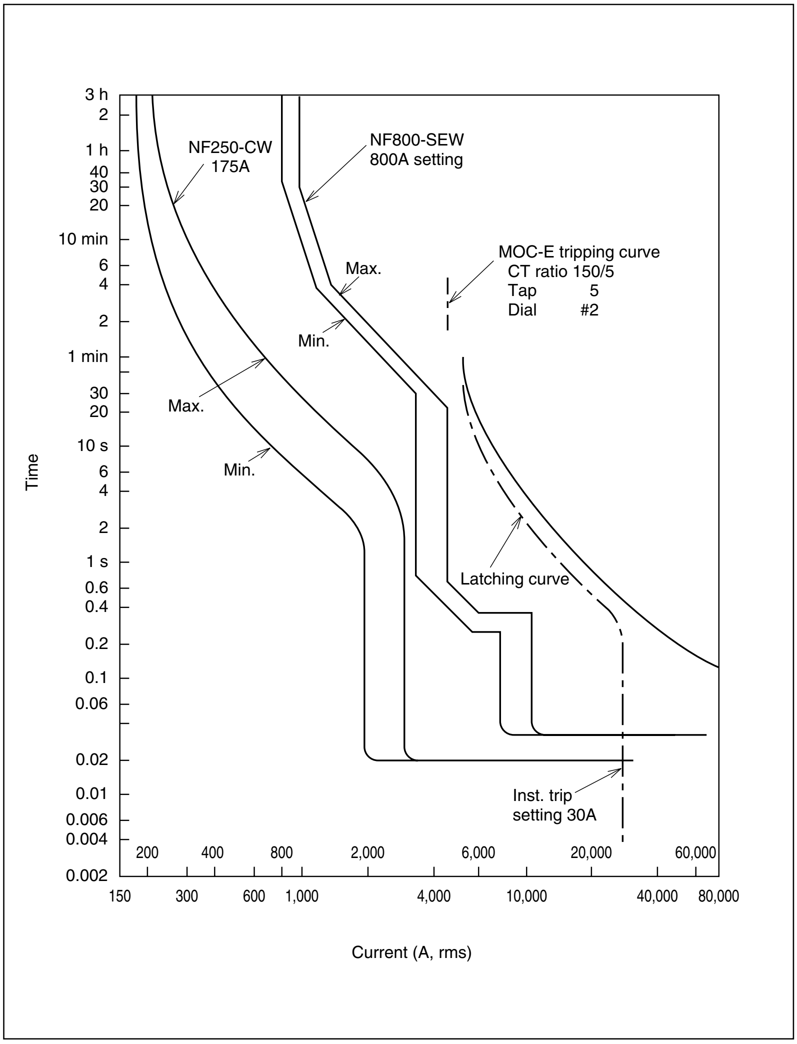


Fig. 6.27 Coordinated OCR and Electronic MCCB Characteristics

7. SELECTION

In selecting MCCBs for a particular application, in addition to purely electrical aspects of load and distribution conductor systems, physical factors such as panelboard configuration, installation environment, ambient-temperature variations, vibration, etc. must also be considered.

MCCBs are rated for an ambient of 40°C, and where panelboard internal temperatures may exceed this, the MCCBs installed should be derated in accordance with Table 7.1.

1. Actual load currents may exceed the nominal-values.
2. Load currents may increase with time, due to deterioration of load devices (i.e., friction in motors).
3. Source voltage and frequency may vary.

Table 7.1 MCCB Deratings Due to Installation Factors

Panelboard max. internal temp. (°C)	Load allowable, due to panelboard temp. (%)
50	90
55	80
60	70

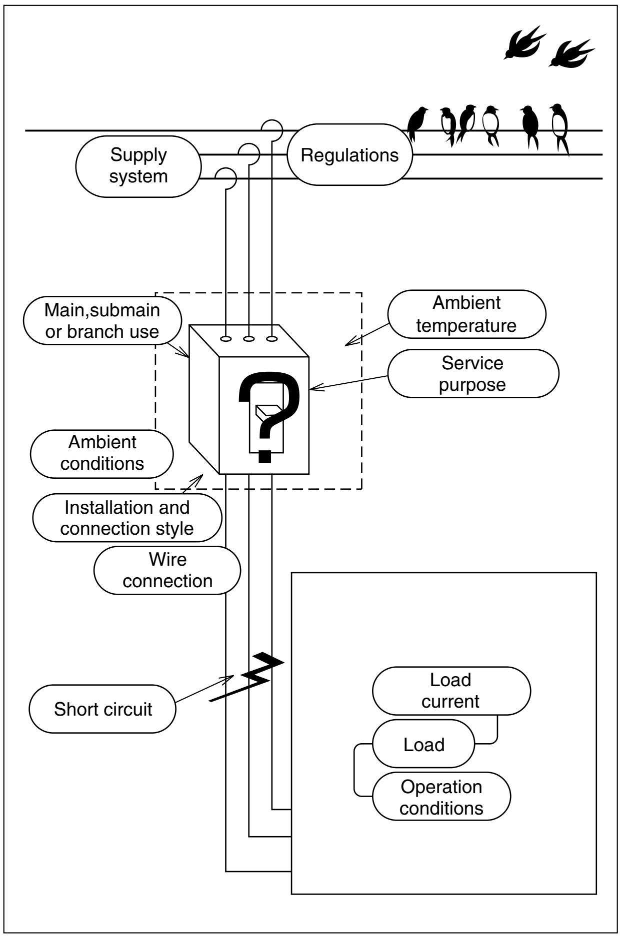


Fig. 7.1 MCCB Selection Consideration

7.1 Motor Branch Circuits

The following discussion assumes single motors and cold-start operation.

7.1.1 General Considerations

The starting current (I_{MS}) and time (T_{MS}) for the motor, and its full-load current, dictate the rated current, long-delay trip and instantaneous-trip curves for the MCCB as shown in Fig. 7.2. A safety-margin of up to 50% should be considered for the starting time, to allow for voltage variations and increase in load friction.

The instantaneous-trip curve should be at least 1.4 x normal starting current to allow for the effect of the DC component attendant to the low power factor (about 0.3) of the starting current. For Y-delta starting the unphased-switching allowance increases the 1.4 margin to 1.9. For running restarting the unphased-switching allowance increases the factor to 2.4.

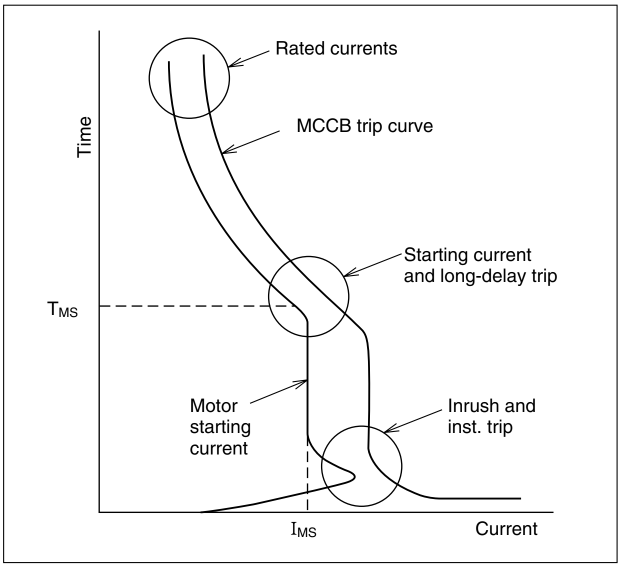


Fig. 7.2 MCCB and Motor Starting

7.1.2 Motor Breaker

Where starting times are relatively short and currents are small, the Mitsubishi M Line motor breakers can be used without the need for a motor starter.

7.2 For Lighting and Heating Branch Circuits

In such circuits, switching-surge magnitudes and times are normally not sufficient to cause spurious tripping problems; however, in some cases, such as mercury-arc lamps or other large starting-current equipment, the methods presented in §7.1 above should be considered.

In general, branch MCCBs should be selected so that the total of ratings of the connected loads is not more than 80% of the MCCB rating.

7.3 For Main Circuits

7.3.1 For Motor Loads

The method of "synthesized motors" is recommended – that is, the branch-circuit loads to be connected are divided into groups of motors to be started simultaneously (assumed), and then each group is regarded as a single motor having a full-load current of the total of the individual motors in the group. The groups are regarded as being sequentially started.

The rating of the branch MCCB for the largest synthesized motor is designated I_B max., those of the subsequent synthesized motors as I_1, I_2, ...I_{n-1}. The rating of the main MCCB becomes:

$$I_{MAIN} = I_B \max + (I_1 + I_2 + ... I_{n-1}) \times D$$

where D is the demand factor (assumed as 1 if indeterminate).

7.3.2 For Lighting and Heating, and Mixed Loads

For lighting and heating loads the rating of the main MCCB is given as the total of the branch MCCB ratings times the demand factor. For cases where both motor-load branches and lighting and heating branches are served by a common main MCCB, the summation procedures are handled separately, as described in the foregoing, then grand-totalized to give the main MCCB rating.

7.4 For Welding Circuits

7.4.1 Spot Welders

A spot welder is characterized by a short, heavy intermittent load, switched on the transformer primary side. The following points must be considered in MCCB selection:

1. The intermittent load must be calculated in terms of an equivalent continuous current.
2. The excitation transient surge due to the breaker being on the transformer primary side must be allowed for.

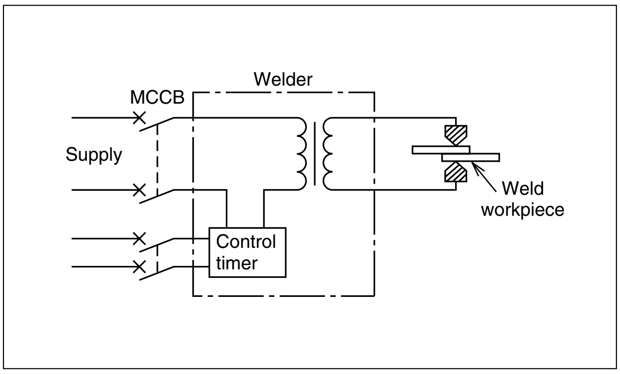


Fig. 7.3 Spot-Welder Circuit

The temperature rise of the MCCB and wiring depends on the thermal-equivalent continuous current. To convert the welder intermittent current into a thermal-equivalent continuous value (I_e), consider the current waveform (Fig. 7.4); load resistance (R) gives power dissipation:

$$W = I_1^2 Rt_1$$

and average heat produced:

$$\frac{W}{t_1 + t_2} = \frac{I_1^2 Rt_1}{t_1 + t_2} = I_1^2 R\beta = R(I_1\sqrt{\beta})^2$$

where β is the duty factor, defined as

$$\frac{\text{total conduction time}}{\text{total time}}$$

This is equivalent to heating by a continuous current of $I_1\sqrt{\beta}$.

In the example of Fig. 7.4:

$$I_e = I_1\sqrt{\beta} = 1200 \times 0.0625 = 300 \text{ (A)}$$

i.e., a continuous current of 300A will produce the average temperature. In practice, however, the instantaneous temperature will fluctuate as shown in Fig. 7.5 and the maximum value (T_m) will be greater than the average (T_e) that would be produced by a continuous current of 300A. The operation of an MCCB thermal element depends on the maximum rather than the average temperature, so it must be selected not to trip at T_m; in other words, it is necessary to ensure that its hot-start trip delay is at least as great as the interval of current flow in the circuit. The rated current of a "mag-only" MCCB (which does not incorporate a thermal trip function) can be selected based on the thermal equivalent current of the load, allowing a margin of approximately 15% to the calculated value to accommodate supply-voltage fluctuations, equipment tolerance, etc. Thus:

$$I_{MCCB} = I_e \times 1.15 = 300 \times 1.15 = 345 \text{ (A)}$$

The MCCB selected becomes the nearest standard value above 345A.

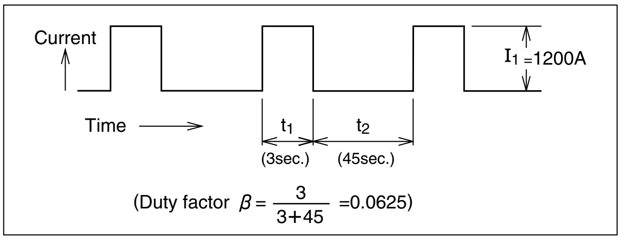


Fig. 7.4 Welder Intermittent Current

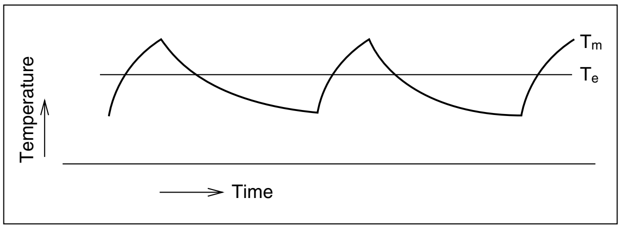


Fig. 7.5 Temperature Due to Intermittent Current

For practical considerations, rather than basing selection on welding conditions, the MCCB should be selected to accommodate the maximum possible duty, based on the capacity and specifications of the welder.

