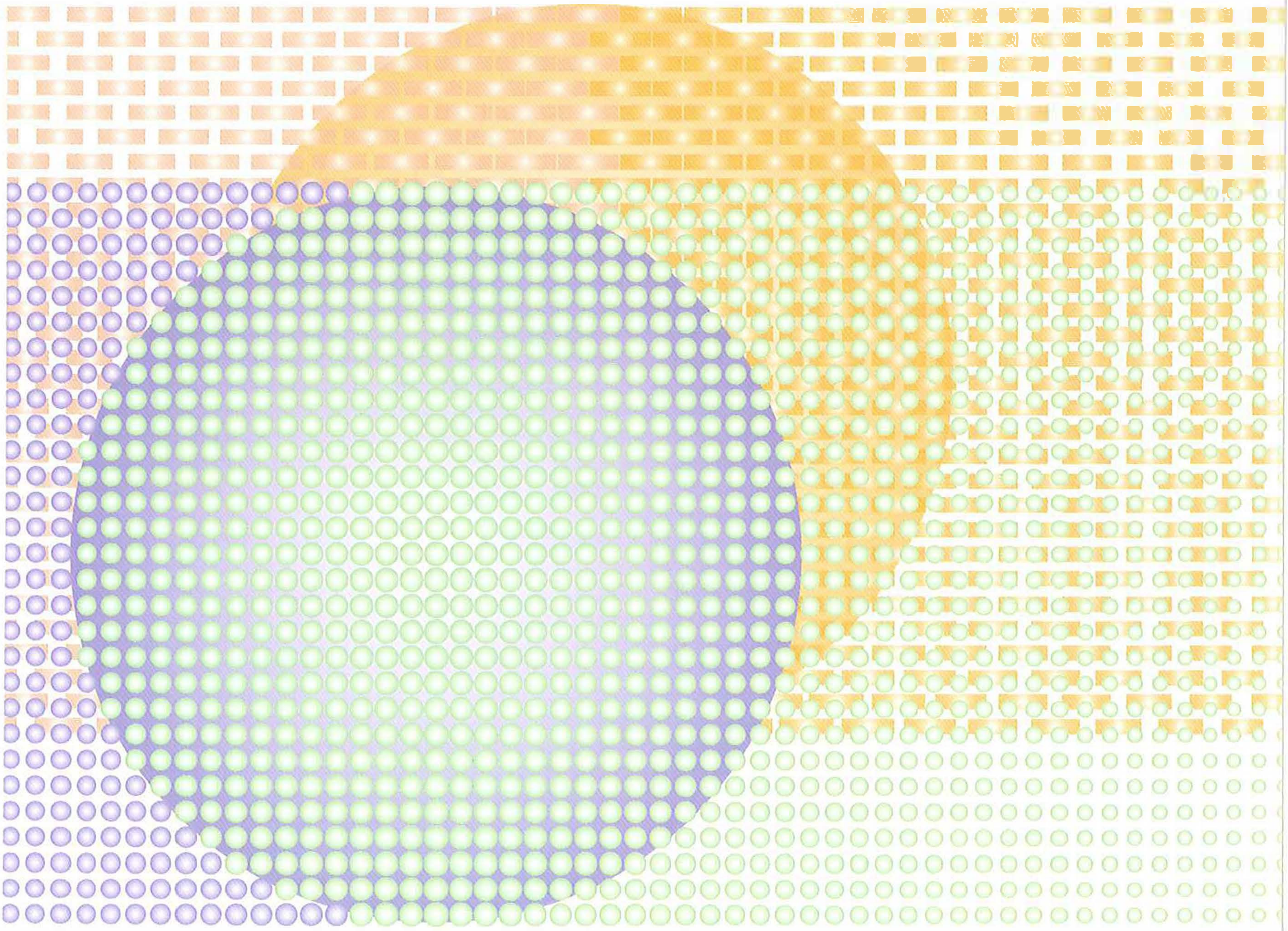
HITACHI

HITACHI Molded-case Circuit Breakers

Technical Notes



FOREWORD

We are very pleased present you our Technical Notes of circuit breakers.
Our circuit breakers are suitable for application as main circuit breakers and for protection, for protection of branch and feeder and for connected apparatuses.
This notes provides fundamental information of circuit breakers regarding structure, usage, tripping characteristics, installation and so on. Please use this effectively to make great power source systems.

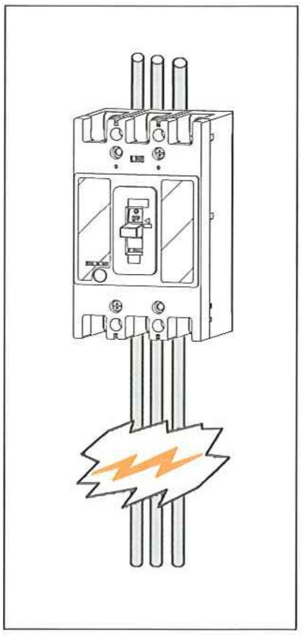
CONTENTS

INTRODUCTION

Circuit breakers

Circuit breakers protect the downstream circuit against overload and short-circuit and the circuit breakers also provide the control and disconnection functions. By attachment of internal accessories, the breaker can ;

- be opened the circuit by the remote control with a shunt trip or under-voltage trip
- signal its ON, OFF or its opening on a fault if it is equipped with auxiliary and alarm switches.



Selection of circuit breaker

In case of selection of circuit breakers, it is necessary to consider as follows;

Voltage: the rated voltage of the circuit breakers must be greater than or equal the line-line voltage of the circuit.

Current: the rating current of the circuit breaker must be greater than or equal the circuit.

Frequency: the rated frequency of the circuit breaker must correspond to the circuit frequency.

Breaking capacity: the breaking capacity of the breaker must be greater than or equal to the short-circuit current at its installation point.

Number of poles: the number of poles depends on the type of neutral system like TN,TT and IT.

Protection

● Protection of personnel against indirect contact

The measures to protect against indirect contact by automatic interruption of the power supply depend on the earthing system.

On TT systems protection are generally provided by residual current devices.

On TN systems or IT systems protection are generally short circuit protection devices.

On IT systems, the necessary protection is based on the continuous insulation monitor.

● Protection of cables

If short circuit occurs, the circuit breakers must limit the value of I^2t to a value lower than that which the cables are able to withstand for protect the cables against deterioration of the insulation of cables and fire.

Selection Table

F series

SERIES			STANDARD BREAKERS– "F" SERIES					
TYPE			**F-30FB**	**F-60RB**	**F-60R**	**F-50KB**	**F-100S**	**F-100RB**
Appearance								
Number of Poles			2 / 3	2 / 3	4	2 / 3 / 4	4	2 / 3
Dimensions		A	52 / 57	52 / 75	100	65 / 90 / 120	120	65 / 90
		B	130	130		150	150	150
		C	60	60		86	60	78
		D	84	84		106	85	98
Net Weight (kg)			0.46 / 0.63	0.53 / 0.74	0.95	1.4 / 1.8 / 2.3	1.3	1.2 / 1.5
Rated Voltage (V)		AC	600	600		600	600	600
		DC	250 (2)	250 (2)		250 (2)	–	–
Rated Current (A) (Bese Ambient Temperature 40°C)			3 5 10 15 20 30	15 20 30 40 50 60		5 10 15 20 30 40 50	15 20 30 50 60 75 100	15 20 30 50 60 75 100
AC INTERRUPTING CAPACITY (kA)								
JIS C8370 (sym)		220V	7.5	–		85	25	85
		460V	2.5	–		50	10	25
		600V	1.5	–		14	2.5	10
IEC 60947-2 (sym)(Icu/Ics)		230V/240V	5/3	25/25		85/85	22/11	50/50
		380V/400V	2.5/1	10/10		50/50	10/5	25/25
		415V	2.5/1	10/10		50/50	10/5	25/25
DC INTERRUPTING CAPACITY (kA)								
JIS		125V	5 / –	7.5 / –	–	40 / –	–	–
		250V	2.5 / –	5 / –	–	40 / –	–	–
TRIPPING SYSTEM								
Full Magnetic			○	○		○	○	○
Thermal Magnetic (non-adjustable)			–	–		–	–	–
Thermal Magnetic (magnetic trip adjustable)			–	–		–	–	–
With Shot-Time Delay			–	–		–	–	–
TRIPPING SYSTEM								
Interior Accessories	Under voltage Trip	UVT	–	–		○	○	○
	Shunt Trip	SHT	○	○		○	○	○
	Alarm Swich 1C	AL-1C	○	○		○	○	○
	Alarm Swich 2C	AL-2C	–	–		–	–	–
	Auxiliary Swich 1C	AUX-1C	○	○		○	○	○
	Auxiliary Swich 2C	AUX-2C	–	–		–	–	–
Exterior Accessories	Rear-Connecting Studs	STB	STB-2M	STB-2M	STB-1B	STB-2	STB-3H (50A or less : STB-2D)	STB-3J (50A or less : STB-2)
	Rear-Connecting Bar Studs	BSD	–	–		–	–	–
	Plug-in Mounting Bass Assembly	PK	○	○		○	○	○
	Drawout Assembly	PDK	–	–		–	–	–
	Flush Mounting Bass Assembly	GKW (GK)	○	○		○	○	○
	Mechanical Interlock	MIW	MIW-2E	MIW-2E	MIW-1C	MIW-3D	MIW-2C	MIW-3C
	Motor-Operating Mechanism	MMK	–	–		–	–	–
	Handle-Operating Mechanism	–	HM-S12	HM-S12	HM-57	HM-S11	HM-S11	HM-S11
	Terminai Cover	TMC	TMC-1	TMC-1		TMC-3C	TMC-2C	TMC-2
Phase Separator (only for the line side)			–	○		○	–	○

Notes: 1. Dimensions of 2-pole breakers marked with * are same as 3-pole breakers.

STANDARD BREAKERS- "F" SERIES

	F-100KB			F-225FB			F-225KC			F-250R		F-400R			FX400	
																
	2	3	4	2*	3	4	2*	3	4	2*	3	2*	3	4	2*	3
	65	90	120	105		140	105		140	140		140		185	140	
	150			165			165			257		257			257	
	86			103			103			103		103			103	
	106			127			127			133		133			133	
	1.4	1.8	2.3	2.0	2.3	3.1	2.0	2.3	3.1	4.7	5.2	5.3	6.1	8.2	5.1	5.9
	600			600			600			600		600				
	250 (2)			250			250			250		250			–	
	15 20 30 50 75 100			125 150 175 200 225			125 150 175 200 225			250		250 300 350 400			200/225/250/300/ 350/400 adjustable	
	85			85			85			–		–			100	
	50			30			50			–		–			50	
	14			18			25			–		–			25	
	85/85			85/85			85/85			85/85		85/85			100/100	
	50/50			30/30			50/50			50/50		50/50			50/50	
	50/50			30/30			50/50			50/50		50/50			50/50	
	40	–		25	–		40	–		40	–	40	–		–	
	40	–		25	–		40	–		40	–	40	–		–	
	○			–			–			–		–			Electronic trip relay (adjustable)	
	–			○			○			○		○				
	–			–			–			–		–				
	–			–			–			–		–			○	
	○			–			–			○		○			○	
	○			○			○			○		○			○	
	○			○			○			○		○			○	
	–			–			–			○		○			○	
	○			○			○			○		○			○	
	–			–			–			○		○			○	
	STB-3J (50A or less : STB-2)			–			–			–		–			–	
	–			○			○			○		○			○	
	○			○			○			○		○			○	
	–			–			–			–		–			–	
	○			○			○			○ (GK)		○ (GK)			○	
	MIW-3D			MIW-4H			MIW-4H			MIW-5D		MIW-5D			MIW-5F	
	–	MMK-S		MMK-S		–	MMK-S		–	MMK-C		MMK-C			MMK-C	
	HM-S11			HM-S21			HM-S21			HM-405		HM-405			HM-405	
	TMC-3C			TMC-4H			TMC-4H			TMC-5B		TMC-5B			TMC-5B	
	○			○			○			○		○			○	

Selection Table (cont.)

F series

SERIES		STANDARD BREAKERS– "F" SERIES							
TYPE		F-600F	FX600	F-8000R	F-8000RH	FX800	FX1000	F-1000C	F-1000K
Appearance									
Number of Poles		2* / 3 / 4	2* / 3	3 / 4	3 / 4	3	3	3 / 4	3 / 4
Dimensions	A	210 / 280	210	210 / 280	210 / 280	210	210	210 / 280	210 / 280
	B	274	274	274	274	274	410	410	410
	C	103	103	103	103	103	150	150	150
	D	141	141	141	141	141	190	190	190
Net Weight (kg)		10 / 13	8.7 / 9.7	10.5 / 13.5	10.5 / 13.5	11	26	26 / 33	26 / 33
Rated Voltage (V)	AC	600	600	600	600	600	600	600	600
	DC	250	–	250 / –	–	–	–	–	–
Rated Current (A) (Bese Ambient Temperature 40°C)		500 600	300/350/400/500/600 adjustable	700 800	700 800	400/450/500/600/700/800 adjustable	500/600/700/800/900/1000 adjustable	500/600/700/800/1000 adjustable	1000

■ AC INTERRUPTING CAPACITY (kA)

		F-600F	FX600	F-8000R	F-8000RH	FX800	FX1000	F-1000C	F-1000K
JIS C8370 (sym)	220V	85	100	–	125	100	125	125	125
	460V	50	50	–	85	50	85	85	85
	600V	22	25	–	42	25	42	42	42
IEC 60947-2 (sym)(Icu/Ics)	230V/240V	85/85	100/100	85/85	125/63	100/100	125/125	125/32	125/32
	380V/400V	50/50	50/50	50/50	85/43	50/50	85/85	85/22	85/22
	415V	50/50	50/50	50/50	85/43	50/50	85/85	85/22	85/22

■ DC INTERRUPTING CAPACITY (kA)

		F-600F	FX600	F-8000R	F-8000RH	FX800	FX1000	F-1000C	F-1000K
JIS	125V	40 / –	–	40 / –	–	–	–	–	–
	250V	40 / –	–	40 / –	–	–	–	–	–