If the welder rated capacity, voltage and duty factor in Fig. 7.3 are 85kVA, 200V and 50% respectively, the thermal-equivalent continuous current (I_e) becomes:

$$I_e = \frac{\text{rated capacity}}{\text{rated voltage}} \times \sqrt{\text{duty factor}}$$

$$= \frac{85 \times 10^3}{200} \times \sqrt{0.5} = 300\text{A}$$

Hence, the MCCB rated current becomes:

$$I_{MCCB} = I_e \times 1.15 = 300 \times 1.15 = 345\text{A}$$

(i.e., the next higher standard value).

The relationship between the duty factor, which does not exceed the working limitations, and the maximum permissible input I_β at the above duty factor is:

$$I_\beta = \frac{I_e}{\sqrt{\beta}} = \frac{300}{\sqrt{\beta}}$$

If the total period is taken as 60 seconds and the duty factor is converted into the actual period during which current flows, the above relationship can be expressed graphically as in Fig. 7.6. Thus, although the thermal equivalent current is 300A, the maximum permissible input current for a duty factor of 50% (30 seconds current flow) is 425A. For a duty factor of 6.25% (3.75 sec current flow) it is 1200A. Even if the secondary circuit of the welder were short circuited, however, the resultant primary current would only increase by about 30% over the standard maximum welding current. If this is 400kVA, the maximum primary current $I_{\beta max}$ is:

$$I_{\beta max} = \frac{\text{standard maximum input}}{\text{primary voltage}} \times 1.3$$

$$= \frac{400 \times 10^3}{200} \times 1.3 = 2600\text{A}$$

Hence the maximum input current I_β should be restricted to 2600A.

The 75% hot-start characteristic of the 350A Type NF400-SW breaker is shown by the broken line in Fig. 7.6, and the temperature-rise characteristics up to the upper limit of the welder, by the solid line. To ensure protection of the welder from burnout, the delay-trip characteristic is selected at higher than the solid line; however, to establish MCCB protection criteria, it is necessary to look at each welder individually.

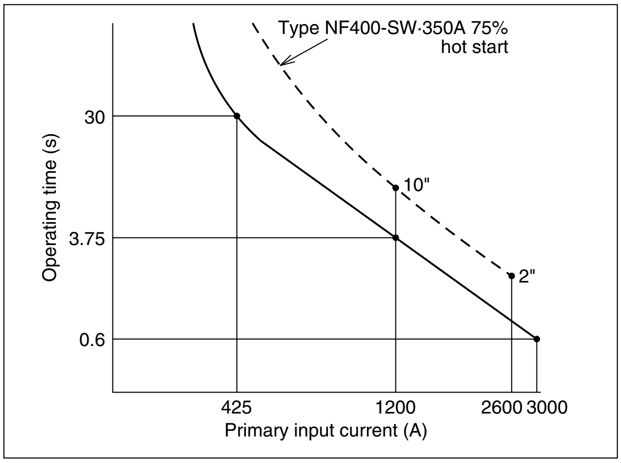


Fig. 7.6 Welder Temperature Rise and MCCB Trip Curve

7.4.2 MCCB Instantaneous Trip and Transformer Excitation Surge

When a welding-transformer primary circuit is closed, depending upon the phase angle at the instant of closure, a transient surge current will flow, due to the super-imposed DC component and the saturation of the transformer core.

In order to prevent spurious tripping of protective devices resulting from such surges, and also to maintain constant welding conditions, almost all welders currently available are provided with a synchronized switch-on function, with or without wave-peak control.

With synchronized switch-on, the measured ratio between the RMS value of the primary current under normal conditions and the maximum peak transient current ranges from $\sqrt{2} \sim 2$.

For nonsynchronized soft-starting-type welders the measured ratio is a maximum of 4.

Maximum instantaneous transient surge excitation currents for various starting methods are as follows:

Synchronized switch-on welders with wave peak control:

$$I_{max} = \sqrt{2} \times I_{\beta max}$$

Synchronized switch-on welders without wave peak control:

$$I_{max} = 2 \times I_{\beta max}$$

Nonsynchronized switch-on welders with soft start:

$$I_{max} = 4 \times I_{\beta max}$$

Nonsynchronized switch-on welders without soft start:

$$I_{max} = 20 \times I_{\beta max}$$

If synchronized switch-on is employed, the transient surge excitation currents are relatively consistent, so that the relationship $I_{max} = 2\ I_{\beta max}$ is sufficient.

For a synchronized switch-on type welder of maximum primary input ($I_{\beta max}$) = 2600A

$$I_{max} = 2 \times I_{\beta max} = 2 \times 2600 = 5200\text{A}$$

Since MCCB instantaneous trip currents are specified in terms of RMS value, I_{inst} is as follows:

$$I_{inst} = \frac{I_{max}}{\sqrt{2}} = \frac{5200}{\sqrt{2}} = 3680\text{A}$$

The MCCB should be selected so that I_{inst} is smaller than the lower tolerance limit, of the instantaneous trip current.

7.4.3 Arc Welders

An arc welder is an intermittent load specified. The MCCB rating can by selected by converting the load current into thermal-equivalent continuous current. If this is taken as the rated current, however, the current duration per cycle will become relatively long, with the attendant danger of thermal tripping of the MCCB. In the total period of 10 minutes, if the duty factor is 50%, a 141% overload exists for 5 minutes; if the duty factor is 40%, a 158% overload exists for 4 minutes; and if the duty factor is 20%, a 224% overload exists for 2 minutes. Thus:

$$I_{MCCB} \geq \frac{1.2 \times P \times 10^3}{E}$$

where 1.2: Allowance for random variations in arc-welder current, and supply-voltage fluctuations
P: Welder rated capacity (kVA)
E: Supply voltage (V)

The switching transient in the arc welder is measured as 8~9 times the primary current. Consequently, using 1.2 allowance, it is necessary to select instantaneous-trip characteristics such that the MCCB does not trip with a current of 11 times the primary current.

7.5 MCCBs for Transformer-Primary Use

Transformer excitation surge current may possibly exceed 10 times rated current, with a danger of nuisance tripping of the MCCB. The excitation surge current will vary depending upon the supply phase angle at the time of switching, and also on the level of core residual magnetism. The maximum is as shown for switching-point P in Fig. 7.7. During the half cycle following switch-on the core flux will reach the sum of the residual flux ϕ_r, plus the switching-surge flux $2\phi_m$. The total, $2\phi_m + \phi_r$, represents an excitation current in excess of the saturation value. The decay-time constant of this tends to be larger for larger transformer capacities. Table 7.2 shows typical values of excitation surge current, but as these do not take circuit impedance into account, the actual values will be larger. If both the primary leakage impedance and circuit impedance are known, the surge current may be derived by considering the transformer as an air core reactor; otherwise the values in Table 7.2 should be used. This table gives maximum values, however, that are based on the application of rated voltages to rated taps; it should be noted that supply overvoltage will result in even larger surges.

Since it is the instantaneous-trip function of the MCCB that responds to the transient current, thermal-magnetic MCCBs, which can more easily be manufactured to handle high instantaneous-trip currents, are advantageous over completely electromagnetic types, where the instantaneous-trip current is a relatively small multiple of the rated current.

Table 7.2 Transformer Excitation Surge Currents

Capacity (kVA)	1ph transformer		3ph transformer	
	First 1/2-cycle peak (multiple)[1]	Decay time constant (Hz)	First 1/2-cycle peak (multiple)[1]	Decay time constant (Hz)
5	37	4	26	4
10	37	4	26	4
15	35	5	26	4
20	35	5	26	4
30	34	6	26	4
50	34	6	23	5
75	29	6	18	5
100	28	6	17	5
150	24	8	14	6
200	22	8	13	6
300	18	9	13	8
500	17	12	11	9

Note: 1 "Multiple" means the first 1/2-cycle peak as a multiple of the rated-current peak.

Table 7.3 Transformer Capacities and Primary-Side MCCBs

Tran. kVA	MCCB Type (rated current (A))			
	1 phase 230V	1 phase 400V	3 phase 230V	3 phase 400V
5	NF125-SW (80)	NF125-SW (40)	NF63-HW (50)	NF32-SW (32)
7.5	NF125-SW (100)	NF125-SW (63)	NF125-SW (40)	NF63-HW (40)
10	NF250-SW (150)	NF125-SW (80)	NF125-SW (63)	NF63-HW (50)
15	NF250-SW (200)	NF250-SW (125)	NF125-SW (100)	NF125-SW (50)
20	NF400-SW (300)	NF250-SW (150)	NF250-SW (125)	NF125-SW (63)
30	NF400-SW (400)	NF250-SW (225)	NF250-SW (175)	NF125-SW (100)
50	NF630-SEW (600)	NF400-SW (400)	NF400-SW (250)	NF250-SW (150)
75	NF1000-SEW (500)	NF630-SW (500)	NF400-SW (300)	NF250-SW (175)
100	NF1000-SEW (500)	NF630-SW (630)	NF400-SW (400)	NF250-SW (225)
150	NF1000-SEW (800)	NF1000-SEW (500)	NF630-SW (500)	NF400-SW (300)
200	NFE2000-S (1200)	NF1000-SEW (600)	NF630-SW (600)	NF400-SW (350)
300	NFE2000-S (1500)	NF1000-SEW (900)	NF1000-SEW (900)	NF630-SW (600)
500	—	NFE2000-S (1400)	NF1600-SEW (1400)	NF1000-SEW (900)

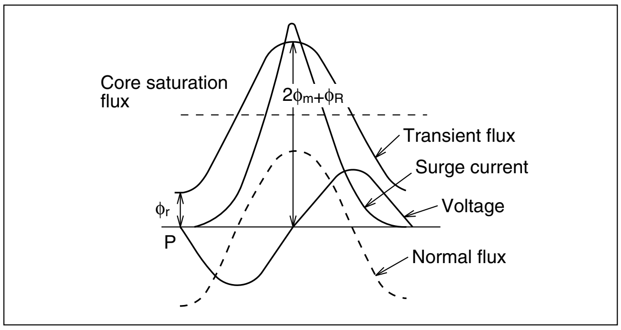


Fig. 7.7 Excitation Surge Effects

In MC CB selection for 400V, 50kVA transformer-primary used, rated RMS current is:

$$I = \frac{\text{Capacity (kVA)} \times 10^3}{\sqrt{3} \times \text{Voltage (V)}} = \frac{50 \times 10^3}{\sqrt{3} \times 400} = 72.2\text{A}$$

From Table 7.2, the peak value of the excitation surge current $I\phi$ is 23 times that of the rated current, hence:

$$I\phi = 23 \times \sqrt{2}\ I = 23 \times \sqrt{2} \times 72.2\text{A} = 2348\text{A}$$

Thus the MCCB selected should have instantaneous trip current of no less than 2348A. The Type NF250-SW 150A MCCB, with:

$$I_{\text{inst}} = \sqrt{2} \times 150 \times 11.2 = 2376\text{A}$$

satisfies the above condition. Thus the 3-pole version of this type is suitable for this application.

Examples of MCCBs selected in this way are shown in Table 7.3; it is necessary to confirm that the short-circuit capacities of the breakers given are adequate for the possible primary-side short-circuit current in each case.

7.6 MCCBs for Use in Capacitor (PF Correction) Circuits

The major surge tendency results from circuit opening due to the leading current. If the capacitor circuit of Fig. 7.8 is opened at time t_1 in Fig. 7.8, arc extinction will occur at time t_2, the zero-point of the leading current (i). Subsequently the supply-side voltage (V_t) will vary normally, but the load-side voltage (V_c) will be maintained at the capacitor charge value. The potential difference (V_c-V_t) will appear across the MCCB contacts and at time t_3, approximately 1/2-cycle after t_2, will become about twice the peak value of the supply voltage (E_m). If the MCCB contacts are not sufficiently open, an arc will reappear across the gap, resulting in an oscillatory capacitor discharge (at a frequency determined by the circuit reactance, including the capacitor) to an initial peak-to-peak amplitude of $4E_m$. When the arc extinguishes, V_c will once again be maintained at a potential of $-E_m$ and the potential difference across the MCCB contacts will increase again. This cycle will repeat until the gap between the contacts becomes too great, and the interruption will be completed.

Since Mitsubishi MCCBs exhibit extremely rapid contact separation, repetitive arcing is virtually nonexistent; however, some MCCBs do not make and break so rapidly, and in such cases, if the load capacitance is large enough, they will not discharge quickly, and if the arc extinguishes near the peak of the reverse-going oscillation voltage, the capacitor voltage will be maintained in the region of $-3E_m$ by the first restriking of the arc; at the second restrike it will become $5E_m$, on the third $-7E_m$, etc., ultimately leading to breakdown of the capacitor. Thus, rapid switching is essential in leading power-factor circuits.

In selecting an MCCB, first consider the surge current. If the supply voltage is V volts, the capacitor C farads, the frequency f Hertz and the current I amp, the kVA rating (P) becomes:

For a three-phase system:

$$1000\ P = \sqrt{3}\ VI = 2\pi fCV^2$$

For a single-phase system:

$$1000\ P = VI = 2\pi fCV^2$$

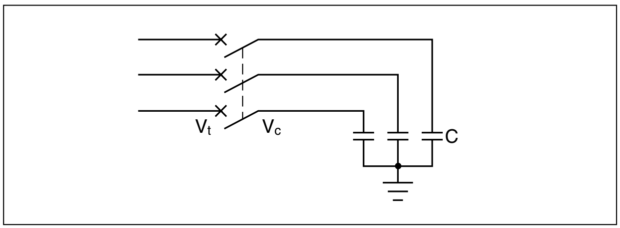


Fig. 7.8 Capacitor Circuit

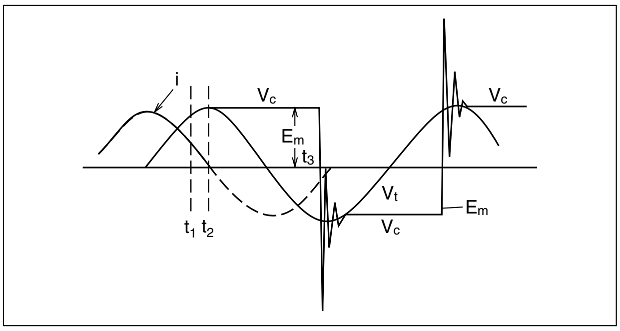


Fig. 7.9 Circuit-Opening Conditions

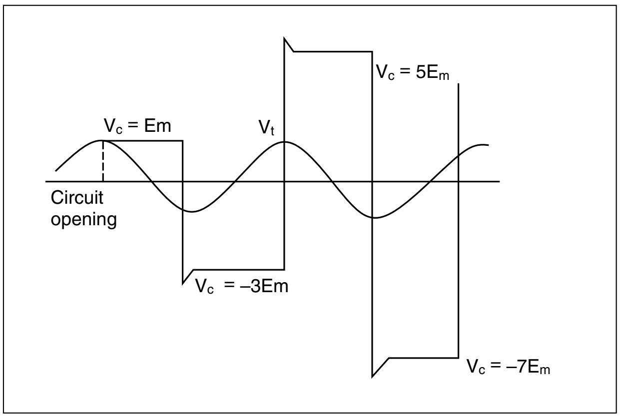


Fig. 7.10 Accumulative Capacitor Charge

When the switch (Fig. 7.11) is closed, a charge (q=CV) must be instantaneously supplied to equal the instantaneous supply voltage (V), according to the phase angle at the instant of circuit closure. This charge results in a large surge current. If the circuit is closed at the peak (E_m) of the supply voltage (V), the surge current (i), according to transient phenomena theory, is:

$$i = \frac{2\,E_m}{\sqrt{\frac{4L}{C} - R^2}}\ \varepsilon^{-\frac{R}{2L}t}\ \sin\frac{\sqrt{\frac{4L}{C} - R^2}}{2L}\,t$$

From Fig. 7.12, the maximum value (i_m) is:

$$i_m = \frac{E_m}{\sqrt{\frac{L}{C}}}\ \varepsilon^{-\frac{R}{\sqrt{\frac{4L}{C} - R^2}}\ \arctan\frac{\sqrt{\frac{4L}{C} - R^2}}{R}}$$

and appears at time t = τ_0 where:

$$\tau_0 = \frac{2L}{\sqrt{\frac{4L}{C} - R^2}}\ \arctan\frac{\sqrt{\frac{4L}{C} - R^2}}{R}$$

Although V is not constant, τ_0 is extremely small, so that V = E_m can be assumed for the transient duration; similarly, the conduction time can be assumed as $2\tau_0$. Thus, an MCCB for use in a capacitive circuit must have an instantaneous-trip current of greater than $i_m \times 2\tau_0$.

Example: MCCB selection for a 3-phase 230V 50Hz 150 kVA capacitor circuit.

From Table 7.4, $C = 0.9026 \times 10^{-2}$ (F) and I = 377(A).

The values of R and L in the circuit must be estimated, and for this purpose it is assumed that the short-circuit current is approximately 100 times the circuit capacity – i.e., 50,000A.

$$Z = \sqrt{R^2 + (2\pi fL)^2}\ \therefore\ 50{,}000 = \frac{V}{\sqrt{3}\ Z}$$

thus: $Z = \dfrac{230}{\sqrt{3} \times 50{,}000} = 2.66 \times 10^{-3}$

and assuming: $\dfrac{2\pi fL}{R} = 5$

then: $2\pi fL = 2.60 \times 10^{-3}\ \Omega$

thus: $R = 5.21 \times 10^{-4}\ \Omega \quad L = 8.29 \times 10^{-6}$ (H)

since: $E_m = \dfrac{\sqrt{2}}{\sqrt{3}}$ V = 188, i_m and τ_0 can be obtained from their respective formulas as,

i_m =6200A
$\tau_0 = 4.27 \times 10^{-4}$ (s).

Since current-flow duration is approximately $2\tau_0$, an MCCB is selected with a latching time of 0.001 seconds at 6200A. The Type NF630-SW is suitable, having a latching time of 0.0029 seconds at 10,000A. Even with a shorter latching time, tripping is unlikely under the application of the above current, but selection of an MCCB with an instantaneous-trip current of greater than $\frac{6200}{\sqrt{2}}$ = 4400A is recommended for an adequate safety margin. Such an MCCB will be rated at 600A. Accordingly, in this example the Type NF630-SW, rated at 600A, is selected. Table 7.4 is a basis for selection, but since, in cases where the short-circuit capacity of the circuit is considerably higher than that of the MCCB, spurious tripping due to the switching surge may occur, it is also necessary to make calculations along the lines of the above example.

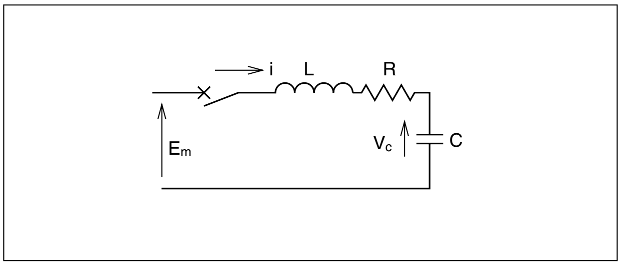


Fig. 7.11 PF Correction Capacitor

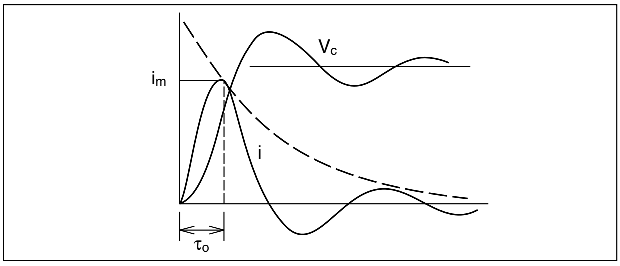


FIg. 7.12 Currents and Voltages

7.7 MCCBs for Thyristor Circuits

Both overcurrent and overvoltage protection must be provided for these elements. MCCBs can be used effectively for overcurrent, although application demands vary widely, and selection must be made carefully in each case. Overvoltage protection must be provided separately; devices currently in use include lightning arresters, dischargers, RC filters and others.

1. MCCB Rated Currents

A primary factor determining the rated current of the MCCB to be used is the question of AC-side or DC-side installation. AC-side installation permits a lower rating, which is a considerable advantage. Fig. 7.13 shows both AC and DC installation (MCCBs 1 and 2); Table 7.5 gives a selection of circuit formats and current configurations; using this table it is possible to determine the MCCB rating for either MCCB 1 or 2, as required. The current curve of the thyristor (average current is usually given) and the tripping curve of the MCCB should be rechecked to ensure that there is no possibility of overlap.

When an overcurrent is due to a fault in the load, causing a danger of thermal destruction of the circuit elements, either AC or DC protection is adequate, provided the parameters are properly chosen. When the fault is in one of the thyristor elements, resulting

Table 7.4 MCCB Selection for Circuits with PF-Correction

a) 230V, 50Hz Circuit

Capacitor rating		Single-phase circuit		Three-phase circuit	
kvar	μF	Capacitor rated current (A)	MCCB rated current (A)	Capacitor rated current (A)	MCCB rated current (A)
5	301	21.7	40	12.6	20
10	602	43.5	75	25.1	40
15	903	65.2	100	37.7	63
20	1203	87.0	125	50.2	80
25	1504	108.7	175	62.8	100
30	1805	130.4	200	75.3	125
40	2407	173.9	250	100.4	150
50	3009	217.4	350	125.5	200
75	4513	326.1	500	188.3	300
100	6017	434.8	700	251.0	400
150	9026	652.2	1000	376.5	600
200	12034	869.6	1400	502.0	800
300	18052	1304.3	2000	753.1	1200
400	24069	1739.1	2500	1004.1	1500

b) 230V, 60Hz Circuit

Capacitor rating		Single-phase circuit		Three-phase circuit	
kvar	μF	Capacitor rated current (A)	MCCB rated current (A)	Capacitor rated current (A)	MCCB rated current (A)
5	251	21.7	40	12.6	20
10	501	43.5	80	25.1	40
15	752	65.2	100	37.7	63
20	1003	87.0	125	50.2	80
25	1254	108.7	175	62.8	100
30	1504	130.4	200	75.3	125
40	2006	173.9	250	100.4	150
50	2507	217.4	350	125.5	200
75	3761	326.1	500	188.3	300
100	5014	434.8	700	251.0	400
150	7522	652.2	1000	376.5	600
200	10029	869.6	1400	502.0	800
300	15043	1304.3	2000	753.1	1200
400	20057	1739.1	2500	1004.1	1500

c) 400V, 50Hz Circuit

Capacitor rating		Single-phase circuit		Three-phase circuit	
kvar	μF	Capacitor rated current (A)	MCCB rated current (A)	Capacitor rated current (A)	MCCB rated current (A)
5	99	12.5	20	7.2	15
10	199	25.0	40	14.4	32
15	298	37.5	63	21.7	40
20	398	50.0	80	28.9	50
25	497	62.5	100	36.1	63
30	597	75.0	125	43.3	80
40	796	100.0	150	57.7	100
50	995	125.0	200	72.2	125
75	1492	187.5	300	108.3	175
100	1989	250.0	400	144.3	225
150	2984	375.0	600	216.5	350
200	3979	500.0	800	288.7	500
300	5968	750.0	1200	433.0	700
400	7958	1000.0	1500	577.4	900

d) 400V, 60Hz Circuit

Capacitor rating		Single-phase circuit		Three-phase circuit	
kvar	μF	Capacitor rated current (A)	MCCB rated current (A)	Capacitor rated current (A)	MCCB rated current (A)
5	83	12.5	20	7.2	15
10	166	25.0	40	14.4	32
15	249	37.5	63	21.7	40
20	332	50.0	80	28.9	50
25	414	62.5	100	36.1	63
30	497	75.0	125	43.3	80
40	663	100.0	150	57.7	100
50	829	125.0	200	72.2	125
75	1243	187.5	300	108.3	175
100	1658	250.0	400	144.3	225
150	2487	375.0	600	216.5	350
200	3316	500.0	800	288.7	500
300	4974	750.0	1200	433.0	700
400	6631	1000.0	1500	577.4	900

Notes: 1. The MCCB rated current should be approx. 150% of the capacitor rated current.
2. The MCCB short-circuit capacity should be adequate for the circuit short-circuit capacity.

in reverse current, the result is often that other circuit elements will be destroyed (see Fig. 7.14) if the circuit is not interrupted immediately. In this case AC-side protection or protection in series with each element is necessary.

2. Tyristor Overcurrent Protection

Total protection of each element is possible in theory, but in practice overall coordination and the best compromise for economy are usually demanded. Where elements are critical, complex combinations of protective devices can be employed, at proportionally higher cost.

Basically, overcurrent leads to excessive temperature rise of the thyristor junction, resulting in loss of the control function, and thermal destruction. A fault, therefore, must be interrupted as quickly as possible, before the junction temperature rises above its specified limit. In the overcurrent region, designated on the current-surge withstand curves of the circuit element, the element can usually withstand the surge for at least one cycle. The current-surge withstand, generally specified as a peak value, must be converted to RMS, to select a suitable MCCB.