■ TRIPPING SYSTEM

	F-600F	FX600	F-8000R	F-8000RH	FX800	FX1000	F-1000C	F-1000K
Full Magnetic	–	Electroric trip relay (adjustable)	–	–	Electroric trip relay (adjustable)	Electroric trip relay (adjustable)	Electroric trip relay (adjustable)	–
Thermal Magnetic (non-adjustable)	–		–	–				–
Thermal Magnetic (magnetic trip adjustable)	○		○	○				–
With Shot-Time Delay	–	○	–	–	○	○	○	○ (2)

■ APPLICABILITY OF VARIOUS ACCESSORIES

				F-600F	FX600	F-8000R	F-8000RH	FX800	FX1000	F-1000C	F-1000K
Interior Accessories	Under voltage Trip		UVT	○	○	○	○	○	○	○	○
	Shunt Trip		SHT	○	○	○	○	○	○	○	○
	Alarm Swich	1C	AL-1C	○	○	○	○	○	○	○	○
		2C	AL-2C	○	○	○	○	○	○	○	○
	Auxiliary Swich	1C	AUX-1C	○	○	○	○	○	○	○	○
		2C	AUX-2C	○	○	○	○	○	○	○	○
Exterior Accessories	Rear-Connecting Studs		STB	–	–	–	–	–	–	–	–
	Rear-Connecting Bar Studs		BSD	○	○	○	○	○	○	○	○
	Plug-in Mounting Bass Assembly		PK	○	○	○	○	○	○	○	○
	Drawout Assembly		PDK	–	–	–	–	–	–	–	–
	Flush Mounting Bass Assembly		GKW (GK)	○	○	○	○	○	○	○	○
	Mechanical Interlock		MIW	MIW-5	MIW-5G	MIW-5	MIW-5	MIW-5G	MIW-8	MIW-8	MIW-8
	Motor-Operating Mechanism		MMK	MMK-C	MMK-C	MMK-C	MMK-C	MMK-C	MMK-C	MMK-C	MMK-C
	Handle-Operating Mechanism		–	HM-402	HM-402	HM-402	HM-402	HM-407	HA-801	HA-801	HA-801
	Terminai Cover		TMC	TMC-5D	TMC-5D	TMC-5D	TMC-5D	TMC-5D	TMC-6B	TMC-6	TMC-6
Phase Separator (only for the line side)				○	○	○	○	○	○	○	○

Notes: 1. Dimensions of 2-pole breakers marked with * are same as 3-pole breakers.
2. Can be provided with short time-delay element if requested when ordering.
3. Attached a terminal cover for line side as standed.
4. Attached Rear-connected bar studs as standard. Specify if Front-connected bar terminals are required.
5. Attached Rear-connected bar studs as standard. Frort-connected bar terminals type can not be supplied.

STANDARD BREAKERS- "F" SERIES

	FX1200	F-1200C	F-1200K	F-1600CB	F-1600B	F-1600E	F-2000E	F-2500E	F-3200CB	F-3200E	F-4000E
											
	3	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3	3	3
	210	210, 280	210, 280	210, 280	210, 280	210, 280	320, 429	320, 429	310	530	750
	410	410	410	410	410	370	450	450	560	610	650
	150	150	150	150	150	140	185	185	226	304	374
	190	190	190	190	190	191	245	245	299	373	428.5
	26	26, 33	26, 33	37, 49	37, 49	27, 35	54, 67	62.5, 78.2	90	200	250
	600	600	600	600	600	600	600	600	600	600	600
	–	–	–	–	–	–	–	–	–	–	–
	600/700/800/ 1000/1200 adjustable	600/700/800/ 1000/1200 adjustable	1200	800/900/1000/ 500 600 adjustable	1000 1200 1400 1600	800/900/1000/ 1200/1400/1600 adjustable	1000/1200/1400/ 1600/1800/2000 adjustable	1200/1400/1600/ 2000/2500 adjustable	2000/2500/2800/ 3000/3200 adjustable	3000 3200	3600 4000

	125	125				130	130	130	125	130	
	85	85				85	85	85	85	85	
	42	42				65	65	65	70	65	
	125/125	125/32				125/94	125/94	125/94	125/32	130/98	
	85/85	85/22				100/75	100/75	00/75	85/22	100/75	
	85/85	85/22				85/64	85/64	85/64	85/22	85/64	85/64

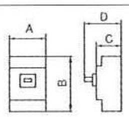
	–					–	–	–	–		
	–					–	–	–	–		

	Electroric trip relay (adjustable)	Electroric trip relay (adjustable)	–	Electroric trip relay (adjustable)	–	Electroric trip relay (adjustable)	Electroric trip relay (adjustable)	Electroric trip relay (adjustable)	Electroric trip relay (adjustable)	–	–
			–		–					○	○
			○		○					–	–
	○	○	○ (2)	○	○	○	○ (2)	○ (2)	○	○	○

	○	○	○	○	○	○	○	○	○	○	–
	○	○	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	–	○	○	○	○	○
	○	○	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○	○	○
	–	–	–	–	–	–	–	–	–	–	–
	○	○	○	○	○	○	○ (4)	○ (4)	○ (5)	○ (5)	○ (5)
	○	○	○	–	–	–	–	–	–	–	–
	–	–	–	–	–	○	○	○	○	○	–
	○	○	○	○	○	○	○	○	–	–	–
	MIW-8	MIW-8	MIW-8	MIW-8	MIW-8	○	○	○	–	–	–
	MMK-C	MMK-C	MMK-C	MMK-C	MMK-C	MMK	MMK	MMK	MMK	MMK	MMK
	HA-801	HA-801	HA-801	HA-801	HA-801	○	○	○	–	–	–
	TMC-6B	TMC-6	TMC-6	–	–	–	–	–	–	–	–
	○	○	○	○	○	○	○	○	–	–	–

Selection Table (cont.)

S series

SERIES		STANDARD BREAKERS– "S" SERIES					
TYPE		**S-30E**	**S-50EB**	**S-50SB**	**S-60RB**	**S-100EB**	**S-100SB**
Appearance							
Number of Poles		2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3
Dimensions 	A	50 / 75	50 / 75	52 / 75	52 / 75	52 / 75	52 / 75
	B	96	95	130	130	130	130
	C	60	60	60	60	60	60
	D	76	79	84	84	84	84
Net Weight (kg)		0.25 / 0.37	0.32 / 0.47	0.48 / 0.6	0.46 / 0.63	0.5 / 0.7	0.53 / 0.74
Rated Voltage (V)	AC	500	220	600	600	220	600
	DC	–	–	250 (2)	250 (2)	250 (2)	250 (2)
Rated Current (A) (Bese Ambient Temperature 40°C)		3 5 10 15 20 30	5 10 15 20 30 40 50	5 10 15 20 30 50	5 10 15 20 20 30 50	60 75 100	60 75 100
AC INTERRUPTING CAPACITY (kA)							
JIS C8370 (sym)	220V	5	5	7.5	–	10	35
	460V	1.5	1.5	2.5	–	–	10
	600V	–	–	1.5	–	–	2.5
IEC 60947-2 (sym)(Icu/Ics)	230V/240V	5/2	5/2	5/3	10/3	10/3	30/8
	380V/400V	1.5/1	1.5/1	2.5/1	5/2	–	10/3
	415V	1.5/1	1.5/1	2.5/1	5/2	–	10/3
DC INTERRUPTING CAPACITY (kA)							
JIS	125V	–	–	5 / –	5 / –	5 / –	7.5 / –
	250V	–	–	2.5 / –	2.5 / –	2.5 / –	5 / –
TRIPPING SYSTEM							
Full Magnetic		○	○	○	○	○	○
Thermal Magnetic (non-adjustable)		–	–	–	–	–	–
Thermal Magnetic (magnetic trip adjustable)		–	–	–	–	–	–
With Shot-Time Delay		–	–	–	–	–	–
APPLICABILITY OF VARIOUS ACCESSORIES							
Interior Accessories: Under voltage Trip	UVT	–	–	–	–	–	–
Interior Accessories: Shunt Trip	SHT	○	○	○	○	○	○
Interior Accessories: Alarm Swich 1C	AL-1C	○	○	○	○	○	○
Interior Accessories: Alarm Swich 2C	AL-2C	–	–	–	–	–	–
Interior Accessories: Auxiliary Swich 1C	AUX-1C	○	○	○	○	○	○
Interior Accessories: Auxiliary Swich 2C	AUX-2C	–	–	–	–	–	–
Exterior Accessories: Rear-Connecting Studs	STB	–	–	STB-2M	STB-2M	STB-3K	STB-3K
Exterior Accessories: Rear-Connecting Bar Studs	BSD	–	–	–	–	–	–
Exterior Accessories: Plug-in Mounting Bass Assembly	PK	–	–	○	○	○	○
Exterior Accessories: Drawout Assembly	PDK	–	–	–	–	–	–
Exterior Accessories: Flush Mounting Bass Assembly	GKW (GK)	–	–	○	○	○	○
Exterior Accessories: Mechanical Interlock	MIW	–	–	MIW-2E	MIW-2E	MIW-2E	MIW-2E
Exterior Accessories: Motor-Operating Mechanism	MMK	–	–	–	–	–	–
Exterior Accessories: Handle-Operating Mechanism	–	–	–	HM-S12	HM-S12	HM-S12	HM-S12
Exterior Accessories: Terminai Cover	TMC	TMC-0G	TMC-0G	TMC-1	TMC-1	TMC-1	TMC-1
Phase Separator (only for the line side)		–	–	–	–	–	○

Notes: 1. Dimensions of 2-pole breakers marked with * are same as 3-pole breakers.

STANDARD BREAKERS- "F" SERIES

	S-100S	S-225SB	SXK225	S-400S	SX400	S-600S	SX600	S-800S	SX800
									
	2 3	2* 3	2* 3	2* 3	2* 3	2* 3	2* 3	3	3
	65 90	105	105	140	140	210	210	210	210
	150	165	165	257	257	274	274	274	274
	150	165	165	257	257	103	103	103	103
	85	85	95	133	133	141	141	141	141
	0.7 10	1.6	1.6	5.3 6.1	5.1 5.9	10	8.7 9.7	10.5	11
	600	600	600	600	600	600	600	600	600
	250 (2)	250	250 (2)	250	–	250	–	250	–
	60 75 100	125 150 175 200 225	125 150 175 200 225	125 150 175 200 225	200/225/250/ 300/350/400 adjustable	500 600	300/350/400/ 500/600 adjustable	700 800	400/450/500/ 600/700/800 adjustable

	25	35	35	35	50	42	50	85	50
	10	15	15	22	35	22	35	35	35
	2.5	5	5	10	10	18	10	18	10
	22/11	35/18	35/18	50/13	50/25	43/22	50/25	85/43	50/25
	10/5	15/8	15/8	25/7	36/18	22/11	36/18	36/18	36/18
	10/5	15/8	15/8	25/7	36/18	22/11	36/18	36/18	36/18

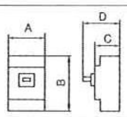
	7.5 –	15 –	15 –	25 –	–	40 –	–	40	–
	5 –	10 –	10 –	25 –	–	40 –	–	40	–

	○	–	–	–	Electroric trip relay (adjustable)	–	Electroric trip relay (adjustable)	–	Electroric trip relay (adjustable)
	–	○	○	○		–		–	
	–	–	–	–		○		○	
	–	–	–	–	○	–	○	–	○

	○	○	–	–	○	○	○	○	○
	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○
	–	–	–	○	○	–	○	○	○
	○	○	○	○	○	○	○	○	○
	–	–	–	○	○	○	○	○	○
	STB-3H	–	–	–	–	–	–	–	–
	–	○	○	○	○	○	○	○	○
	○	–	○	–	–	–	–	–	–
	–	–	–	–	–	○	○	○	○
	○	○	○	○ (GK)	○	○ (GK)	○ (GK)	○ (GK)	○ (GK)
	MIW-2C	MIW-4F	MIW-4L	MIW-5D	MIW-5F	MIW-5	MIW-5G	MIW-5	MIW-5G
	–	MMK-S	–	○	○	○	○	○	○
	HM-S11	HM-S22	HM-S23	HM-405	HM-406	HM-402	HM-407	HM-402	HM-407
	TMC-2	TMC-4K	TMC-4J	TMC-5B	TMC-5B	TMC-5D	TMC-5D	TMC-5D	TMC-5D
	○	○	○	○	○	○	○	○	○

Selection Table (cont.)

L series

SERIES			STANDARD BREAKERS– "L" SERIES										
TYPE			L-50E		L-100E		L-225E		L-400E		L-600E		L-800E
Appearance													
Number of Poles			3	4	3	4	3	4	3	4	3	4	3
Dimensions		A	90	120	90	120	140	185	140	185	210	280	210
		B	150		150		257		257		274		274
		C	103		103		103		103		103		103
		D	123		123		133		133		141		141
Net Weight (kg)			2.0	2.5	2.0	2.5	5.2	7.0	6.1	8.2	10	13	10.5
Rated Voltage (V)		AC	600		600		600		600		600		600
		DC	–		–		–		–		–		–
Rated Current (A) (Bese Ambient Temperature 40°C)			5 10 15 20 30 50		15 20 30 50 60 75 100		125 150 175 200 225		250 300 350 400		500 600		700 800

AC INTERRUPTING CAPACITY (kA)

JIS C8370 (sym)	220V	175
	460V	125
	600V	42
IEC 60947-2 (sym)(Icu/Ics)	230V/240V	175/88
	380V/400V	125/32
	415V	125/32

DC INTERRUPTING CAPACITY (kA)

		L-50E	L-100E	L-225E	L-400E	L-600E	L-800E
JIS	125V	–	–	–	–	–	–
	250V	–	–	–	–	–	–

TRIPPING SYSTEM

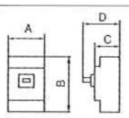
		L-50E	L-100E	L-225E	L-400E	L-600E	L-800E
Full Magnetic		○	○	–	–	–	–
Thermal Magnetic (non-adjustable)		–	–	○	○	–	–
Thermal Magnetic (magnetic trip adjustable)		–	–	–	–	○	○
With Shot Time Delay	–	–	–	–	–	–	–

APPLICABILITY OF VARIOUS ACCESSORIES

				L-50E	L-100E	L-225E	L-400E	L-600E	L-800E
Interior Accessories	Under voltage Trip		UVT	○	○	○	○	○	○
	Shunt Trip		SHT	○	○	○	○	○	○
	Alarm Swich	1C	AL-1C	○	○	○	○	○	○
		2C	AL-2C	○	○	○	○	○	○
	Auxiliary Swich	1C	AUX-1C	○	○	○	○	○	○
		2C	AUX-2C	○	○	○	○	○	○
Exterior Accessories	Rear-Connecting Studs		STB	○	○	–	–	–	–
	Rear-Connecting Bar Studs		BSD	–	–	○	○	○	○
	Plug-in Mounting Bass Assembly		PK	○	○	○	○	○	○
	Drawout Assembly		PDK	–	–	–	–	–	–
	Flush Mounting Bass Assembly		GKW (GK)	○	○	○ (GK)	○ (GK)	○ (GK)	○ (GK)
	Mechanical Interlock		MIW	MIW-3E	MIW-3E	MIW-5D	MIW-5D	MIW-5	MIW-5
	Motor-Operating Mechanism		MMK	MMK-S	MMK-S	○	○	○	○
	Handle-Operating Mechanism		–	HM-S11	HM-S11	HM-405	HM-405	HM-402	HM-402
	Terminai Cover		TMC	TMC-3C	TMC-3C	TMC-5B	TMC-5B	TMC-5C	TMC-5D
Phase Separator (only for the line side)				○	○	○	○	○	○

Selection Table (cont.)

M series

SERIES		STANDARD BREAKERS– "M" SERIES							
TYPE		MS-30E	MS-50EB	MS-50SB	MS-100SB	MF-100RB	MS-225SB	MSXK225	MF-225FB
Appearance									
Number of Poles		3	3	3	3	3	3	3	3
Dimensions 	A	75	75	75	75	90	105	105	105
	B	96	96	130	130	150	165	165	165
	C	60	60	60	60	78	60	68	103
	D	76	76	84	84	98	85	93	127
Net Weight (kg)		0.37	0.37	0.63	0.74	1.5	1.6	1.6	2.3
Rated Voltage (V)	AC	600	600	600	600	600	600	600	600
Rated Current (A) (Bese Ambient Temperature 40°C)		1.2 1.4 2 2.9 4 5 7.1 8 10 12 16 25 32	10 12 16 25 32 40 45	0.7 1.4 2.3 2.6 4.2 5.6 7.4 9.0 10 14 16 25 33 40 45	60 75 90	60 75 90	125 150 175 225	125 150 175 225	125 150 175 225

■ AC INTERRUPTING CAPACITY (kA)

		MS-30E	MS-50EB	MS-50SB	MS-100SB	MF-100RB	MS-225SB	MSXK225	MF-225FB
JIS C8370 (sym)	220V	5	5	7.5	35	85	35	35	85
	460V	1.5	1.5	2.5	10	25	15	15	30
	600V	–	–	1.5	2.5	10	5	5	18
IEC 60947-2 (sym)(Icu/Ics)	230V	5/2	5/2	5/3	30/8	85/85	35/18	35/18	85/85
	380V/400V	5/1	1.5/1	2.5/1	10/3	25/25	15/8	15/8	30/30
	415V	1.5/1	1.5/1	2.5/1	10/3	25/25	15/8	15/8	30/30

■ TRIPPING SYSTEM

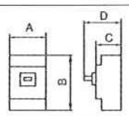
	MS-30E	MS-50EB	MS-50SB	MS-100SB	MF-100RB	MS-225SB	MSXK225	MF-225FB
Full Magnetic	○	○	○	○	○	–	–	–
Thermal Magnetic (non-adjustable)	–	–	–	–	–	○	○	○
Thermal Magnetic (magnetic trip adjustable)	–	–	–	–	–	–	–	–
With Shot Time Delay	–	–	–	–	–	–	–	–

■ APPLICABILITY OF VARIOUS ACCESSORIES

				MS-30E	MS-50EB	MS-50SB	MS-100SB	MF-100RB	MS-225SB	MSXK225	MF-225FB
Interior Accessories	Under voltage Trip		UVT	–	–	–	–	○	–	–	–
	Shunt Trip		SHT	○	○	○	○	○	○	○	○
	Alarm Swich	1C	AL-1C	○	○	○	○	○	○	○	○
		2C	AL-2C	–	–	–	–	–	–	–	–
	Auxiliary Swich	1C	AUX-1C	○	○	○	○	○	○	○	○
		2C	AUX-2C	–	–	–	–	–	–	–	–
Exterior Accessories	Rear-Connecting Studs		STB	–	–	STB-2M	STB-3K	STB-3J (5OA or less : STB-2)	–	–	–
	Rear-Connecting Bar Studs		BSD	–	–	–	–	–	○	○	○
	Plug-in Mounting Bass Assembly		PK	–	–	○	○	○	–	–	○
	Drawout Assembly		PDK	–	–	–	–	–	–	–	–
	Flush Mounting Bass Assembly		GKW (GK)	–	–	○	○	○	○	○	○
	Mechanical Interlock		MIW	–	–	MIW-2E	MIW-2E	MIW-3C	MIW-4F	MIW-4L	MIW-4H
	Motor-Operating Mechanism		MMK	–	–	–	–	–	MMK-S	–	MMK-S
	Handle-Operating Mechanism		–	–	–	HM-S12	HM-S12	HM-S11	HM-S22	HM-S23	HM-S21
	Terminai Cover		TMC	TMC-0G	TMC-0G	TMC-1	TMC-1	TMC-2	TMC-4K	TMC-4J	TMC-4H

Selection Table (cont.)

B series

TYPE		B-50E			B-60E			B-100E	
Appearance									
Number of Poles		1	2	3	1	2	3	2	3
Dimensions 	A	25	50	75	25	50	75	50	75
	B	95	95	95	95	95	95	95	95
	C	60	60	60	60	60	60	60	60
	D	77.5	77.5	82.5	76	76	76	77.5	77.5
Net Weight (kg)		0.15	0.3	0.45	0.15	0.32	0.50	0.44	0.65
Rated Voltage (V)	AC	265	460	460	230/400	400		460	
Rated Current (A) (Bese Ambient Temperature 40°C)		10 15 20 30 40 50	15 20 30 40 50		5 10 15 20 25 30 40 50 60	10 15 20 25 30 40 50 60	15 20 25 30 40 50 60	60 75 100	

■ AC INTERRUPTING CAPACITY (kA)

		B-50E 1P	B-50E 2P	B-50E 3P	B-60E 1P	B-60E 2P	B-60E 3P	B-100E 2P	B-100E 3P
JIS C8370	110V	5	–		–	–	–	5	
	110/220V	–	5	–	–	–	–	5	
	220V	–	5	5	–	–	–	5	
	265V	2.5	2.5	–	–	–	–	2.5	
IEC 60898	230/400V	–	–	–	6	–	–	–	–
	400V	–	–	–	–	6	6	–	–

■ TRIPPING SYSTEM

		B-50E	B-60E	B-100E
Thermal Magnetic (non-adjustable)		○	○	○

1. CONSTRUCTION

General

Our circuit breaker consists of a switching mechanism, arc extinguishing device, tripping device, and a heat-proof molded case and cover to put in them.

Making and breaking are performed by moving molded handle. Typical example of its structure is shown in the Fig. 1.1.1.

Arc extinguishing device

A series of grid plate is mounted in parallel between insulating supports the slot in the steel plates extend directly over the contact and attract arc from moving contact into divided chamber and the are is confined, divided and extinguished.

Moreover, a special silver alloy which is capable of withstanding the arc is used as the contacts.

Switching mechanism

The switching mechanism is a quick-make, quick-break mechanism utilizing a trip free toggle mechanism

Handle

Indication of tripping

In case of automatic tripping due to troubles such as overload, short circuit and so on,

the handle moves midway between ON and OFF and the white line on the handle will disappear. It is evident at a glance that the automatic trip has operated as a result of some troubles.

Reset

If the Circuit breakers have automatically tripped, ON and OFF operation can be resumed by moving the handle to the OFF direction, after the cause of trouble has been eliminated.

Trip free

Even if the handle is held at ON position, automatic tripping is also possible for overload and short circuit.

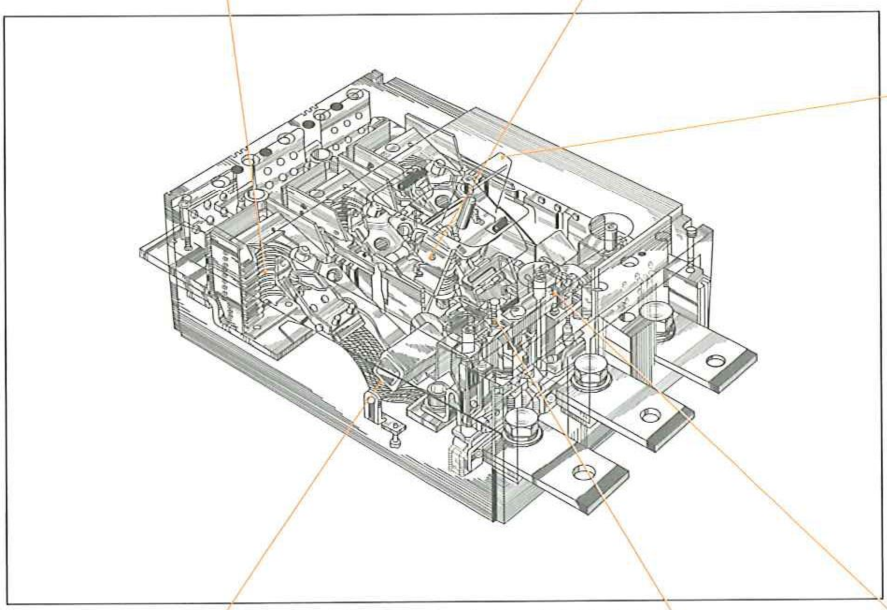


Fig 1.1.1 Structure of circuit breaker

Common tripping mechanism

All poles open their circuits simultaneously, if an overload current flows in any phase and it is possible to prevent single phase.

Trip button

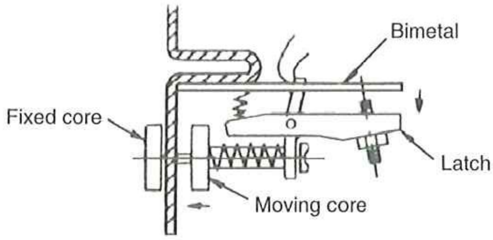
The circuit breakers can be mechanically tripped from the exterior. Checking performance of the alarm switch is also possible.

Adjustable magnetic trip lever

The instantaneous tripping current can be adjusted by changing the knob position.

Tripping device

Thermal-magnetic device



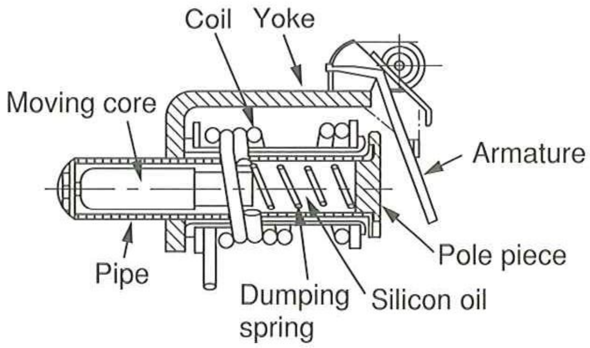
Time delay trip

The bimetal will warp in the direction of the arrow due to heating caused by over-current and it will activate the tripping mechanism and perform automatic tripping.

Instantaneous trip

If high fault current occurred the moving core is instantaneously attracted to the fixed core, the tripping device will be activated and automatic tripping is performed.

Full-magnetic tripping device



Time delay trip

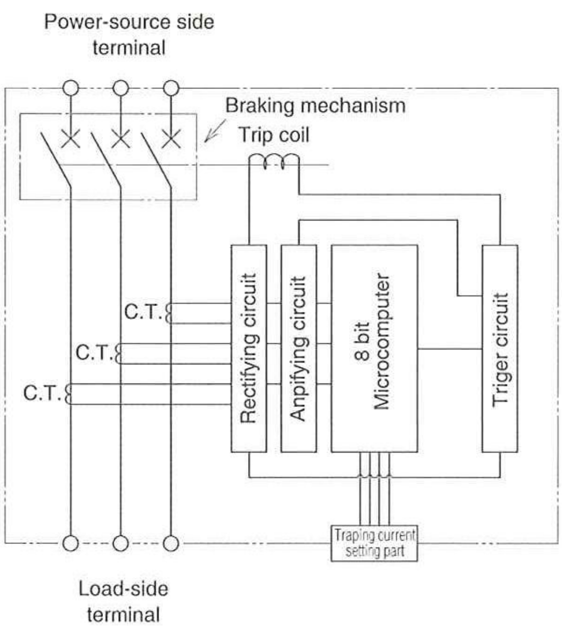
If over-current flows, the magnetic force of the coil overcomes the spring, the moving core closes to the pole piece, attracts the armature and actuates the trip bar.

The time delay occurred by silicon oil.

Instantaneous trip

If excessive current occurred the armature is instantly attracted without time delay caused by silicon oil.

Electronic type tripping unit



The load current transformed to small current with current transformers (C.T.s) provided each pole is monitored with the over current detective circuit.

If the load current is in excess of the rated current, long time delay, short time delay circuit or the instantaneous tripping circuit will be operated in accordance with the level of the load current, so that after the preset delay time, trigger circuit will energize the trip coil and the faulty circuit will be interrupted.

2. OVER CURRENT AND SHORT CIRCUIT

2.1 Over current characteristics and performance

2.1.1 Over-current tripping

Because of its tripping device with proper time delay characteristics, circuit breakers automatically open circuit for over-current up to about 800% of its ampere rating. For large short-circuit current, its instantaneous magnetic tripping device functions to break the circuit. These characteristics are specified in IEC60947-2 Low-voltage switchgear and control-gear in table 2.1.1, according to the table, HITACHI circuit breakers are designed. Tripping time of each rated current are shown in table 2.1.1.

Rated current (A)	Tripping time (minutes)		Non-tripping time (minutes)
	130%	200%	105%
30 or less	60	2	60
31 ~ 63	60	4	60
64 ~ 100	120	6	120
101 ~ 225	120	8	120
226 ~ 400	120	10	120
401 ~ 600	120	12	120
601 ~ 800	120	14	120
801 ~ 1000	120	16	120
1001 ~ 1200	120	18	120
1201 ~ 1600	120	20	120
1601 ~ 2000	120	22	120
2001 ~ 4000	120	24	120

Table 2.1.1 Over-current tripping time

2.1.2 Base ambient temperature

The tripping device of circuit breakers are adjusted in ambient temperature of 40°C.