An overload of short-circuit proportion, either external or in a bridge-circuit thyristor element, necessitates rapid interruption of the circuit. Normally, such

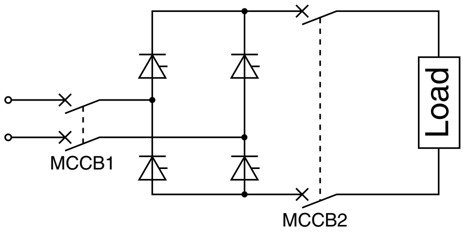


Fig. 7.13 AC- and DC-side Protectors for Thyristors

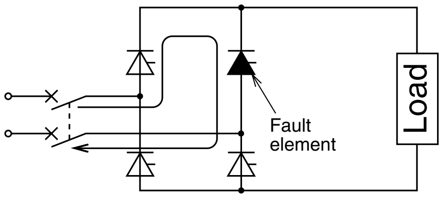
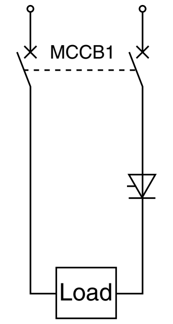
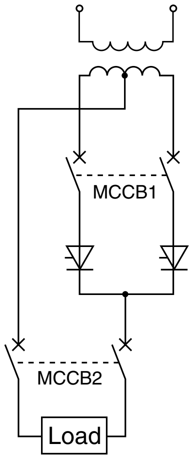
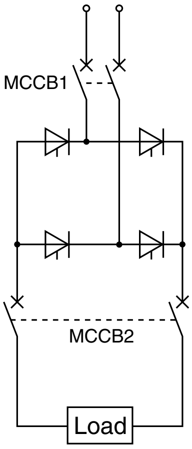
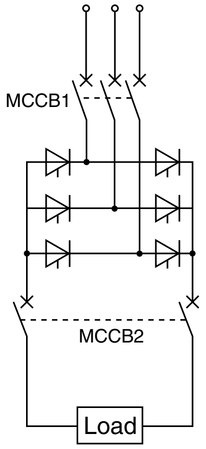
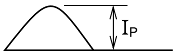
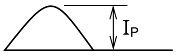
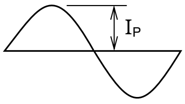
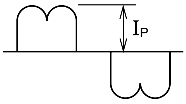
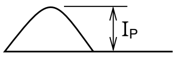
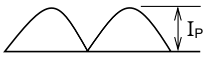
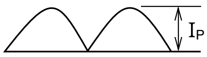
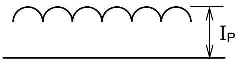


Fig. 7.14 Fault-Current Flow

Table 7.5 Thyristor Circuits and Current Formats

			Circuit No. I	Circuit No. II	Circuit No. III	Circuit No. IV
Circuit diagram						
Element average current I_F (A)			$\frac{I_P}{\pi}$	$\frac{I_P}{\pi}$	$\frac{I_P}{\pi}$	$\frac{I_P}{\pi}$
Element RMS current I_e (A)			$\frac{I_P}{2}$	$\frac{I_P}{2}$	$\frac{I_P}{2}$	$\sqrt{\frac{1}{6}+\frac{\sqrt{3}}{4\pi}}\,I_P$ ($\fallingdotseq 0.552\ I_P$)
Average DC current I_D (A)			I_F	$2I_F$	$2I_F$	$3I_F$
Current flow	MCCB1	RMS current I_B (A)	$\frac{\pi}{2}I_F$ or $\frac{\pi}{2}I_D$	$\frac{\pi}{2}I_F$ or $\frac{\pi}{4}I_D$	$\frac{\pi}{\sqrt{2}}I_F$ ($\fallingdotseq 2.22\,I_F$) or $\frac{\pi}{2\sqrt{2}}I_D$ ($\fallingdotseq 1.11\,I_D$)	$\pi\sqrt{\frac{1}{3}+\frac{\sqrt{3}}{2\pi}}\,I_F$ ($\fallingdotseq 2.45\,I_F$) or $\frac{\pi}{3}\sqrt{\frac{1}{3}+\frac{\sqrt{3}}{2\pi}}\,I_D$ ($\fallingdotseq 0.817\,I_D$)
		Current waveform				
	MCCB2	RMS current I_B (A)	I_e or $\frac{\pi}{2}I_D$	$\frac{\pi}{\sqrt{2}}I_F$ or $\frac{\pi}{2\sqrt{2}}I_D$	$\frac{\pi}{\sqrt{2}}I_F$ or $\frac{\pi}{2\sqrt{2}}I_D$	$\pi\sqrt{\frac{1}{2}+\frac{3\sqrt{3}}{4\pi}}\,I_F \fallingdotseq 3I_F$ or $\frac{\pi}{3}\sqrt{\frac{1}{2}+\frac{3\sqrt{3}}{4\pi}}\,I_D \fallingdotseq I_D$
		Current waveform				

Note: Load is assumed resistive, with elements conductive through 180°.

interruption takes place within one cycle; thus, from the point of view of element thermal destruction, the time integral of the current squared must be considered. Quantitatively, the permissible $\int i^2 dt$ of the element must be greater than the $\int i^2 dt$ of the MCCB current through interruption, converted to apply to the element. The latter is influenced by the short-circuit current magnitude, the interruption time, and the current-limiting capability of the MCCB.

It is important to note that the MCCB interruption time will be considerably influenced by the short-circuit current rise rate, di/dt, on the load side. In the short circuit of Figs. 7.15 and 7.16, the current is:

$$i = \frac{E}{R}\left(1 - \varepsilon^{-\frac{R}{L}t}\right)$$

and the current rise rate di/dt is:

$$\left(\frac{di}{dt}\right)_{t=0} = \frac{E}{L}$$

Thus, the inductance of the line, and the smoothing inductance significantly affect di/dt. Where the potential short-circuit current is very large, the inductance should be increased, to inhibit the rise rate and assist the MCCB to interrupt the circuit in safe time. This is illustrated in Fig. 7.17, for MCCB2 of Fig. 7.15.

The MCCB current during total time (t_T) is $\int i^2\,dt$, which, converted to the $\int i^2\,dt$ applied to the circuit element, must be within the limit specified. Having determined the circuit constants, testing is preferable to calculation for confirmation of this relationship.

Assuming a large current-rise rate, with an AC-side short-circuit current $i = I_{ps} \sin \omega t$, and an MCCB interruption time of one cycle, the $\int i^2\,dt$ applied to the thyristor is as follows:

1. For circuits I, II and III of Table 7.10:

$$\int i^2 dt = \int_0^{\frac{1}{2f}} I_p^2 \sin^2 \omega t dt = \frac{1}{4f} I_p^2 \quad (A^2s)$$

2. For circuit IV:

$$\int i^2 dt = 2\int_{\frac{1}{6f}}^{\frac{1}{3f}} I_p^2 \sin^2 \omega t dt = \frac{I_p^2}{f}\left(\frac{1}{6} + \frac{\sqrt{3}}{4\pi}\right) \quad (A^2s)$$

where I_p is the peak value of the element current and f is the supply frequency.

If the $\int i^2\,dt$ of the circuit element is known, the permissible $\int i^2 dt$ for the MCCB can be determined, using the last two equations given above. Provided that the interruption time is not greater than one cycle, the MCCB current will be the same as the element current for circuits I and II, and twice that for circuits III and IV. This means that the MCCB $\int i^2 dt$ through the interruption time should be within twice the permissible $\int i^2 dt$ of the element.

Diodes are generally stronger against overcurrent than thyristors, and since diodes can handle larger $I^2 \cdot t$, protection is easier.

Fig. 7.17 shows the protection coordination situation of a selection of devices, plotted together with the thyristor current-surge withstand curve. AC-side protection (MCCB1, Fig. 7.15) is presented, but the DC-protection case (MCCB2) can be plotted in the same way.

Region 2 in Fig. 7.17 is the area of overcurrent for which protection is effected by the MCCB. For protection of region 1, an overload relay is effective, and for region 2, inductance L must be relied on to limit the fault-current rise rate, or a high-speed current-limiting fuse must be used. Practical considerations, including economy and the actual likelihood of faults in the regions concerned, may dictate the omission of the protective devices for regions 1 and 3, in many cases. The lower the instantaneous-trip setting of the MCCB, the wider the region 2 coverage becomes.

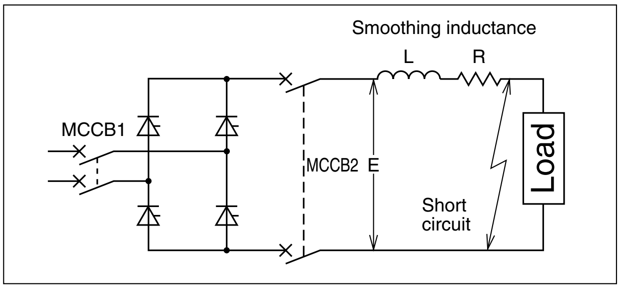


Fig. 7.15 Thyristor Short Circuit

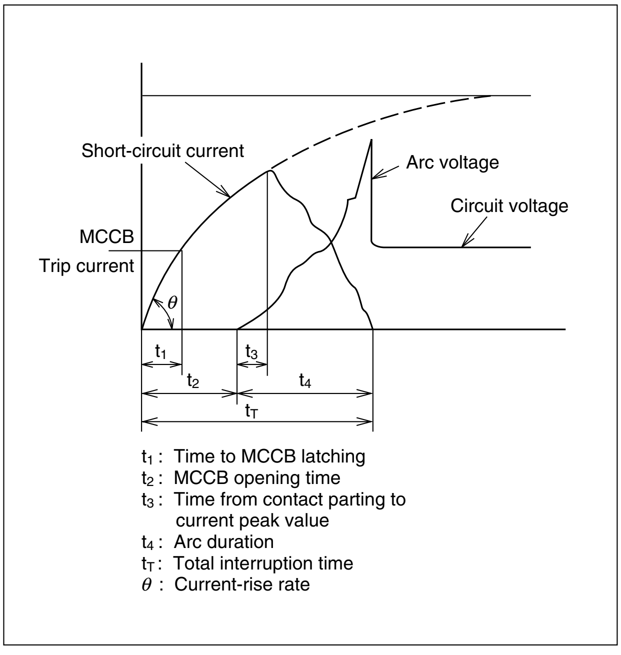


Fig. 7.16 Thyristor Short-Circuit Interruption

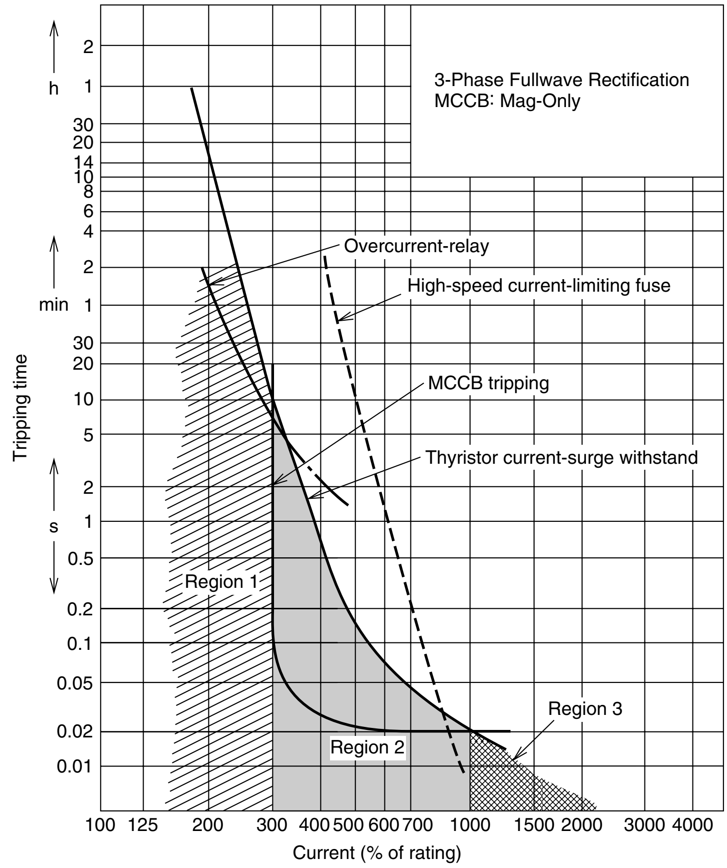


Fig. 7.17 Thyristor and Protector Operating Curves

3. Element Breakdown in Thyristor-Leonard Systems In this system of DC motor control, if power outage or commutation failure due to a thyristor control-circuit fault occurs during inversion (while motor regenerative power is being returned to the AC supply), the DC motor, acting as a generator while coasting, will be connected to a short-circuit path, as in Fig. 7.18. For thyristor protection, MCCBs must be placed in the DC side, as shown.

A Mag-Only MCCB with a tripping current of about 3 times the rated current is employed, either 3- or 4-pole, series-connected as shown in Fig. 7.20. Since the element short-circuit current is the same as the MCCB current, circuit protection is effected provided that the $\int i^2dt$ limit for the element is larger than that for the MCCB interruption duration. This must be established by test.