2.1.3 Thermal magnetic type

If circuit breakers are used in the place whose temperature is different from 40°C, the operating current for tripping varies. It is necessary to compensate for the rated current according to the temperature compensation curve prepared for each frame. An example is shown in Fig 2.1.1. The rated current of the circuit breakers adjusted at the ambient temperature of 40°C and it is necessary to decrease the rated current to 90% at 50°C.

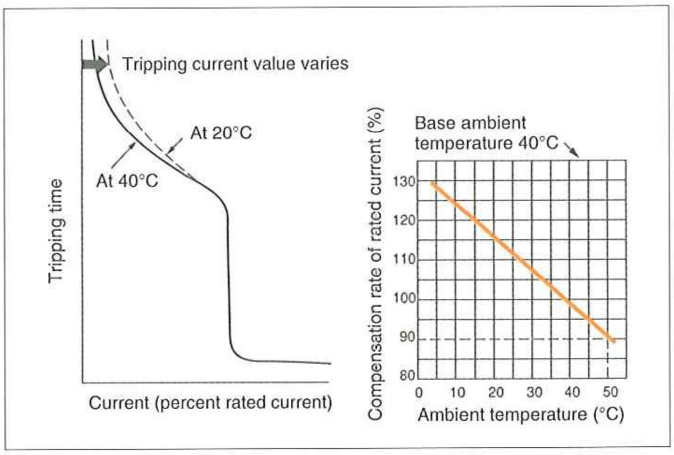


Fig. 2.1.1 Ambient temperature compensation curve for thermal-magnetic type

2.1.4 Full-magnetic type

The rated current of a full-magnetic type which has no thermal element will not be affected by variations in ambient temperature. Instead, the viscosity of the silicon oil in its pipe varies with temperature. Causing the operating time to change as shown in Fig. 2.1.2.

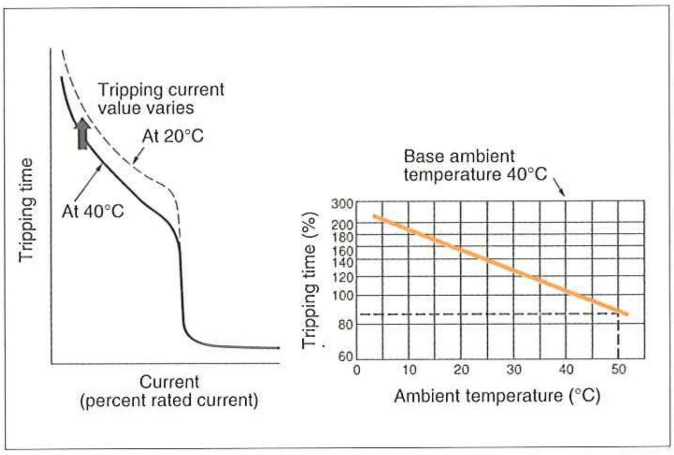


Fig. 2.1.2 Ambient temperature compensation curve for full-magnetic type

2.1.5 Maximum applicable temperature

Circuit breakers are applicable to ambient temperature up to 50°C. Application at the site whose ambient temperature exceeds 50°C is a special case, for which users are requested to contact HITACHI for advice.

2.2 Influence of mounting attitudes

Mounting circuit breakers is designed on the basis of vertical mounting as shown in the figure 2.2.1.

The thermal-magnetic type circuit breakers can be mounted in any attitude and it can even be mounted horizontally. The full full-magnetic type circuit breakers presents no problem even if it is inclined at any angles of less than 15 degree from vertical. If this angle of inclination is increased, however, its characteristics will varies due to the variety of gravitational effect to its moving core. If the thermal-magnetic type circuit breakers are equipped with under voltage trip or a shunt trip, it must confirm to the vertical mounting so that its ON side is top and its OFF side is below. If mounting in another attitude is inevitable, be sure to mention this fact to HITACHI when placing an order. Moreover, a sufficiently plane plate must be used.

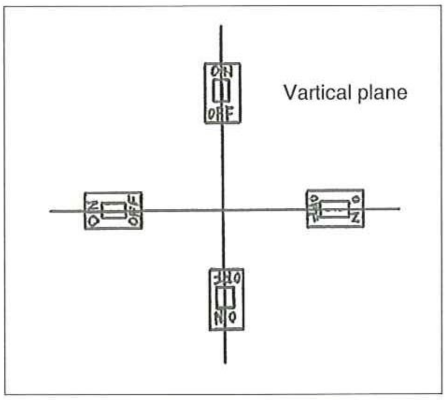


Fig. 2.2.1 Standard installation

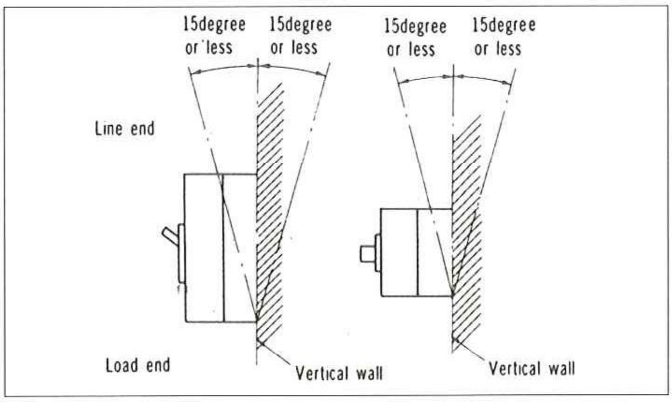


Fig. 2.2.2 Permissible inclination of full-magnet type

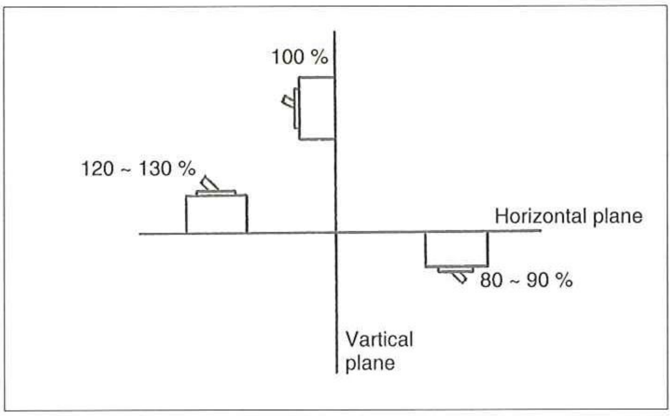


Fig. 2.2.3 Effect of non-vertical plane mounting on current rating of full-magnet type

2.3 Tripping characteristics in DC circuit of AC-rated circuit breakers

Type of trip device	Time delay trip	Instantaneous trip
Full-magnetic	DC minimum trip values are about 110 ~ 140% of AC values	DC instant tripping value is about 140% of AC
Thermal- magnetic	There is no effect up to 800A Above this, AC rated MCCB can not be used in DC circuit	

table. 2.3.1 Effect of DC current for AC-rated circuit breakers

2.4 Durability

Since the purpose of circuit breakers are to protect the distribution systems from trouble such as overload, short circuit and so on, so they are not suitable for operations performing frequent switching. For controlling such frequent switching operations, always be sure to use magnetic contactors or other available switches.

Rated current	Number of operation cycles per hour	Number of operation cycles		
		With out current	With current	Total
Up to 100A	120	8500	1500	10000
101 ~ 315	120	7000	1000	8000
316 ~ 630	60	4000	1000	5000
631 ~ 2500	20	2500	500	3000
2500 or more	10	1500	500	2000

Table 2.4.1 Operational capability in IEC60947-2

3. PROTECTIVE COORDINATION

3.1 Outline

Fig. 3.1.1 indicates a diagram of a typical low voltage distribution system.

The purposes of over current protect the distribution system from faults such as short circuit are to ensure high power distribution reliability and to make an economical protection system.

First consideration is whether an air circuit breaker or circuit breakers is most suitable and next is the type of system to be used. There are three types of system as follows;

- **Fully-rated system**
- **Discrimination coordination**
- **Cascade back up coordination**

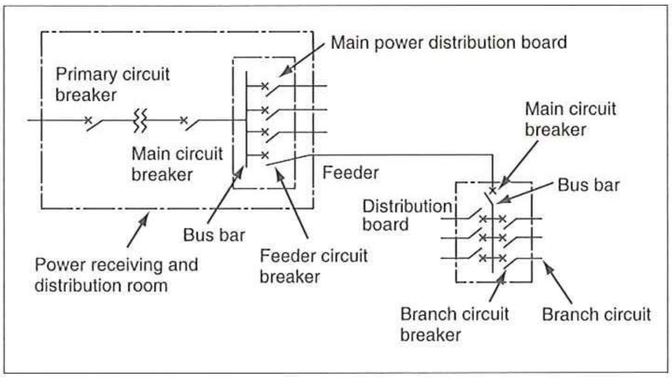


Fig. 3.1.1 Typical low voltage distribution system

Fully-rated system

This system is the most reliable. All of the breakers are rated for the maximum fault level at the point of their installation. The disadvantage is high performance may be necessary.

Discrimination coordination

Discrimination coordination 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 discrimination coordination of the main circuit breakers varies considerably depending on the breakers used.

Cascade back up coordination

This system is more economical breaking method. Only the upstream breakers have adequate breaking capacity for the maximum fault current. The downstream breakers cann't manage this maximum fault current and rely on the opening of the upstream breakers for protection. Advantage of this system is providing an economical system.

3.2 Breaking capacity

AC 230V

Frame (AF)

Transformer capacity (kVA)	~30	50~100	150	200~500				750~1500	2000~3000		
Interruping capacity kA (sym)	5	10	14	25	35	42	50	85	100	125	175
30	S-30E F-30FB										
50	F-50FC S-50SB	F-50C	F-50HB			F-50KB			L-50E		
60	S-60RB		F-60RB								
100	S-100EB		S-100S		S-100SB	F-100RB		F-100KB	L-100E		
225 (250)	S-225SB, SXK225					F-225FB F-225KC F-250R			L-225E		
400	SX400, S-400S							F-400R	FX400	L-400E	
600	S-600S						SX600	F-600F	FX600	L-600E	
800	SX800							F-800R S-800S	SX800	F-800R S-800S	L-800E
1000~1200	FX1000, FX1200, F-1000K, F-1200K										L-1000E
1600~4000	F-1600CB, F-1600B, F-2000E(130), F-2500E(130), F-3200CB, F-3200E, F-4000E										L-1200E

AC 415V

Frame (AF)

Transformer capacity (kVA)	~50		75~100		200~500			750~1500			1500~2000			2000~3000	
Interruping capacity kA (sym)	1.5	2.5	5	7.5	10	15	18	22	25	30	35	50	85	125	175
30	S-30E	F-30FB													
50	S-50EB	S-50SB	F-50FC		F-50HB	F-50KB							L-50E		
60	S-60RB			F-60RB											
100	S-100S, S-100SB					F-100RB				F-100KB			L-100E		
225 (250)	S-225SB, SXK225						F-225FB				F-225KC F-250R		L-225E		
400	SX400, S-400S									SX400		F-400R FX400	L-400E		
600	S-600S									SX600		F-600R FX600	L-600E		
800	SX800, S-800S											F-800R FX800	F-800RH F-800KB	L-800E	
1000~1200	FX1000, FX1200, F-1000K, F-1200K													L-1000B L-1200B	
1600~4000	F-1600CB, F-1600B, F-2000E, F-2500E, F-3200CB, F-3200E, F-4000E														

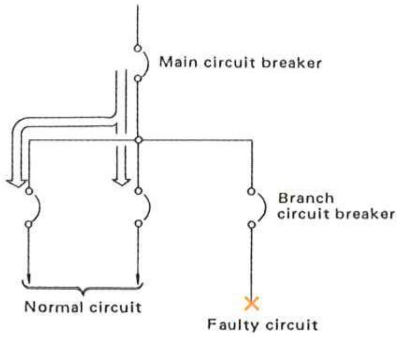
F Series (orange shading)

S Series (pale shading)

3.3 Discrimination coordination

In the discrimination coordination system, only the breakers nearest the fault point breaks to isolated faulty circuit from rest of the power system.

This system results in maximum continuity of power supply. Electronics type breakers are suitable for this system as the upstream breakers.



240V

For branch circuit Type \ For main circuit Type	Interrupting capacity (kA)	FX400	FX600	FX800	FX1000	FX1200	F-1600CB	F-2000E	F-2500E
Interrupting capacity (kA)		100	100	100	125	125	125	125	125
F-30FB	5	5	5	5	5	5	5	5	5
F-50FC	10	5	7.5	7.5	10	10	10	10	10
F-60RB	25	5	10	10	25	25	25	25	25
F-50HB	35	5	10	10	35	35	35	35	35
F-50KB	85	5	14	14	85	85	85	85	85
F-100RB	50	5	10	10	50	50	50	50	50
F-100KB	85	5	14	14	85	85	85	85	85
F-225FB, F-225KC, F-250R	85	4	10	10	35	35	65	85	85
F-400FB, FX400, F-400R	85	–	–	10	18	22	25	35	35
F-600F, FX600	85	–	–	–	–	22	25	35	35
F-800F, FX800, F-800R	85	–	–	–	–	–	25	35	35
FX1000	125	–	–	–	–	–	–	–	35
FX1200	125	–	–	–	–	–	–	–	35
S-30E, S-50EB, S-50SB	5	4	5	5	5	5	5	5	5
S-100EB, S-60RB	10	4	7.5	7.5	10	10	10	10	10
S-100SB	35	5	14	14	25	25	25	25	25
S-225SB, SXK225	35	4	10	10	25	25	25	25	25
SX400, S-400S	50	–	–	10	18	22	25	35	35
SX600, S-600S	50	–	–	–	–	22	25	35	35
SX800, S-800S	50	–	–	–	–	–	25	35	35
L-50E	175	5	14	14	125	125	125	125	125
L-100E	175	5	14	14	125	125	125	125	125
L-225E	175	4	10	10	42	65	125	125	125
L-400E	175	–	–	10	18	22	42	65	65
L-600E	175	–	–	–	–	22	42	65	65
L-800E	175	–	–	–	–	–	42	65	65

415V

For branch circuit Type \ For main circuit Type	Interrupting capacity (kA)	FX400	FX600	FX800	FX1000	FX1200	F-1600CB	F-2000E	F-2500E
Interrupting capacity (kA)		50	50	50	85	85	85	100	100
F-30FB	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
F-50FC	7.5	4	7.5	7.5	7.5	7.5	7.5	7.5	7.5
F-50HB, F-60RB	10	4	7.5	7.5	10	10	10	10	10
F-50KB	50	4	7.5	7.5	50	50	50	50	50
F-100FB, F-100RB	25	4	7.5	7.5	25	25	25	25	25
F-100KB	50	4	7.5	7.5	35	50	50	50	50
F-225FB	30	4	7.5	7.5	22	22	30	30	30
F-225KC, F-250R	50	4	7.5	7.5	22	22	30	50	50
FX400, F-400R	50	–	–	7.5	18	22	22	30	30
F-600F, FX600	50	–	–	–	–	22	22	30	30
FX800, F-800R	50	–	–	–	–	–	22	30	30
FX1000	85	–	–	–	–	–	–	–	30
FX1200	85	–	–	–	–	–	–	–	30
S-50SB	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
S-60RB	5	4	5	5	5	5	5	5	5
S-100S, S-100SB	10	4	7.5	7.5	10	10	10	10	10
S-225SB, SXK225	15	4	7.5	7.5	15	15	15	15	15
SX400, S-400S	35	–	–	7.5	22	22	22	30	30
SX600, S-600S	35	–	–	–	–	22	22	30	30
SX800, S-800S	35	–	–	–	–	–	22	30	30
L-50E	125	4	10	10	30	30	85	85	85
L-100E	125	4	10	10	30	30	85	85	85
L-225E	125	4	7.5	7.5	22	22	50	85	85
L-400E	125	–	–	7.5	18	22	22	30	30
L-600E	125	–	–	–	–	22	22	30	30
L-800E	125	–	–	–	–	–	22	30	30

3.4 Cascade back up coordination

Even if breaking capacity of branch breakers are less than faulty current, branch breakers can break the faulty current with back up of main breaker under the condition as follows;

1) Branch breakers should have the mechanical strength to withstand the peak let –through current
2) Branch breakers should with-stand the let-through I^2t
3) Branch breakers should with-stand the arc energy $\int v_2 \cdot i\,dt$

Various breaker-breakers or breaker-fuse combinations suitable for backup for have been reported. However, testing and other standards don't defined for backup protection at this point. Protective equipments combinations will have to be defined through uniform testing method and criteria in order to ensure proper backup protection with minimal confusion.

Appendix A in IEC60947-2 stipulates protection coordination standard for cascade systems.

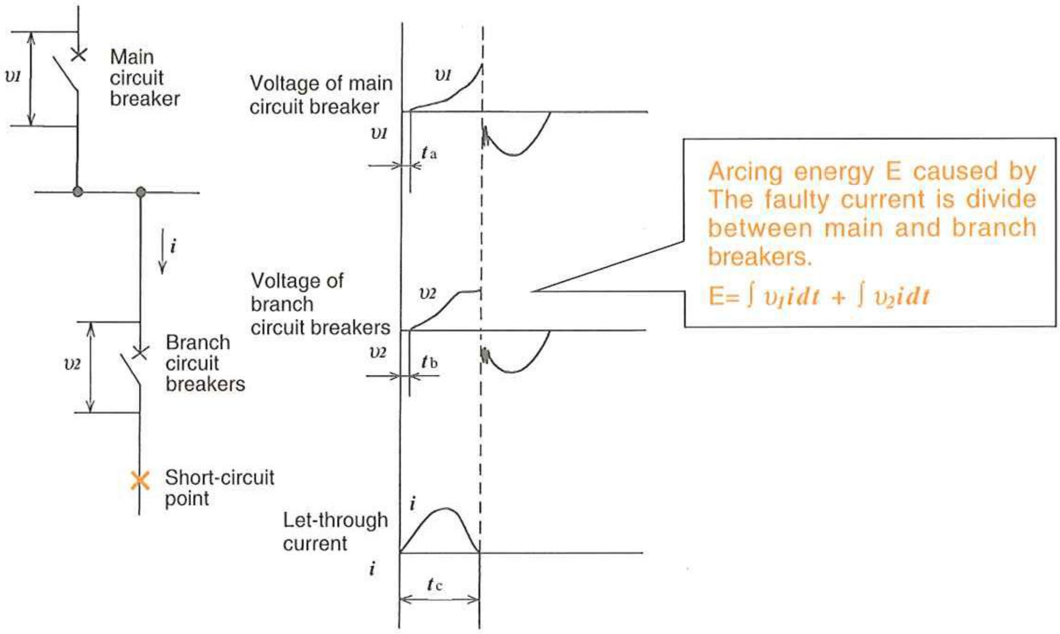


Fig.3.4.1 Cascade back up coordination

Table 3.4.2 Cascade back up coordination

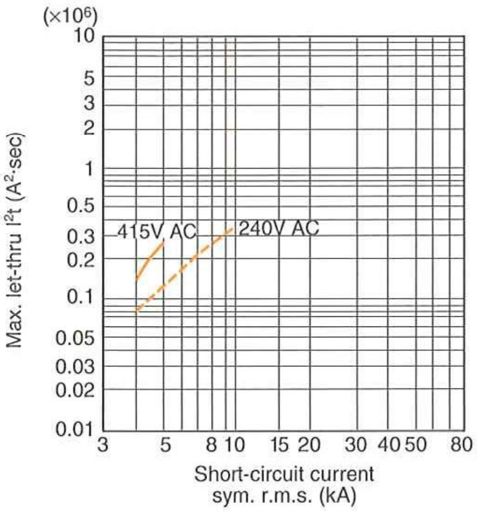
240V AC

Branch Breaker \ Main Breaker	Inter-rupting Capacity (kA)	F-100RB	F-100KB	L-100E	F-225FB F-225KC	L-225E	F-400R F-600F	FX400 FX800	L-400E	L-600E L-800E	F-800R	FX800	F-800RH	FX1000 F-1000C F-1000K FX1200 F-1200C F-1200K	F-1600CB F-1600B F-1600E F-2000E F-2500E F-3200E F-4000E
		50	85	175	85	175	85	100	175	175	85	100	125	125	125
F-30FB	5	42	42	42	7.5	7.5	7.5	7.5	7.5	5	5	5	5	5	5
S-50SB	5	42	42	42	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	5
S-60RB	10	42	85	85	42	42	42	42	42	42	42	42	42	10	10
F-60RB	25	42	85	85	85	85	85	85	85	85	85	85	85	42	25
F-50KB	85	–	85	85	85	85	85	85	85	85	85	85	85	85	85
S-100S S-100SB	22 30	–	–	–	85	85	85	85	85	85	85	85	85	42	42
F-100RB	50	–	–	–	85	85	85	85	85	85	85	85	85	50	50
F-100KB	85	–	–	–	85	85	85	85	85	85	85	85	85	85	85
S-225SB SXK225	35	–	–	–	–	–	42	42	42	42	42	42	42	35	35
F-225FB F-225KC	85	–	–	–	–	–	85	85	85	85	85	85	85	85	85
F-250R	85	–	–	–	–	–	85	85	85	85	85	85	85	85	85
S-400S SX400	50	–	–	–	–	–	85	85	85	85	85	85	85	50	50
F-400R	85	–	–	–	–	–	–	–	–	85	85	85	85	85	85
FX400	100	–	–	–	–	–	–	–	–	100	100	100	100	100	100
S-600S	42	–	–	–	–	–	–	–	–	85	85	85	85	85	85
SX600	50	–	–	–	–	–	–	–	–	85	85	85	85	85	85
F-600F	85	–	–	–	–	–	–	–	–	85	85	85	85	85	85
FX600	100	–	–	–	–	–	–	–	–	100	100	100	100	100	100

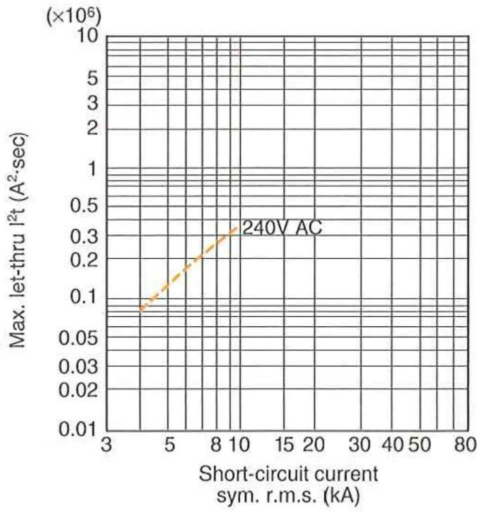
415V AC

Branch Breaker \ Main Breaker	Inter-rupting Capacity (kA)	F-100RB	F-100KB	L-100E	F-225FB	F-225KC	L-225E	FX400 F-400R FX600 F-600F	L-400E	L-600E L-800E	FX800 F-800R	F-800RH FX1000 F-1000C F-1000K FX1200 F-1200C F-1200K	F-1600CB F-1600B F-1600E F-2000E F-2500E F-3200E F-4000E
		25	50	125	30	50	125	50	125	125	50	85	85
F-60RB	10	18	18	85	10	10	10	10	10	10	10	10	10
F-50KB	50	–	50	85	50	50	65	50	50	50	50	50	50
S-100S S-100SB	10	–	–	–	10	10	10	10	10	10	10	10	10
F-100RB	25	–	–	–	25	42	65	25	25	25	25	25	25
F-100KB	50	–	–	–	–	50	65	50	85	85	50	50	50
S-225SB SXK225	15	–	–	–	–	–	–	15	15	15	15	15	15
F-225FB	30	–	–	–	–	–	–	30	85	85	30	30	30
F-225KC	50	–	–	–	–	–	–	50	85	85	50	50	50
SX400	36	–	–	–	–	–	–	36	42	42	42	42	42
F-400FB FX400	50	–	–	–	–	–	–	–	–	85	50	50	50
SX600	36	–	–	–	–	–	–	–	–	85	42	42	42
F-600F FX600	50	–	–	–	–	–	–	–	–	85	50	50	50

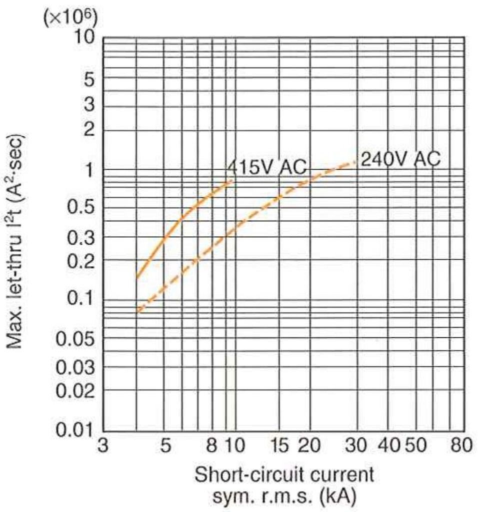
3.5 I²t let through



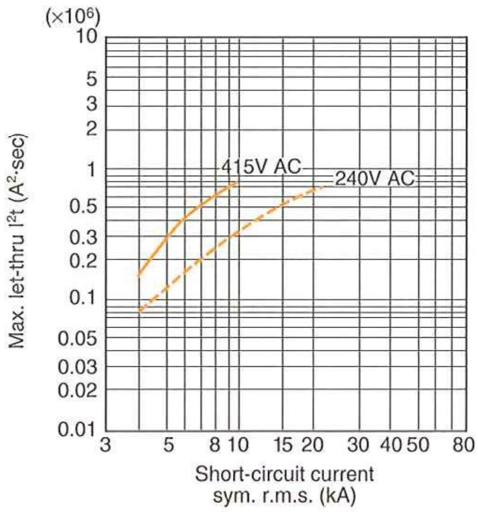
S-60RB



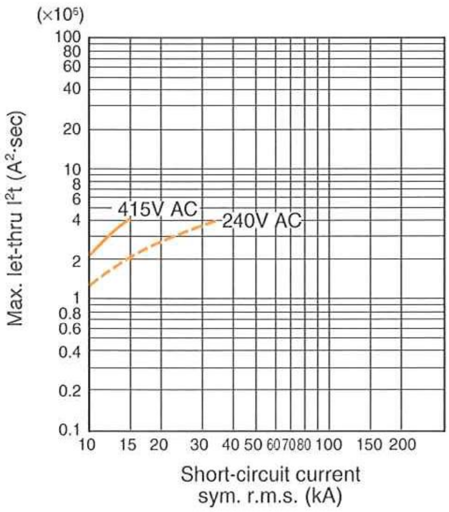
S-100EB



S-100SB

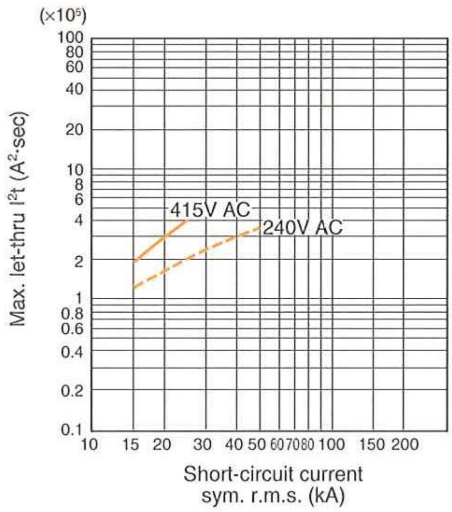


S-100S



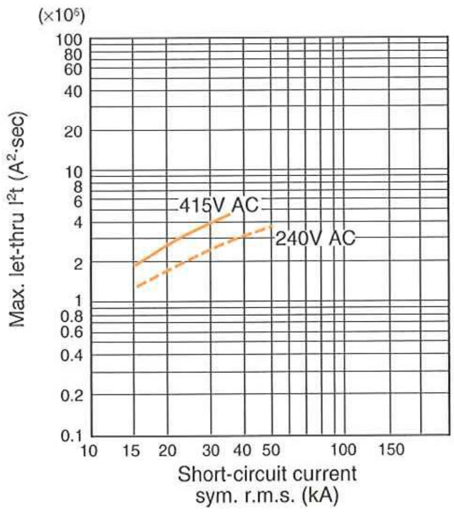
S-225SB

SXK225

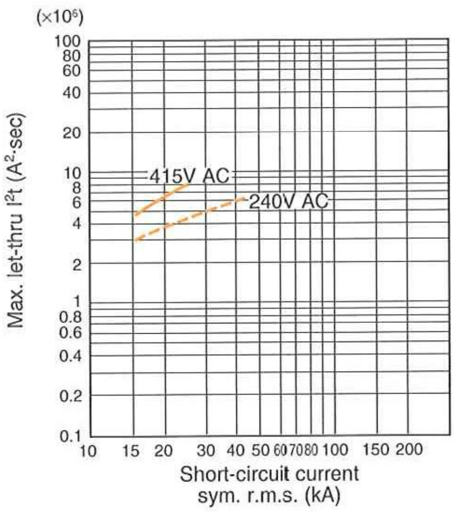


S-400S

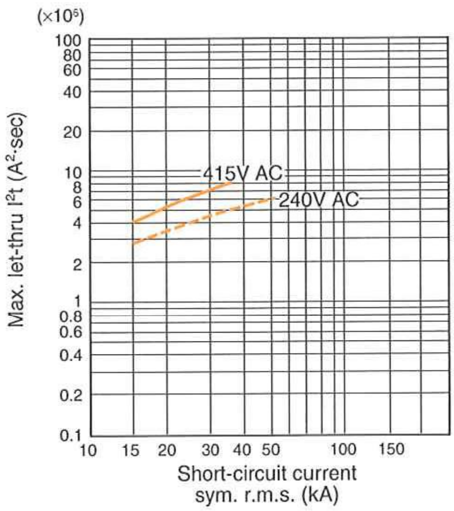
3.5 I²t let through (cont.)