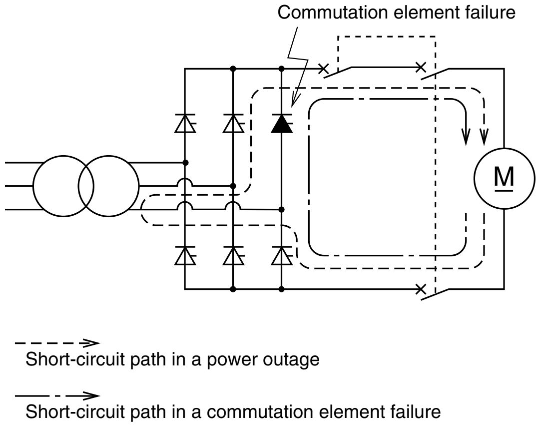


Fig. 7.18 Ward-Leonard Thyristor Protection

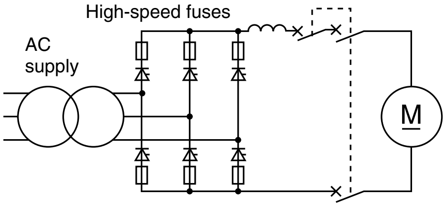
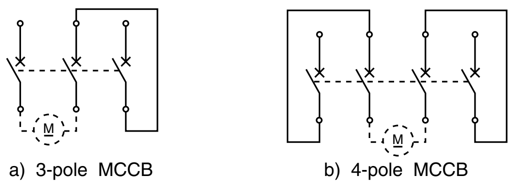


Fig. 7.19 High-Speed Fuses for Thyristor-Circuit Protection



a) 3-pole MCCB
b) 4-pole MCCB

Fig. 7.20 Series Connection of MCCB Poles

Fig. 7.19 shows connection of high-speed fuses for protection against thyristor breakdown that would otherwise result in short-circuit flow from the AC supply side.

4. MCCBs for Lamp Mercury-Lamp Circuits

The ballasts (stabilizers) used in this type of lamp cover a variety of types and characteristics. For 200V applications (typical), choke-coil ballasts are used. For 100V applications a leakage-transformer ballast is employed. Normal ballasts come in low power-factor versions and high power-factor versions, with correction capacitors. More sophisticated types include the constant-power (or constant-output) type, which maintains constant lamp current both in starting and normal running, and flickerless types, which minimize the flicker attendant on the supply frequency.

In selecting an MCCB where normal (high or low PF) ballasts are to be used, the determining factor is the starting current, which is about 170% of the stable running current. In the cases of constant-power or flickerless types, the determining factor is the normal running current, which is higher than the starting current. For MCCB selection, the latter types can be regarded as lighting and heating general loads, as previously discussed.

For selection of MCCBs for regular ballasts, the 170% starting current is assumed to endure for a maximum of 5 minutes. MCCBs of 100A or less frame size have a tripping value very close to rating for overloads of duration of this order, so that the MCCB rating should be the nearest standard value above 170% of the stable running current. MCCBs of above 100A frame size can handle a current of around 120% of the rating for 5 minutes without tripping; thus the nearest standard MCCB rating above $\frac{1.7}{1.2} = 1.4$ times the stable-running current of the lamp load is the suitable protector.

As an example, consider MCCB selection for 10 units of 100W, 100V, 50Hz general-purpose high power-factor mercury lamps. The stable-running current per lamp is 1.35A. Thus:

$1.35 \times 10 \times 1.7 = 23$A, and the selection becomes NF32-SW, 32A rated.

7.8 Selection of MCCBs in inverter circuit

7.8.1 Cause of distorted-wave current

Distorted-wave current is caused by factors such as the CVCF device of a computer power unit, various rectifiers, induction motor control VVVF device corresponding to more recent energy-saving techniques, etc, wherein thyristor and transistor are used. Any of these devices generates DC power utilizing the switching function of a semiconductor and, in addition, transforms the generated DC power into intended AC power. Generally, a large capacity capacitor is connected on its downstream side from the rectification circuit for smoothing the rectification, so that the charged current for the capacitor flows in pulse form into the power circuit. Because voltage is chopped at high frequency in AC to DC transforming process, load current to which high frequency current was superimposed by chopping basic frequency flows into the load line. This paragraph describes the VVVF inverter, of these devices, which will develop further as main control methods for induction motors currently in broad use in various fields . Fig. 7.27 illustrates an example of MCCBs application to inverter circuit. Two control methods of PAM (Pulse Amplitude Modulation) and PWM (Pulse Wide Modulation) are available for the VVVF inverter and generating higher harmonic wave components differs depending on the difference between the control methods. As seen from Tables 7.9 and 7.10, this harmonic wave component of input current can be made smaller (improved) by inputting DC reactor (DCL) or AC reactor (ACL). Further, in the case of the output current waveform in Fig. 7.29, the PWM generates higher harmonic wave components than that of the PAM.

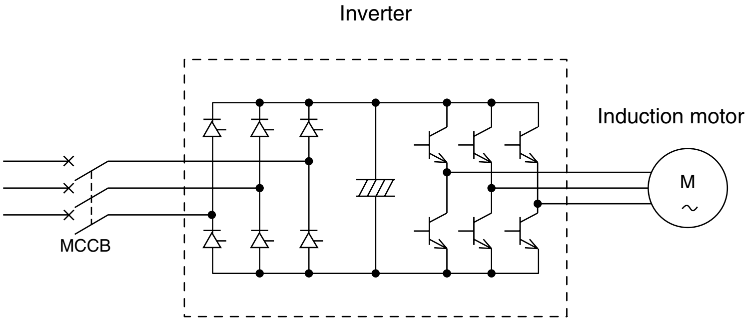


Fig.7.27 Example of MCCBs Application to Inverter Circuit

7.8.2 Selection of MCCBs

MCCBs characteristic variations and temperature rises dependent on distortion of the current wave must be considered when selecting MCCBs for application to an inverter circuit (power circuit). The relation of rated current I_{MCCB} to load current I of MCCBs is selected as follows from the MCCBs tripping system.

$$I_{MCCB} \geqq K \times I$$

Thermal-magnetic type (bimetal system) and electronic type (RMS value detection) are both RMS current detection systems which enable exact overload protection even under distorted-wave current. Due to the above explanation, it is advantageous to select RMS current detection type MCCBs.

Table 7.8 Reduction Rate

MCCBs tripping system	Reduction rate K
Thermal-magnetic (bimetal system)	1.4
(Note 1) Hydraulic-magnetic	1.4
Electronic (RMS value detection)	1.4

This table is subject to the current which meets the following requirements.

① $\text{Distortion factor} = \dfrac{\text{RMS value of total harmonic wave component}}{\text{RMS value of basic frequency}} \times 100 \leqq 100\%$ or less

② $\text{Peak factor} = \dfrac{\text{Peak value}}{\text{RMS value}} \leqq 3$ or less

③ Higher harmonic wave components are mainly No.7 or a lower harmonic wave.

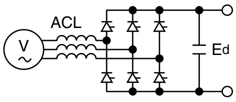
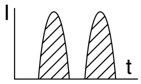
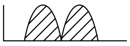
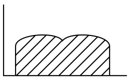
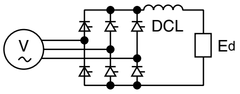
Notes: 1. The characteristics of hydraulic-magnetic type MCCBs vary significantly depending on wave distortion. Therefore, use of thermal-magnetic type MCCBs is recommended.

Table 7.9 Data of High Harmonic Wave Current Content in Inverter Power Circuit (Example)

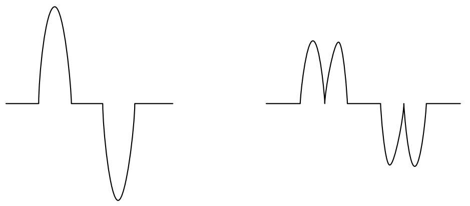
High harmonic wave degree	High harmonic wave current content (%)			
	P W M		P A M	
	No ACL (Standard)	With power factor modifying ACL	With standard ACL	With power factor modifying ACL
Basic	81.6	97.0	83.6	97.2
2	–	–	–	–
3	3.7	–	2.5	–
4	–	–	–	–
5	49.6	21.9	48.3	21.7
6	–	–	–	–
7	27.4	7.1	23.7	7.0
8	–	–	–	–
9	–	–	–	–
10	–	–	–	–
11	7.6	3.9	6.2	3.7
12	–	–	–	–
13	6.7	2.8	4.7	2.6

Note: No DCL Output frequency 60Hz , subject to 100% load

Table 7.10 Peak Factor of Inverter Input Current

Circuit			Input current			
			Power factor	Waveform factor	Peak factor	Waveform (half wave portion)
with ACL	Large ←ACL→ Small		Below 58.7	Above 1.99	Above 2.16	
			58.7%	1.99	2.16	
			58.7–83.5%	1.99–1.27	2.16–1.71	
			83.5%	1.27	1.71	
			83.5–95.3%	1.27–1.23	1.71–1.28	
With DCL			95.3%	1.23	1.28	

Power factor = (DC voltage x DC) /($\sqrt{3}$ x AC RMS voltage x AC RMS current)
Waveform factor = (RMS value) /(Mean value)
Peak factor = (Max value) /(RMS value)



(a) PAM system (b) PWM system

Fig.7.28 Inverter Input Current

(a) PAM system (b) Equal-value PWM system

Fig.7.29 Inverter Output Current

8. ENVIRONMENTAL CHARACTERISTICS

8.1 Atmospheric Environment

Abnormal environments may adversely affect performance, service life, insulation and other aspects of MCCB quality. Where service conditions differ substantially from the specified range as below, derating of performance levels may result.

1. Ambient temperature range	–10˚C~+40˚C (Average temperature for 24 hours, however, shall not be higher than 35˚C.)
2. Relative humidity	85% max. with no dewing
3. Altitude	2,000m max.
4. Ambient	No excessive water or oil vapour, smoke, dust, salt content, corrosive substance, vibration, and impact Expected service life (MTTF) under the above conditions is 15 years.

8.1.1 High Temperature Application

To comply with relevant standards, all circuit breakers are calibrated at 40˚C. If the circuit breaker is to be used in an environment where the ambient temperature is likely to exceed 40˚C please apply the derating factor shown in table 8.2.

For example: To select a circuit breaker for use on a system where the full load current is 70A in an ambient temperature at 50˚C then from table 8.2

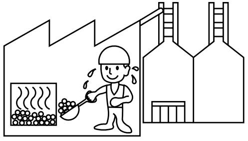
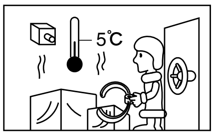
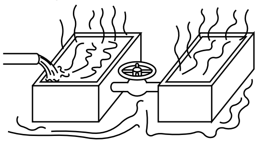
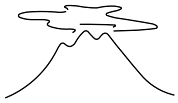
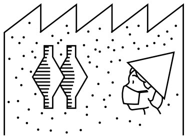
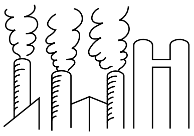
$$\frac{70A}{0.9} = 77.8A$$

Select a circuit breaker with a trip unit adjustable from 80-100A or fixed at 100A.

Table 8.2 MCCB Derating

Ambient Temperature (°C)	Derating factor
50	0.9
55	0.8
60	0.7

Table 8.1 Abnormal Environments, and Countermeasures

Environment	Trouble	Countermeasures
High temperature 	1. Nuisance tripping 2. Insulation deterioration	1. Reduce load current (derate). 2. Avoid ambients above 60˚C.
Low temperature  	1. Condensation and freezing 2. Low-temperature fragility in shipping (around –40˚C)	1. Install heater for defrosting and drying. 2. Ship tripped, or if not possible, OFF.
High humidity 	1. Insulation resistance loss 2. Corrosion	1. Use MCCB enclosure such as Type W. 2. Inspect frequently, or install high-corrosion-resistant MCCBs.
High altitude 	1. Reduced temperature, otherwise no problem up to 2,000m	1. See “Low temperature”, above.
Dirt and dust 	1. Contact discontinuity 2. Impaired mechanism movement 3. Insulation resistance loss	1. Use Type I MCCB enclosure.
Corrosive gas, salt air 	1. Corrosion	1. Use Type W MCCB enclosure or install high-corrosion-resistant MCCBs.

8.1.2 Low Temperature Application

In conditions where temperatures reach as low as –5˚C special MCCBs are usually required. Mitsubishi, however, have tested their standard MCCBs to temperatures as low as –10°C without any detrimental effects.

For conditions where temperatures drop below –10˚C special MCCBs must be used.

If standard MCCBs experience a sudden change from high temperature, high humidity conditions to low temperature conditions, there is a possibility of ice forming inside the mechanism. In such conditions we recommend that some form of heating be made available to prevent mal-operation.

In conditions of low temperature MCCBs should be stored in either the tripped or OFF position.

Low Temperature MCCBs

Special low temperature MCCBs are available that can withstand conditions where temperatures fall to as low as –40˚C. These special MCCBs are available in sizes up to 1200A in the standard series and above 50A in the compact series.