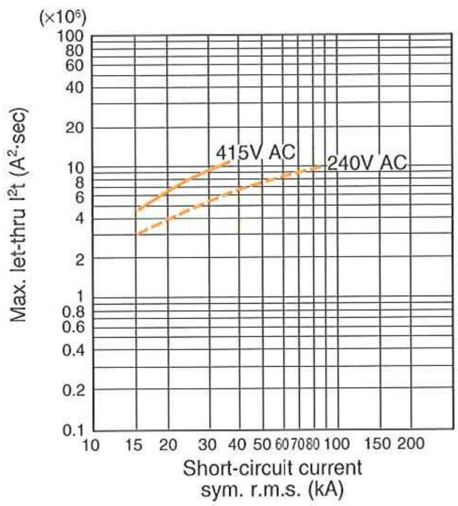
SX400



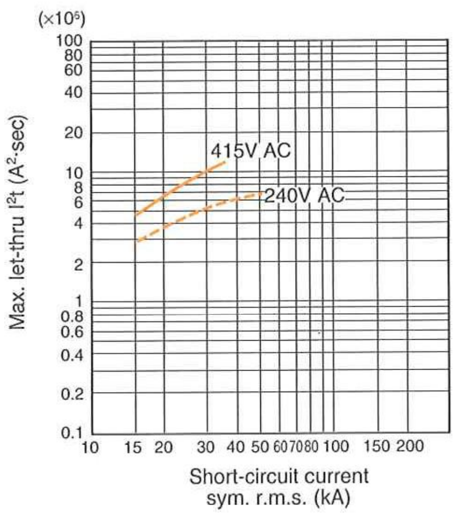
S-600S



SX600

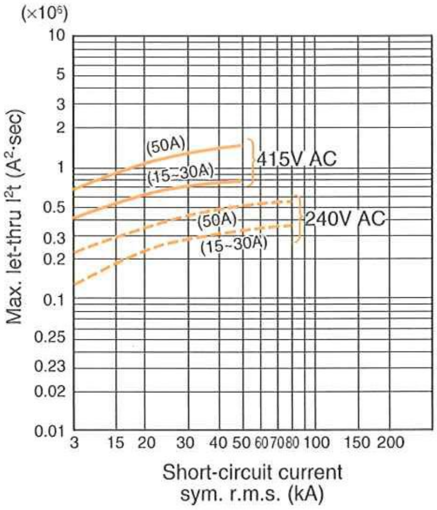


S-800S

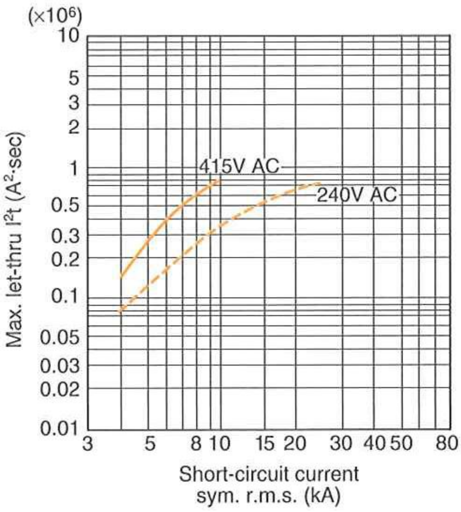


SX800

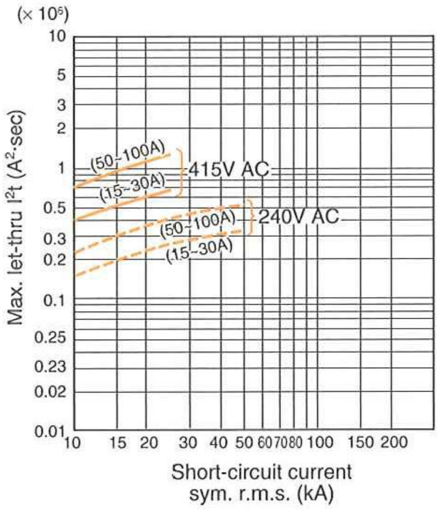
3.5 I²t let through (cont.)



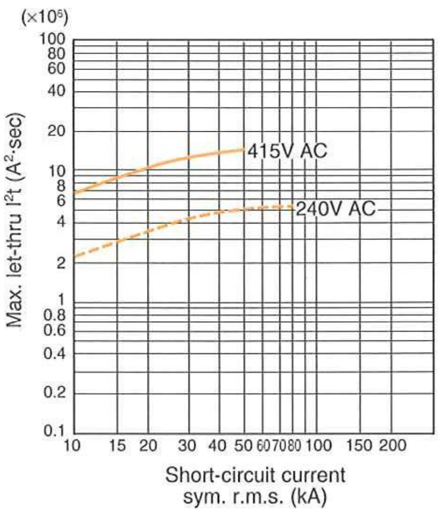
F-50KB



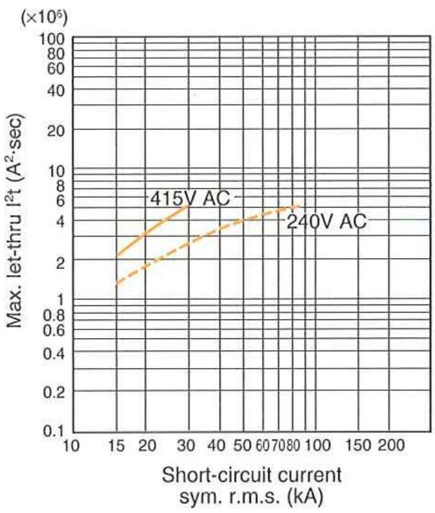
F-60RB



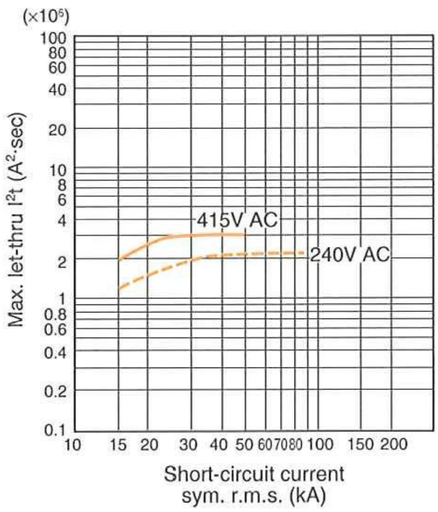
F-100RB



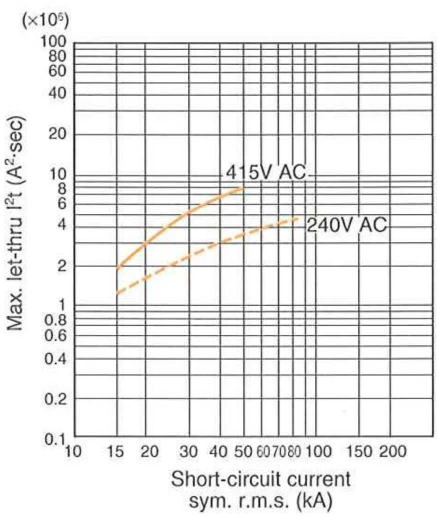
F-100KB



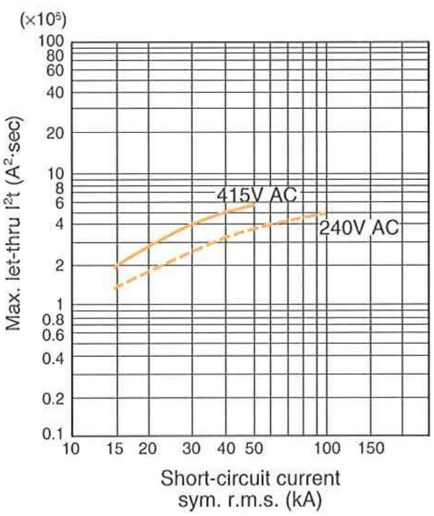
F-225FB



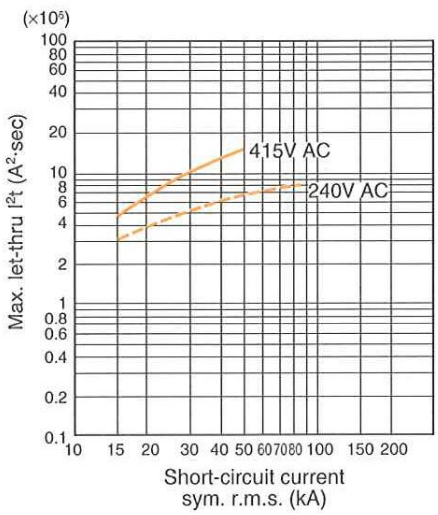
F-225KC



F-250R
F-400R

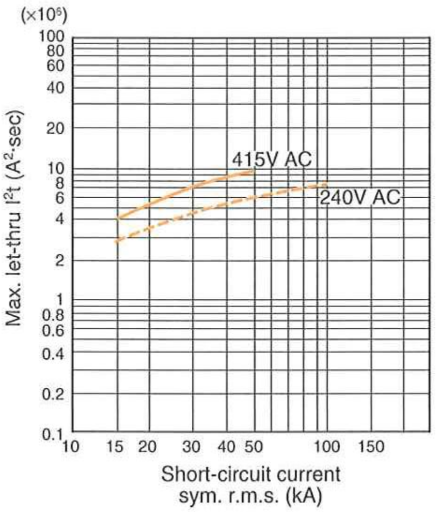


FX400

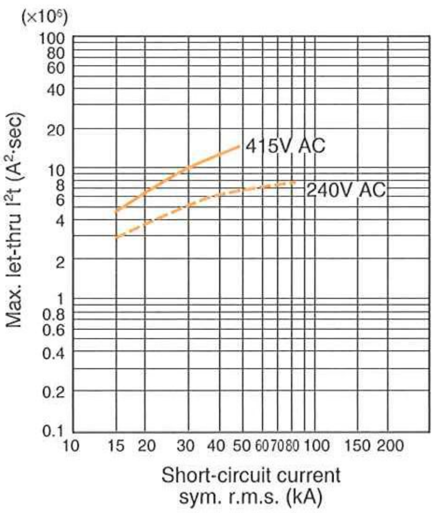


F-600F

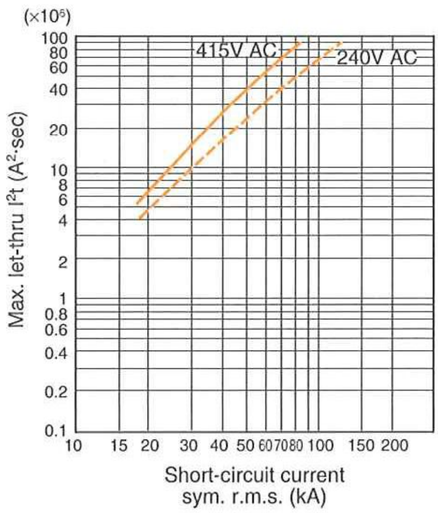
3.5 I²t let through (cont.)



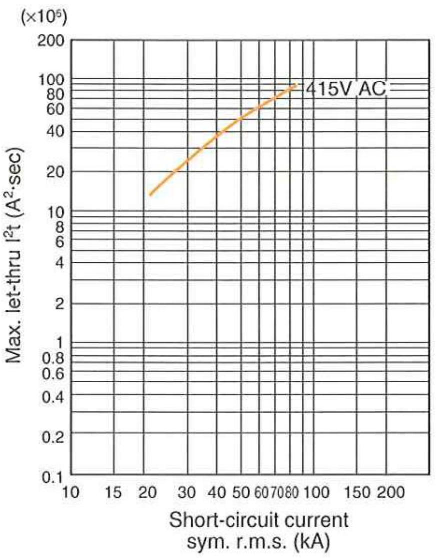
FX600



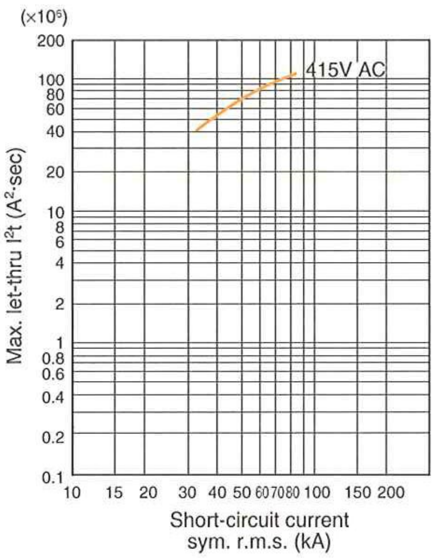
F-800R, F-800RH
FX800



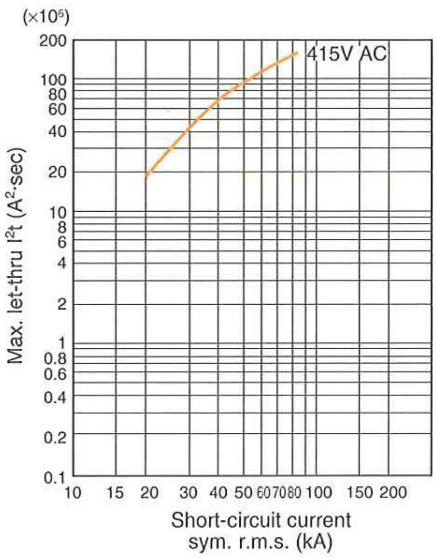
FX1000, F-1000C, F-1000K
FX1200, F-1200C, F-1200K
F-1600CB, F-1600B



F-1600E

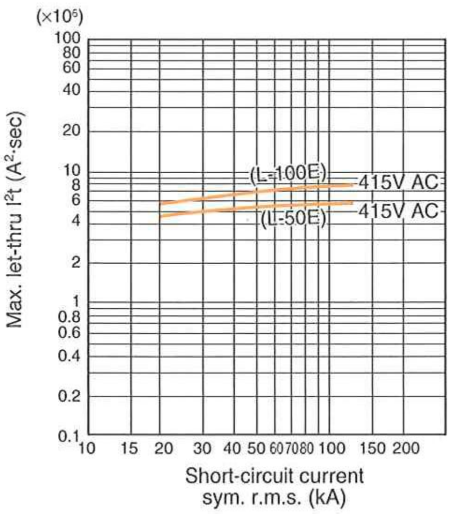


F-2000E
F-2500E

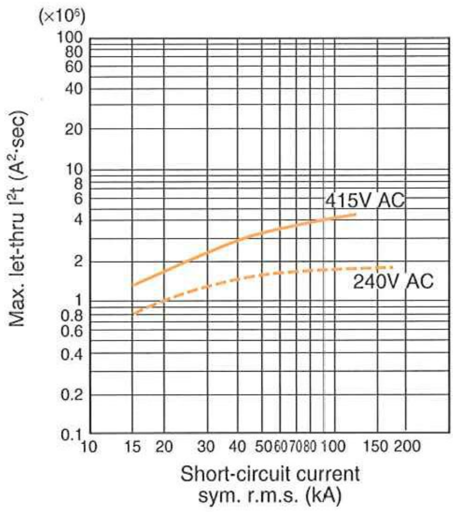


F-3200E
F-4000E

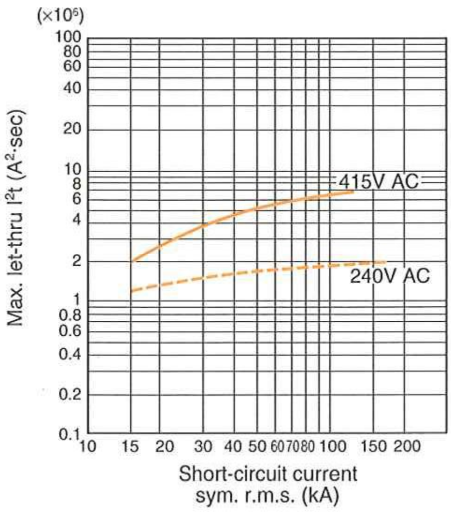
3.5 I^2t let through (cont.)



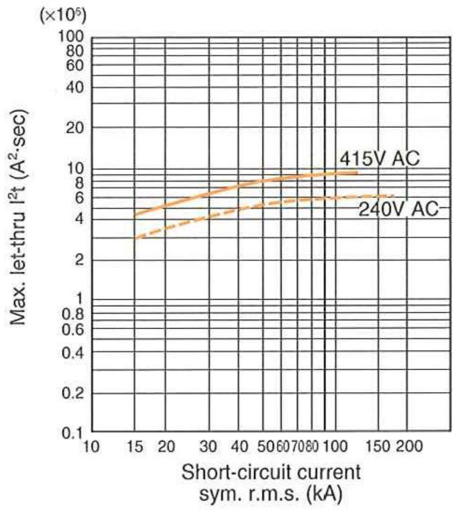
L-50E
L-100E



L-225E



L-400E



L-600E
L-800E

3.6 Selective trip coordination with Power Fuse

In case of PF S type of economical high–voltage power receiving system shown fig. 3.5.1 and power fuse are often used as protective device.

In this types of facilities, selective trip coordination must be maintained between the power fuse and the MCCB installed in the secondly circuit of transformer.

To established selective trip coordination between the power fuse and the circuit breakers the following condition must be satisfied;

> When permissible current-time characteristic curve of the power fuse is superimposed on the over current tripping characteristics curve MCCB shown Fig 3.5.2.
>
> In this case, it is necessary to convert the characteristic curve to low-voltage or the over current tripping characteristics of circuit breakers to high-voltage side and these curves must not be crossed.

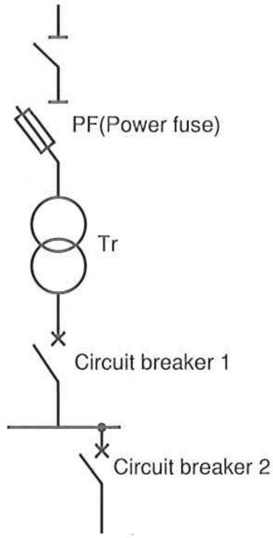


Fig. 3.5.1 PF·S type of economical high–voltage power receiving system

Fig. 3.5.2 shows the over current tripping characteristics curve of Circuit breaker converted high-voltage side.

Conversion to the high-voltage side is done by dividing the current in the over current tripping characteristics by the voltage ratio of the transformer.

In case, primary is 20kV, secondary is 400V and voltage ratio is 50.

Conversion to the low voltage side is done by multiplying the current value in the permissible current time characteristic curve of the power fuse by the same voltage ratio.

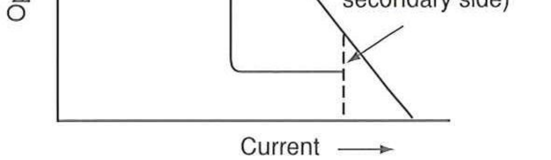


Fig 3.5.2 Selective trip coordination PF and circuit breakers

3.7 Protective coordination with wiring

The circuit breakers have to break fault current lower than permissible temperature value which is based on the kind of insulation material of wires but this permissible temperature value is limit of the current to prevent of worsening insulation material and it is not just only one value.

In case of short time, worsening of insulating materials of wires is very low even if temperature of conductor is very high.

And therefore, we have to consider about permissible temperature each region like continuous use, short time, short circuit.

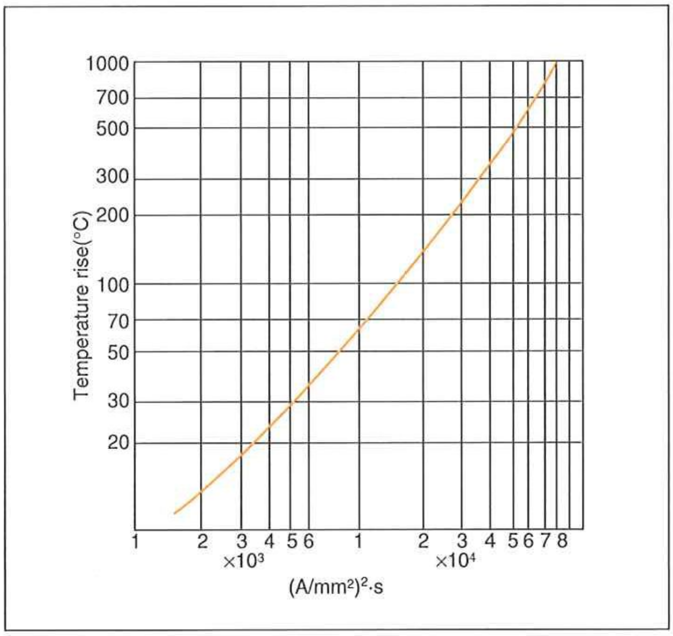


Fig. 3.7.1 temperature rise of cupper wires

3.7.1 Region of short circuit

If large current pass through the wire and assuming that generated heat dissipated in the wire, the following formula is formed;

(for cupper wires)

$$\left(\frac{I}{S}\right)^2 t = 5.05 \times 104 \log_e \frac{234 + T}{234 + To}$$

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)

And Fig 3.7.1 shows temperature rise of cupper wires

Assuming that short circuit occurs in a wire carrying its rated current(temperature To is 60°C)

If permissible temperature T is 150°C for insulation of wires,

Above formula is

$I^2t = 14000S^2$

Table 3.7.2 shows permissible I^2t by above formula.

The impedance of the wire and circuit breakers have effect in limiting the peak of the fault current and the value of let through I^2t, so have to consider impedance of them to determine the actual fault current flow

S Wire size mm²	Permissible I²t A² × s	Is Permissible short-circuit current according to I²t kA, sym. (PF)
1	0.014 × 10⁶	1.17 (0.9)
1.5	0.032 × 10⁶	1.76 (0.9)
2.5	0.088 × 10⁶	2.93 (0.9)
4	0.224 × 10⁶	4.68 (0.9)
6	0.504 × 10⁶	6.79 (0.9)
10	1.40 × 10⁶	10.5 (0.9)
16	3.58 × 10⁶	16.0 (0.9)
25	8.75 × 10⁶	17.3 (0.9)
35	17.2 × 10⁶	24.2 (0.9)
50	35.0 × 10⁶	34.5 (0.9)
70	68.6 × 10⁶	48.3 (0.9)
95	126 × 10⁶	65.6 (0.9)
120	202 × 10⁶	82.8 (0.9)
150	315 × 10⁶	103 (0.9)
185	479 × 10⁶	128 (0.9)
240	806 × 10⁶	166 (0.9)

Notes: 1. Permissible I²t 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. I²t an asym. value of permissible short circuit current reduced to below the permissible I²t, assuming half cycle interruption for 16mm² or less and one cycle interruotion 25mm² or more.

Fig. 3.7.2 Permissible fault current of cupper

3.7.2 Region of over current

There are various kind of criteria regarding relation of permissible time to temperature of vinyl-insulated wire.

Japanese Electrical Installation technical standard specify within several hours in condition 100°C. On the other hand, study by B.M. Jones and J.A Scot, which proposes about 20 seconds or more in condition 100°C.

In case of tripping time of time delay of circuit breakers, it can be considered permissible temperature is about 100°C. Relation between current and reaching time to 100°C of vinyl-insulated wire is shown in Fig 3.7.3.

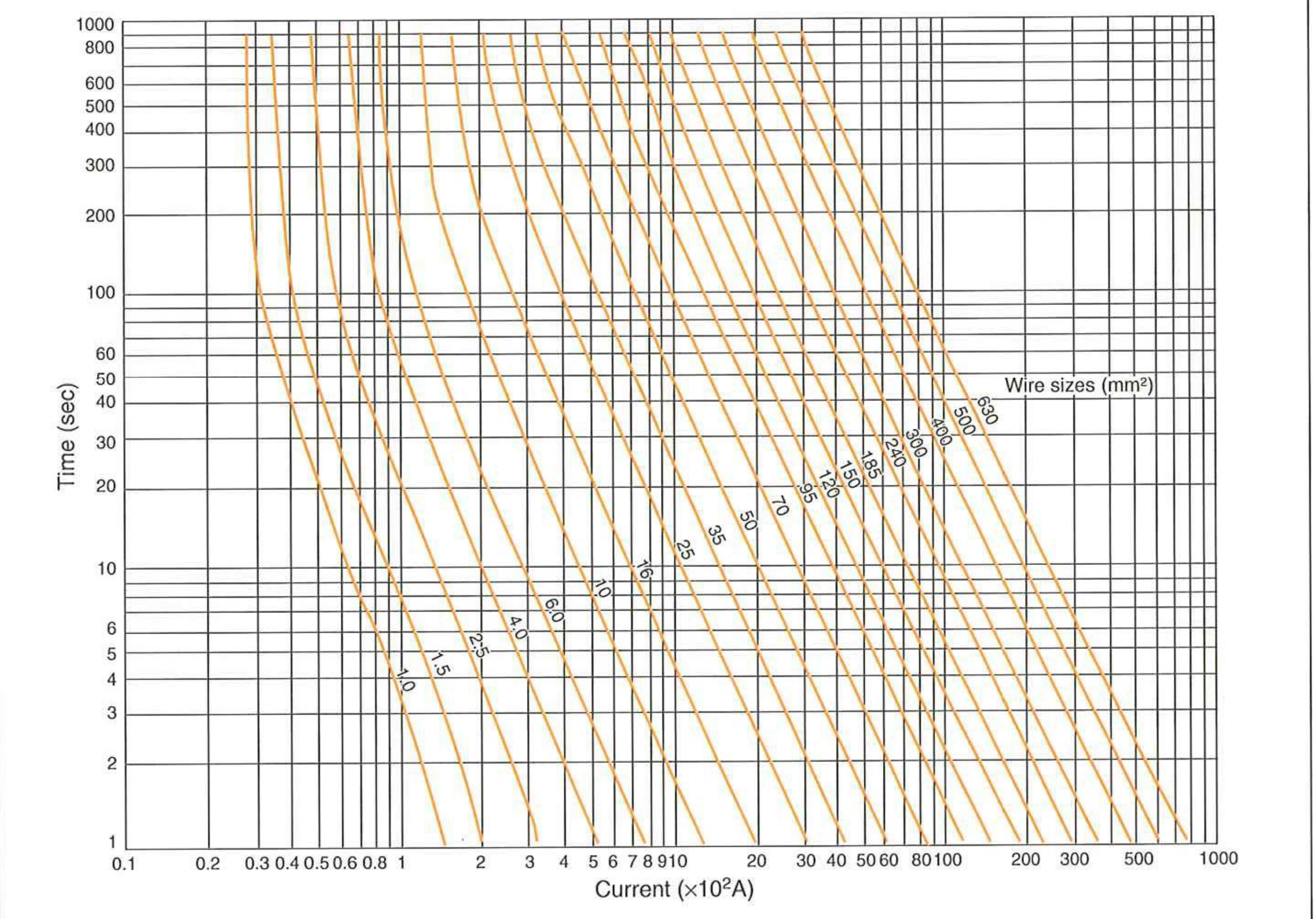


Fig. 3.7.3 Reaching time to 100°C of vinyl-insulated wire for 600V
(Starting conditions are 30°C, no load)

4. SELECTION AND APPLICATION

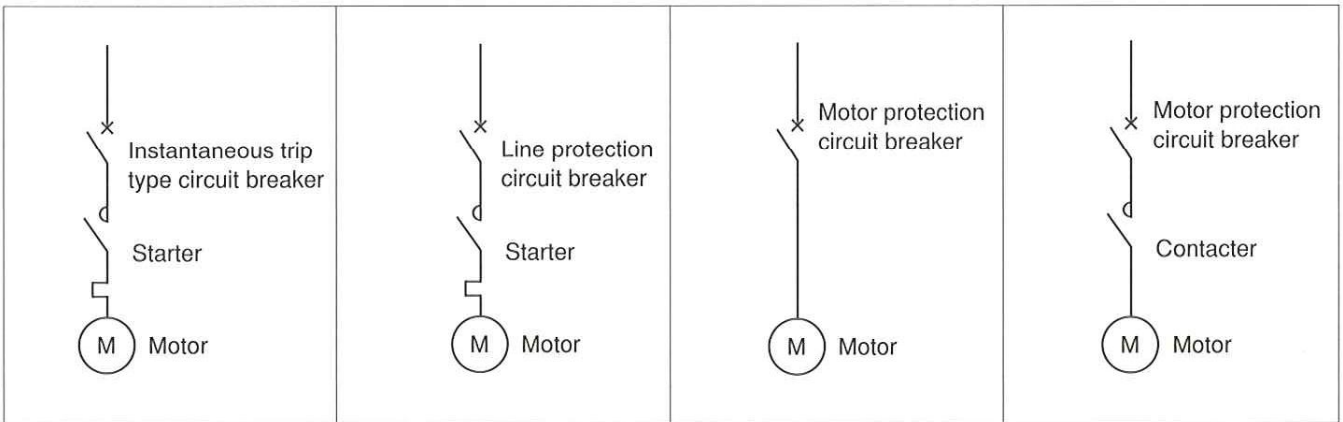
4.1 Motor branch circuit

4.1.1 General

The design of motor power supply circuits presents certain special features due to the special characteristics of motors.