8.1.3 High Humidity

In conditions of high humidity the insulation resistance to earth will be reduced as will the electrical life.

For applications where the relative humidity exceeds 85% the MCCB must be specially prepared or special enclosures used. Special preparation includes plating all metal parts to avoid corrosion and special painting of insulating parts to avoid the build up of mildew.

There are two degrees of tropicalisation:

Treatment 1-	painting of insulating material to avoid build up of mildew plus special plating of metal parts to avoid corrosion.
Treatment 2-	painting of insulating material to avoid build up of mildew only.

8.1.4 Corrosive Atmospheres

In the environment containing much corrosive gas, it is advisable to use MCCB of added corrosion resistive specifications.

For the breakers of added corrosionproof type, corrosion-proof plating is applied to the metal parts.

Where concentration of corrosive gas exceeds the level stated below, it is necessary to use MCCB of added corrosion resistive type being enclosed in a water-proof type enclosure or in any enclosure of protective structure.

Allowable containment for corrosive gas.

H_2S 0.01ppm SO_2 0.05ppm
NH_3 0.25ppm

8.1.5 Affecting of Altitude

When MCCBs are used at altitudes exceeding 2000m above sea level, the effects of a drop in pressure and drop in temperature will affect the operating performance of the MCCBs. At an altitude of 2200m, the air pressure will drop to 80% and it drops to 50% at 5500m, however interrupting capacity is unaffected. The derating factors that are applicable for high altitude applications are shown in table 8.3. (According to ANSI C 37.29-1970)

Table 8.3 Derating Factors for High Altitude Applications

Altitude	Rated current	Rated voltage
3000m	0.98	0.91
4000m	0.96	0.82
5000m	0.94	0.73
6000m	0.92	0.65

For example: NF800-SEW on 4000m

1. Voltage

The rated operating voltage is AC690V. You should derate by 690x0.82=565.8V. It means that you can use this NF800-SEW up to AC565.8V rated voltage.

2. Current

The rated current is 800A. You should derate by 800x0.96=768A. It means that you can use this NF800-SEW up to 768A rated current.

8.2 Vibration-Withstand Characteristics

8.2.1 The Condition of Test

1. Installation position and Direction of vibration
   - Every vertical and horizontal at vertical installed (as shown in Fig. 8.1)
2. The position of MCCBs and vibration time
   Forty minutes in each position (ON, OFF and TRIP)
3. Vibration criteria

• Frequency	10~100Hz
• Vibration acceleration	22 m/s^2
• Period	10min./cycle

8.2.2 The Result of Test

The samples must show no damage and no change of operating characteristic (200% release), and must not be tripped or switched off by the vibration.

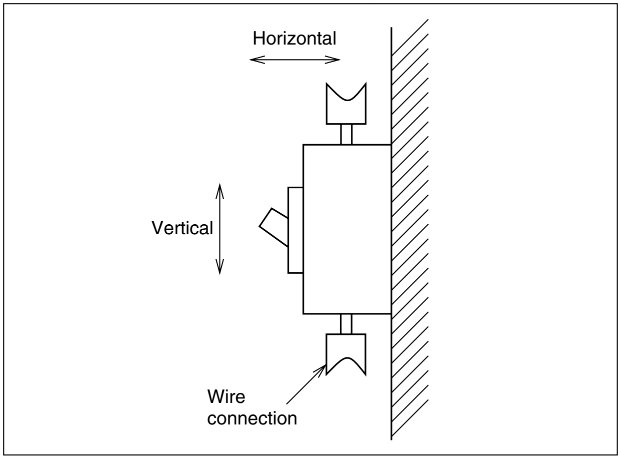


Fig. 8.1 Applied Vibration

8.3 Shock-Withstand Characteristics

8.3.1 The Condition of Test

1. MCCBs are drop-tested, as described in Fig. 8.2. The arrows show the drop direction.
2. The samples are set to ON, with no current flowing.

8.3.2 The Result of Test (as Shown in Table 8.4)

The samples must show no physical damage, and the switched condition must not be changed by the drop in any of the drop-attitudes tested.

The judgment of failure:

- A case the switched condition changed from ON to OFF
- A case the switched condition changed from ON to Trip
- A case the sample shows physical damage

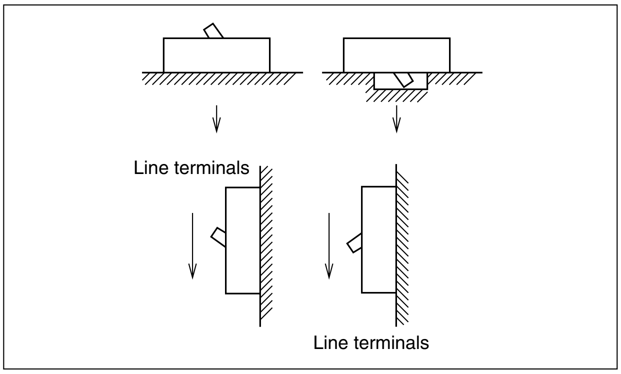


Fig. 8.2 Drop-Test Attitudes

Table 8.4 Shock-Withstand Characteristics of Mitsubishi MCCB

Series		Type	No tripped (m/s^2)	No damage (m/s^2)
BH		BH-K BH-P, BH-S, BH-PS, BH-D	147	490
MB		MB30-CS	147	
		MB30-SW MB50-CW MB50-SW MB100-SW MB225-SW	196	
NF	S·H	NF32-SW NF63-HW NF63-SW NF125-SW NF125-SGW NF125-HW NF125-HGW NF160-SW NF160-SGW NF160-HW NF160-HGW NF250-SW NF250-SGW NF250-HW NF250-HGW NF400-SW NF400-SEW NF400-HEW NF400-REW NF630-SW NF630-SEW NF630-HEW NF630-REW NF800-SDW NF800-SEW NF800-HEW NF800-REW NF1000-SEW NF1250-SEW NF1600-SEW	196	
	C	NF30-CS	147	
		NF63-CW	196	
		NF125-CW NF250-CW NF400-CW NF630-CW NF800-CW	196	
	U	NF125-RGW NF125-UGW NF250-RGW NF250-UGW NF400-UEW NF800-UEW	196	

9. SHORT-CIRCUIT CURRENT CALCULATIONS

9.1 Purpose

Japanese and international standards require, in summary, that an overcurrent protector must be capable of interrupting the short-circuit current that may flow at the location of the protector. Thus it is necessary to establish practical methods for calculating short-circuit currents for various circuit configurations in low-voltage systems.

9.2 Definitions

1. % Impedance

The voltage drop resulting from the reference current, as a percentage of the reference voltage (used for short-circuit current calculations by the % impedance method).

$$\%\ \text{impedance} = \frac{\text{voltage drop at capacity load}}{\text{reference voltage}} \times 100\ (\%)$$

(Reference voltage: 3-phase – phase voltage)

2. Reference Capacity

The capacity determined from the rated current and voltage used for computing the % impedance (normally 1000kVA is used).

3. Per-Unit Impedance

The % impedance expressed as a decimal (used for short-circuit current calculations by the per-unit method).

4. Power Supply Short-Circuit Capacity

$$\text{3-phase supply (MVA)} = \sqrt{3} \times \text{rated voltage (kV)} \times \text{short circuit current (kA)}$$

5. Power Supply Impedance

Impedance computed from the short-circuit capacity of the supply (normally indicated by the electric power company; if not known, it is defined, together with the X/R ratio, as 1000MVA and X/R=25 for a 3-phase supply (from NEMA.AB1).

6. Motor contribution Current

While a motor is rotating it acts as generator; in the event of a short circuit it contributes to increase the total short-circuit current. (Motor current contribution must be included when measuring 3-phase circuit short-circuit current).

7. Motor Impedance

The internal impedance of a contributing motor. (A contributing motor equal to the capacity of the transformer is assumed to be in the same position as the transformer, and its % impedance and X/R value are assumed as 25% and 6 (from NEMA.AB1).

8. Power Supply Overall Impedance

The impedance vector sum of the supply (Z_L), the transformer (Z_T) and the motor (Z_M).

Overall impedance of 3-phase supply

$$(Z_s) = \frac{(Z_L + Z_T) \bullet Z_M}{Z_L + Z_T + Z_M}\ (\%\Omega)$$

9. Short-Circuit Current Measurement Locations

In determining the interruption capacity required of the MCCB, generally, the short-circuit current is calculated from the impedance on the supply side of the breaker.

Fig. 9.1 represents a summary of Japanese standards.

9.3 Impedances and Equivalent Circuits of Circuit Components

In computing low-voltage short-circuit current, all impedances from the generator (motor) to the short-circuit point must be included; also, the current contributed by the motor operating as a load. The method is outlined below.

9.3.1 Impedances

1. Power Supply Impedance (Z_L)

The impedance from the power supply to the transformer-primary terminals can be calculated from the short-circuit capacity specified by the power company, if known.

Otherwise it should be defined, together with X/R, as 1000MVA and X/R=25 for a 3-phase supply. Note that it can be ignored completely if significantly smaller than the remaining circuit impedance.

2. Transformer Impedance (Z_T)

Together with the line impedance, this is the largest factor in determining the short-circuit current magnitude. Transformer impedance is designated as a percentage for the transformer capacity; thus it must be converted into a reference-capacity value (or if using Ohm's law, into an ohmic value).

Tables 9.1 show typical impedance values for transformers, which can be used when the transformer impedance is not known.

3. Motor Contribution Current and Impedance (Z_M)

The additional current contributed by one or more motors must be included, in considering the total 3-phase short-circuit current. Motor impedance depends on the type and capacity, etc.; however, for typical induction motors, % impedance can be taken as 25% and X/R as 6. The short-circuit current will thus increase according to the motor capacity, and the impedance up to the short-circuit point. The following assumptions can normally be made.

a. The total current contribution can be considered as a single motor, positioned at the transformer location.
b. The total input (VA) of motor contribution can be considered as equal to the capacity of the transformer (even though in practice it is usually larger). Also, both the power factor and efficiency can be assumed to be 0.9; thus the resultant motor contribution output is approximately 80% of the transformer capacity.
c. The % impedance of the single motor can be considered as 25% and the X/R as 6.

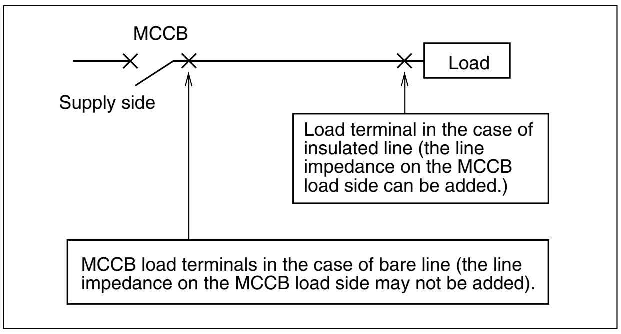


Fig. 9.1 Short-Circuit Locations for Current Calculations

4. Line and Bus-Duct Impedance (Z_W, Z_B)

Table 9.2 gives unit impedances for various configurations of wiring, and Table 9.3 gives values for ducting.

Since the tables give ohmic values, they must be converted, if the %-impedance method is employed.

Table 9.1 Impedances of 3-Phase Transformers

Transformer capacity (kVA)	Impedance (%)	
	%R	%X
50	1.81	1.31
75	1.78	1.73
100	1.73	1.74
150	1.61	1.91
200	1.63	2.60
300	1.50	2.82
500	1.25	4.06
750	1.31	4.92
1000	1.17	4.94
1500	1.23	5.41
2000	1.13	5.89

5. Other Impedances

Other impedances in the path to the short-circuit point include such items as CTs, MCCBs, control devices, and so on. Where known, these are taken into consideration, but generally they are small enough to be ignored.

Table 9.2 Wiring Impedance

Cable size (mm^2)	Resistance (mΩ/m)	Reactance(mW/m)					
		50Hz			60Hz		
		2-or 3-core cables	1-core cables (close-spaced)	1-core cables (6cm-spaced)	2-or 3-core cables	1-core cables (close-spaced)	1-core cables (6cm-spaced)
1.5	12.10	0.1076	0.1576	0.2963	0.1292	0.1891	0.3555
2.5	7.41	0.1032	0.1496	0.2803	0.1238	0.1796	0.3363
4.0	4.61	0.0992	0.1390	0.2656	0.1191	0.1668	0.3187
6.0	3.08	0.0935	0.1299	0.2527	0.1122	0.1559	0.3033
10.0	1.83	0.0873	0.1211	0.2369	0.1048	0.1453	0.2843
16.0	1.15	0.0799	0.1043	0.2138	0.0959	0.1251	0.2565
25.0	0.727	0.0793	0.1014	0.2000	0.0952	0.1217	0.2400
35.0	0.524	0.0762	0.0964	0.1879	0.0915	0.1157	0.2254
50.0	0.387	0.0760	0.0924	0.1774	0.0912	0.1109	0.2129
70.0	0.268	0.0737	0.0893	0.1669	0.0884	0.1072	0.2001
95.0	0.193	0.0735	0.0867	0.1573	0.0882	0.1040	0.1888
120.0	0.153	0.0720	0.0838	0.1498	0.0864	0.1006	0.1798
150.0	0.124	0.0721	0.0797	0.1427	0.0865	0.0956	0.1712
185.0	0.0991	0.0720	0.0806	0.1356	0.0864	0.0967	0.1627
240.0	0.0754	0.0716	0.0818	0.1275	0.0859	0.0982	0.1530
300.0	0.0601	0.0712	0.0790	0.1195	0.0854	0.0948	0.1434
400.0	0.0470	–	0.0777	0.1116	–	0.0932	0.1339
500.0	0.0366	–	0.0702	0.1043	–	0.0843	0.1252
630.0	0.0283	–	0.0691	0.0964	–	0.0829	0.1157

Notes: 1. Resistance values per IEC 60228
2. Reactance per the equation: $L(mH/km) = 0.05 + 0.4605\log_{10}D/r$(D=core separation, r=conductor radius)
3. Close-spaced reactance values are used.

Table 9.3 Bus-Duct Impedance

Rated current (A)	Resistance (mΩ/m) at 20°C	Reactance (mΩ/m)	
		50Hz	60Hz
400	0.125	0.0250	0.0300
600	0.114	0.0231	0.0278
800	0.0839	0.0179	0.0215
1000	0.0637	0.0139	0.0167
1200	0.0397	0.0191	0.0230
1500	0.0328	0.0158	0.0190
2000	0.0244	0.0118	0.0141
2500	0.0192	0.0092	0.0110
3000	0.0162	0.0077	0.0092

9.3.2 Equivalent Circuits

1. Three-Phase

Based on the foregoing assumptions for motors, the equivalent circuits of Fig. 9.2 can be used for calculating 3-phase short-circuit current. The motor impedance (Z_M) can be considered as shunting the series string consisting of the supply (Z_L) and transformer (Z_T) impedances, by busbars of infinite short-circuit capacity. When the three impedances are summed, the total impedance and the resistive and reactive components are given as:

$$Z_S = \frac{(Z_L + Z_T) \cdot Z_M}{Z_L + Z_T + Z_M} = R_S + j\,X_S$$

$$R_S = \frac{\left[\begin{array}{l}(R_L + R_T + R_M)\,\{R_M(R_L + R_T) - X_M(X_L + X_T)\} \\ + (X_L + X_T + X_M)\,\{X_M(R_L + R_T) + R_M(X_L + X_T)\}\end{array}\right]}{(R_L + R_T + R_M)^2 + (X_L + X_T + X_M)^2}$$

$$X_S = \frac{\left[\begin{array}{l}(R_L + R_T + R_M)\,\{X_M(R_L + R_T) + R_M(X_L + X_T)\} \\ - (X_L + X_T + X_M)\,\{R_M(R_L + R_T) - X_M(X_L + X_T)\}\end{array}\right]}{(R_L + R_T + R_M)^2 + (X_L + X_T + X_M)^2}$$

Thus, when calculating the short-circuit current at various points in a load system, if the value Z_S is first computed, it is a simple matter to add the various wire or bus-duct impedances. Table 9.4 gives values of total supply impedance (Z_S), using transformer impedance per Table 9.1, power-supply short-circuit capacity of 1000MVA, and X/R of 25.

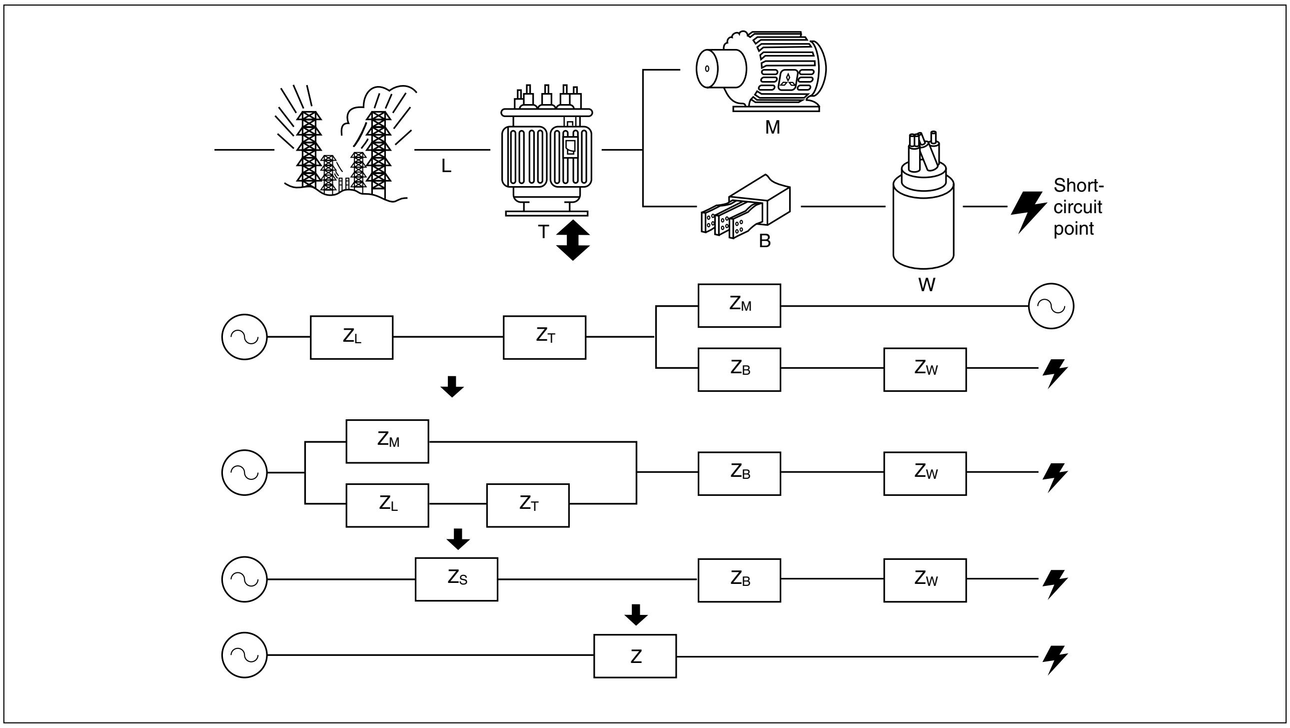


Fig. 9.2 3-Phase Equivalent Circuits

Table 9.4 Total Impedances for 3-Phase Power Supplies

Transformer capacity (kA)	Impedance based on 1000kVA(%)	Ohmic value (mΩ)	
		230V	440V
50	33.182 +j 26.482	17.553 +j 14.009	64.240 +j 51.269
75	21.229 +j 22.583	11.230 +j 11.946	41.099 +j 43.720
100	15.473 +j 17.109	8.185 +j 9.051	29.956 +j 33.123
150	9.56 +j 12.389	5.057 +j 6.554	18.508 +j 23.985
200	6.977 +j 12.15	3.691 +j 6.427	13.507 +j 23.522
300	4.306 +j 8.795	2.278 +j 4.653	8.336 +j 17.027
500	2.089 +j 7.27	1.105 +j 3.846	4.044 +j 14.074
750	1.427 +j 5.736	0.755 +j 3.034	2.763 +j 11.104
1000	0.969 +j 4.336	0.513 +j 2.294	1.876 +j 8.394
1500	0.671 +j 3.142	0.355 +j 1.662	1.299 +j 6.083
2000	0.467 +j 2.544	0.247 +j 1.346	0.904 +j 4.925

Notes: 1. Total power-supply impedance $Z_S = \frac{(Z_L + Z_T)Z_M}{Z_L + Z_T + Z_M}$

2. For line voltages (E') other than 230V, multiply the ohmic value by $\left(\frac{E'}{230}\right)^2$

9.4 Classification of Short-Circuit Current

A DC current (Fig. 9.3) of magnitude determined by the voltage phase angle at the instant of short circuit and-the circuit power factor will be superimposed on the AC short-circuit current.

This DC component will rapidly decay; however, where a high-speed circuit-interruption device such as an MCCB or fuse is employed, the DC component must be considered. Further, the mechanical stress of the electric circuit will be affected by the maximum instantaneous short-circuit current; hence, the short-circuit current is divided, as below.

1. RMS Symmetrical Short-Circuit Current (I_s)
This is the value exclusive of the DC component; it is $A_s/\sqrt{2}$ of Fig. 9.3.

2. RMS Asymmetrical Short-Circuit Current (I_{as})
This value includes the DC component. It is defined as:

$$I_{as} = \sqrt{\left(\frac{A_s}{\sqrt{2}}\right)^2 + A_d{}^2}$$

Accordingly, when the DC component becomes maximum (i.e., $\theta - \varphi = \pm\frac{\pi}{2}$, where the voltage phase angle at short circuit is θ, and the circuit power factor is $\cos\varphi$), I_{as} will also become maximum $\frac{1}{2}$ cycle after the short circuit occurs, as follows:

$$I_{as} = I_s \cdot \sqrt{1 + 2e^{-\frac{2\pi R}{x}}} = I_s \cdot K_1\text{, that is: } K_1 = \sqrt{1 + 2e^{-\frac{2\pi R}{x}}}$$

where K_1 is the single-phase maximum asymmetrical coefficient, and I_{as} can be calculated from the asymmetrical value and the circuit power factor. In a 3-phase circuit, since the voltage phase angle at switch-on differs between phases, I_{as} will do the same. If the average of these values is taken $\frac{1}{2}$ cycle later, to give the 3-phase average asymmetrical short-circuit current, the following relationship is obtained:

$$I_{as} = I_s \cdot \frac{1}{3}\left\{\sqrt{1 + 2e^{-\frac{2\pi R}{x}}} + 2\sqrt{1 + \frac{1}{2}e^{-\frac{2\pi R}{x}}}\right\} = I_s \cdot K_3$$

$$\text{that is: } K_3 = \frac{1}{3}\left\{\sqrt{1 + 2e^{-\frac{2\pi R}{x}}} + 2\sqrt{1 + \frac{1}{2}e^{-\frac{2\pi R}{x}}}\right\}$$

K_3 is the asymmetrical coefficient, derived from the symmetrical value and the circuit power factor.

3. Peak Value of Asymmetrical Short-Circuit Current
This value (I_p in Fig. 9.3) depends upon the phase angle at short circuit closing and on the circuit power factor; it is maximum when $\theta = 0$. It will reach peak value in each case, $\omega_t \fallingdotseq \frac{\pi}{2} + \varphi$ after the short circuit occurrence. It can be computed as before, by means of the circuit power factor and the symmetrical short-circuit current.

$$I_p = I_s\left[1 + \sin\varphi \cdot e^{-(\frac{\pi}{2} + \varphi)\cdot\frac{R}{x}}\right] = I_s \cdot K_p$$

$$\text{thus: } K_p = \sqrt{2}\left[1 + \sin\varphi \cdot e^{-(\frac{\pi}{2} + \varphi)\cdot\frac{R}{x}}\right]$$

K_p, the peak asymmetrical short-circuit current coefficient, is also known as the closing-capacity coefficient, since I_p is called the closing capacity. Thus, in each case, the asymmetrical coefficients can be derived from the symmetrical values and the circuit power factor. These coefficients are shown Fig. 9.4.

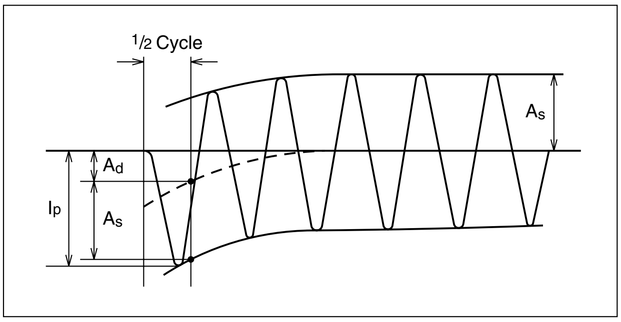


Fig. 9.3 Short-Circuit Current

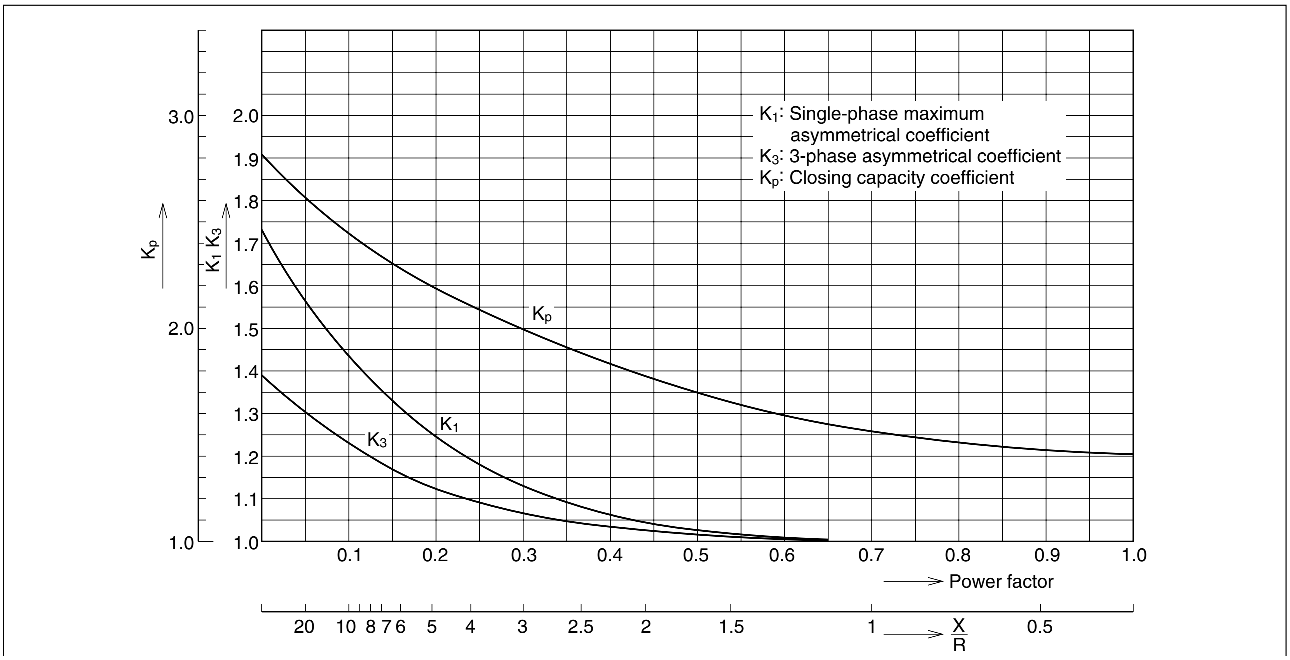


Fig. 9.4 Short-Circuit Current Coefficients

9.5 Calculation Procedures

Table 9.5 Necessary Equations

	Ohmic method	% impedance method	Remarks
3-phase	$I_S = \frac{V}{\sqrt{3} \cdot Z}$ ....Eq. 1	$I_S = \frac{P}{\sqrt{3} \cdot V \cdot \%Z} \times 100$ ....Eq. 2 $= \frac{I_B}{\%Z} \times 100$ ....Eq. 3	$\%Z = \frac{I_B \cdot Z}{V/\sqrt{3}} \times 100$ ....Eq. 1' $P = \sqrt{3} \cdot V \cdot I_B$..............................Eq. 2' ● Eq. 2 is derived from Eqs. 1, 1' and 2'. ● Eq. 3 is derived from Eqs. 1 and 1'. ● Because Eq. 1 can be obtained from Eqs. 2 and 12, it can be seen that I_s of the % impedance method is not affected by the selection of the reference capacity. ● The single-phase short-circuit current in a 3-phase circuit is $\sqrt{3}/2$ times the 3-phase short-circuit current. Consequently, a 3-phase circuit can be examined via the 3-phase short-circuit current.
	$I_{as} = K_3 \cdot I_s$.......................Eq. 4 Key I_s : 3-phase short-circuit current (A, sym) V : Line-line voltage (V) Z : Circuit impedance (1-phase component) I_{as} : 3-phase short-circuit current (A, asym.) P : Reference capacity (3-phase component, VA) %Z : % impedance of circuit (single-phase component, %) I_B : Reference current (A) K_3 : 3-phase asymmetrical coefficient $K_3 = \frac{1}{3}\left\{\sqrt{1 + 2e^{-\frac{2\pi R}{x}}} + 2\sqrt{1 + \frac{1}{2}e^{-\frac{2\pi R}{x}}}\right\}$		
Impedance	● Conversion from percentage value to ohmic value $Z = \frac{V^2}{P} \cdot \%Z \times 10^{-2}\Omega$........................Eq. 9 Where P is the capacity at which %Z was derived. ● Power supply impedance seen from primary side $Z = \frac{(\text{primary voltages})^2}{\text{short-circuit capacity}}$ ....Eq. 10 ● Supply impedance seen from secondary side $Z = \text{primary-side power supply impedance} \times \left(\frac{\text{secondary voltages}}{\text{primary voltage}}\right)^2$ ....Eq. 11	● Conversion from ohmic value to percentage value $\%Z = \frac{P}{V^2} \cdot Z \times 100\%$......................Eq. 12 ● Conversion to %Z at reference capacity Power-supply impedance: $\%Z = \frac{\text{reference capacity}}{\text{short-circuit capacity}} \times 100$......Eq. 13 Transformer impedance, motor impedance: $\%Z = \frac{\text{reference capacity}}{\text{equipment capacity}} \times \text{\%Z at equipment capacity}$ ....Eq. 14	● Eqs. 9 and 12 are derived from Eqs. 1' and 2', and Eqs. 3' and 4'. ● As the supply impedance is defined as 100% at short circuit capacity, for Eq. 13 conversion to reference capacity is made. ● When the supply short-circuit capacity is unknown, the impedance is taken as 0.0040+j0.0999 (%) for 3-phase supply, and 0.0080+j0.1998 (%) for a 1-phase supply (see Table 9.6). ● The motor and transformer impedances are converted from %Z at their equipment capacities into %Z at reference capacity, using Eq. 14. ● Eq. 14 for motor impedance becomes $(4.11 + j24.66) \times \frac{\text{reference capacity}}{\text{equipment capacity}}$ (For details see Table 9.6.)

9.5.1 Computation Methods

Regardless of method, the aim is to obtain the total impedance to the short-circuit point. One of two common methods is used, depending upon whether a percentage or ohmic value is required.

1. Percentage Impedance Method

This method is convenient in that the total can be derived by simply adding the individual impedances, without the necessity of conversion when a voltage transformer is used.

Since impedance is not an absolute value, being based on reference capacity, the reference value must first be determined. The reference capacity is normally taken as 1000kVA; thus, the percentage impedance at the transformer capacity, the percentage impedance derived from the power supply short-circuit capacity, and also the motor impedance must be converted into values based on 1000kVA (Eqs. 13 and 14). Also, the wiring and bus-duct impedances that are given in ohmic values must be converted into percentage impedances (Eq. 12).

2. Ohmic Method

In calculating short-circuit currents for a number of points in a system, since the wire and bus-duct impedances will be different in each case, it is convenient to use Ohm's law, in that if, for example, the total supply impedance (Z_s) is derived as an ohmic value, the total impedance up to the short-circuit point can be obtained by simply adding this value to the wire and bus-duct impedances, which are in series with the supply. For total 3-phase supply impedance (Z_s), refer to Table 9.4 (which shows calculations of Z_s based on standard transformers) to eliminate troublesome calculations attendant to the motor impedance being in parallel with Z_s.

9.5.2 Calculation Examples

1. 3-phase Circuit

For the short circuit at point S in Fig. 9.5, the equivalent circuit will be as shown in Fig. 9.6. The 3-phase short-circuit current can be obtained by either the %-impedance method or Ohm's law, as given in Table 9.6.

Table 9.6 Calculation Example: 3-Phase Short-Circuit Current

	% impedance method	Ohmic method
Power supply impedance Z_L	The supply short-circuit capacity, being unknown, is defined as 1000MVA with $X_L/R_L = 25$. From Eq. 13, at the 1000kVA reference capacity: $Z_L = \frac{1000 \times 10^3}{1000 \times 10^6} \times 100 = 0.1$ (%) since $X_L/R_L = 25$, $0.1 = \sqrt{R_L^2 + (25R_L)^2} = 25.02R_L$ $Z_L = R_L + jX_L = 0.0040 + j0.0999$ (%)	The supply short-circuit capacity, being unknown, is defined as 1000MVA with $X_L/R_L = 25$. From Eq. 10, the supply impedance seen from the primary sicde: $Z_L = \frac{(6600)^2}{1000 \times 10^6} = 0.0436$ (Ω) and since $X_L/R_L = 25$: $Z_L = 1.741 + j43.525$ (mΩ) From Eq. 11, supply impedance converted to the secondary side is: $Z_L = (1.741 + j43.525) \times \left(\frac{440}{6600}\right)^2$ $= 0.00773 + j0.1934$ (mΩ) Note: The supply ohmic impedance can more simply be derived: since it is 100% at short-circuit capacity, Z_L is obtained from Eq. 9, after percentage to ohmic conversion: $Z_L = \frac{440^2}{1000 \times 10^6} \times 100 \times 10^{-2} \times 10^3 = 0.1936$ (mΩ) and since $X_L/R_L = 25$, $Z_L = 0.0069 + j0.1721$ (mΩ)
Transformer impedance Z_T	From Table 9.1: $Z_T = 1.23 + j5.41$ From Eq. 14, after conversion to reference capacity, 1000kVA: $Z_T = (1.23 + j5.41) \times \frac{1000 \times 10^3}{1500 \times 10^3}$ $= 0.82 + j3.607$ (%)	From Table 9.1: $Z_T = 1.23 + j5.41$ (%) From Eq. 9, after percentage to ohmic conversion. $Z_T = \frac{440^2}{1500 \times 10^3} \times (1.23 + j5.41) \times 10^{-2}$ (Ω) $= 1.2906 + j6.9825$ (mΩ)
Motor impedance Z_M	The total motor capacity, being unknown, is assumed equal to the transformer capacity, with: $\%Z_M = 25$(%) $X_M/R_M = 6$ From Eq. 14, at reference capacity, 1000kVA: $Z_M = (4.11 + j24.66) \times \frac{1000 \times 10^3}{1500 \times 10^3 \times 0.8}$ $= 3.42 + j20.55$ (%)	The total motor capacity, being unknown, is assumed equal to the transformer capacity, with: $\%Z_M = 25$(%) $X_M/R_M = 6$ $Z_M = 4.11 + j24.66$ $Z_M = 4.11 + j24.66$ (%) From Eq. 9, after percentage to ohmic conversion: $Z_M = \frac{440^2}{1500 \times 10^3 \times 0.8} \times (4.11 + j24.66) \times 10^{-2}$ (Ω) $= 6.6294 + j39.7847$ (mΩ)
Total power supply impedance Z_S	$Z_S = \frac{(Z_L + Z_T)Z_M}{Z_L + Z_T + Z_M}$ $= 0.671 + j3.142$ (%) (R and X are calculated, per §9.3.2.)	$Z_S = \frac{(Z_L + Z_T)Z_M}{Z_L + Z_T + Z_M}$ $= 1.299 + j6.083$ (mΩ) (R and X are calculated, per §9.3.2.)
Line impedance Z_W	Multiplying the value from Table 9.2 by a wire length of 10M, and converting to the 1000kVA reference, from Eq. 12: $Z_W = \frac{1000 \times 10^3}{440^2} (0.0601 + j0.079) \times 10^{-3} \times 10 \times 100$ $= 0.310 + j0.408$ (%)	Multiplying the value from Table 9.2 by a wire length of 10M. $Z_W = (0.0601 + j0.079) \times 10$ $= 0.601 + j0.79$ (mΩ)
Total impedance Z	$Z = Z_S + Z_W$ $= 0.981 + j3.550 = 3.683$ (%)	$Z = Z_S + Z_W$ $= 1.900 + j6.873 = 7.1307$ (mΩ)
3-phase short-circuit symmetrical current I_s	From Eq. 2: $I_s = \frac{1000 \times 10^3}{\sqrt{3} \times 440 \times 3.683} \times 100$ $= 35.622$ (A)	From Eq. 1 $I_s = \frac{440}{\sqrt{3} \times 7.1307 \times 10^{-3}}$ $= 35.622$ (A)

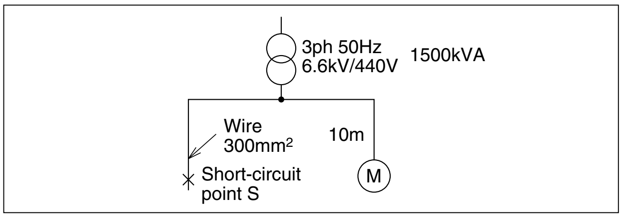


Fig. 9.5 Circuit Configuration

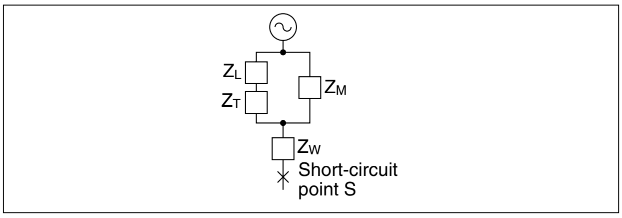


Fig. 9.6 Equivalent Circuit

MOULDED CASE CIRCUIT BREAKERS

Safety Tips : Be sure to read the instruction manual fully before using this product.

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