- Heavy inrush current when start up motors
- Frequent start
- Special overload relay for motor protection

Over current protective devices are installed in motor circuits to protect the motor against over current and rocked rotor and to protect the wiring against over current protection. These protective devices must operate at or below current-time characteristics of the motor windings to reach the permissible temperature. Any of these protection formations stated in Fig 4.1.1 are selected by motor capacity, switching frequency, durability, short circuit capacity and so on.



General protective formation	Most general protective formation	Most economical protective formation	Economical protective formation
Instantaneous trip circuit breakers and starter join together and apply as a circuit breakers which has over current trip function.	Thermal relay will protect motor within the region up to the 8 times of rated current and circuit breakers will protect the region over the 8 times of rated current of circuit breaker.	In case of no required remote control and several times operation a day, breakers is also used as a motor starter, although it is not applicable if frequent operation are required.	In this combination, there is no thermal relay of the magnetic starter and protection of the motor is also performed by the relay of circuit breakers.

Fig. 4.1.1 Motor protection

4.1.2 Inrush current of motor starting

Fig 4.1.2 shows starting power factor of motors and Fig4.1.3 shows relation between starting power factor and overlap ratio of DC component.

For example, in case of 55kW induction motor, the starting power factor is 20% and Maximum asymmetrical effective value coefficient α is 1.23, so asymmetrical starting current is 1.23 times of symmetrical starting current, assuming that the starting current is 600%, the asymmetrical current is around 740%. If the starting current is 800%, the asymmetrical current is around 990%.

The applied circuit breakers instantaneous tripping current have to exceed the asymmetrical current in order to avoid nuisance trip (Area A of Fig. 4.1.4).

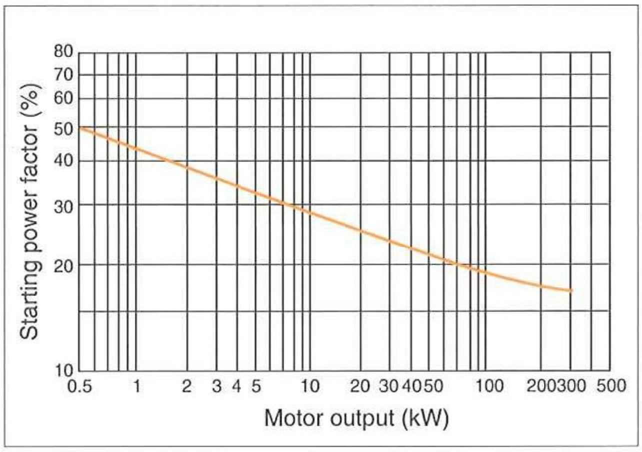


Fig. 4.1.2 Starting power factor of induction motor

4.1.3 Star-delta starter

In case of star-delta starters, when the starters change over from star to delta, higher voltage Vu appears as follows;

$$Vu = (1+1\sqrt{3}) \cdot V = 1.58V$$

V : rated voltage

And 1.58 times of starting current flow, therefore 1.23×1.58=1.94times of starting current flow in case of 55kW and star-delta starter, so circuit breakers whose instantaneous trip current must be higher than the inrush current described above.

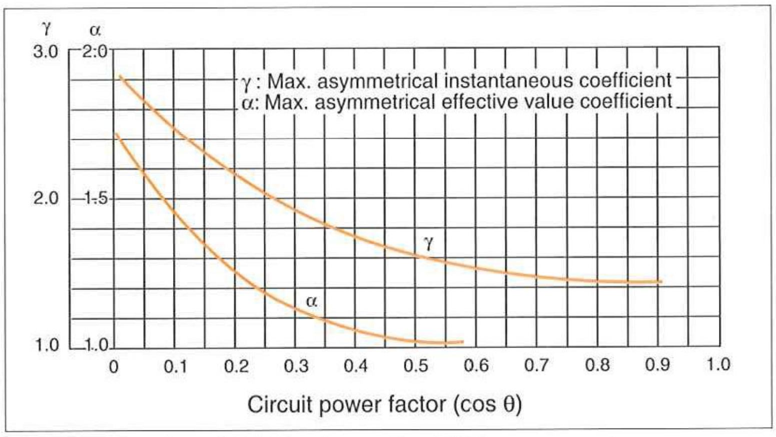


Fig. 4.1.3 Overlap ratio of DC component

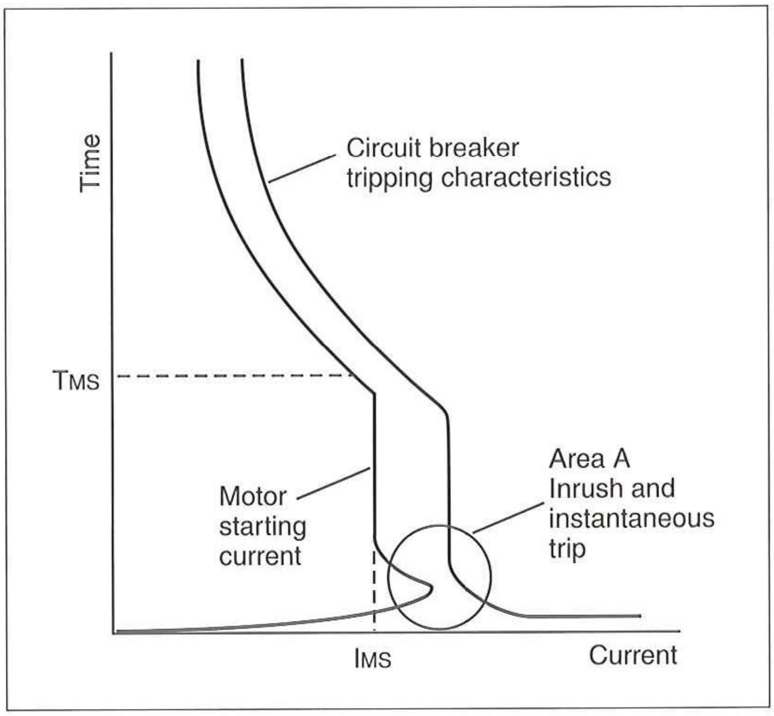


Fig. 4.1.4 Circuit breakers and motor starting

4.1.4 Selection of protect devices

(a) Motor protection with motor breakers

Motor breakers protect motor and wiring simultaneously (please see Fig 4.1.5).

These circuit breakers are applied to the motors whose permissible characteristics is higher than the tripping characteristics of circuit breakers.

In case of selection of motor breakers, it is necessary to be careful that suitable for the various character of motors and it is necessary to pay attention as follows;

- Installation the contactor in case of demanding high frequency operation of motors.
- Avoiding nuisance trip due to inrush current.

Fig 4.1.5 shows protection coordination curve of motor breakers, table 4.1.6 shows applicable motor breakers for 200-220V induction motors and table 4.1.7 shows applicable motor breakers for 400-440V induction motors.

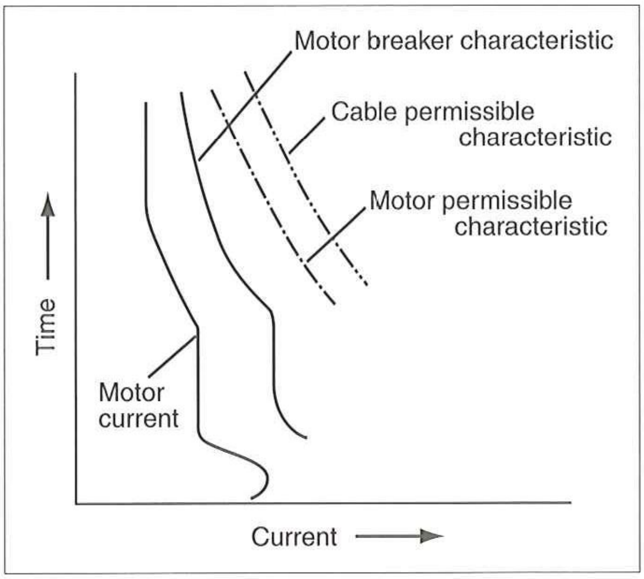


Fig. 4.1.5 Protection coordination of motor breakers

Table 4.1.6 Selection table for AC200-220V induction motors

200-220V AC

Motor capacity (kW)	Motor breaker		Motor capacity (kW)	Motor breaker	
	Rated current (A)	Type		Rated current (A)	Type
0.2	1.4	MS-30E	11	45	MS50EB, MS50SB
0.4	2.6		15	60	MS-100SB MF-100RB
0.75	4.2		18.5	75	
1.5	7.4		22	90	
2.2	10		30	(125)*	MS-225SB
3.7	16		37	(150)*	MF-225FB
5.5	25				
7.5	33				

Table 4.1.7 Selection table for AC400-440V induction motors

400-440V AC

Motor capacity (kW)	Motor breaker		Motor capacity (kW)	Motor breaker	
	Rated current (A)	Type		Rated current (A)	Type
0.2	0.7	MS-30E	11	25	MS-30E
0.4	1.4		15	33	MS-50EB
0.75	2.3		18.5	40	MF-50SB
1.5	4.2		22	45	
2.2	5.6		30	60	MS-100SB MF-100RB
3.7	9.0		37	75	
5.5	14		45	90	
7.5	16		50	(125)*	MS-225SB, MF-225FB

Notes: 1. Starting conditions are set within 3 seconds at 500% (2seconds at 600%) of full load for types MS-30E, MS-50EB, MS-50SB and within 8 seconds at 500% (5 seconds at 600%) of full load current for other types.

2. Specify the rated current since the figures with asterisks are the mere reference current.

(b) Motor protection with combination of circuit breakers and motor starters

These arrangement consist of circuit breakers and motor starters and circuit breakers protect short-circuit and motor starters protect over current. This is the most popular formation of the protect motor circuit.

If the motor is small capacity but short circuit is relatively large, such as Motor Control Center, instantaneous trip circuit breakers are used. This is because general circuit breakers are equipped bimetal elements as tripping devices, which have limited over current withstand values and may cause damage due to overheating incase of short circuit current.

Fig. 4.1.8 shows an example of a protection coordination curve of a motor circuit.

In case of combination of circuit breakers and motor starters, the basic rules for protection are as follows;

- The combined protection characteristics of circuit breakers and motor starters must protect against damages to motor and wiring.
- The circuit breakers don't trip in starting current or in current while the motor is running at the full load.
- The circuit breakers must be able to breaking short circuit currents.
- In case of overload, the motor starters must be operated before operated circuit breakers.
- The circuit breakers must protect the motor starters if more current flow than the motor starters can manage.

Even though the above requirements are satisfied and the circuit breakers interrupt, heating element of the thermal over load relay may be damage due to the overheating caused by the magnetic force or the energy of the short circuit current.

This means that it is impossible for the circuit breakers to provide perfect protection for motor starters by means of circuit breakers.

Therefore motor starters protection put into two types in IEC 60947-4-1 and table 4.1.9 shows protection types of motor starters.

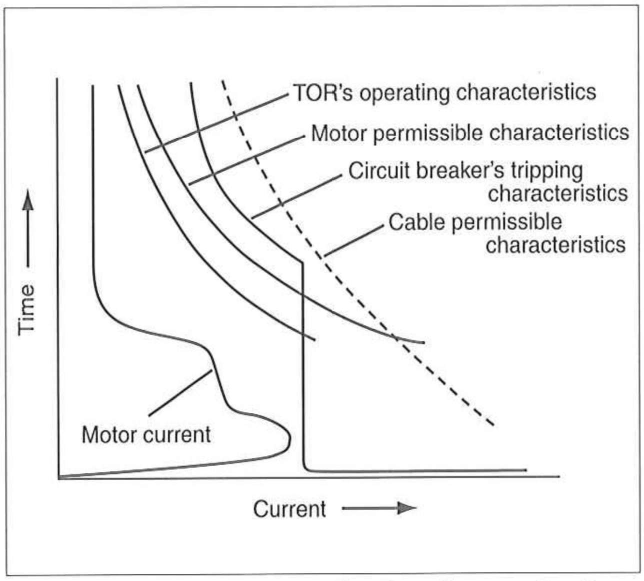


Fig 4.1.8 Protection coordination of motor circuit

Table 4.1.9 Protection types of motor starter

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 futher service without repair and replacement of parts.
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 futher 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.

4.1.5 Selection table for induction motors

(a) Direct Starting 3-phase Motors (380-415V AC)

<table>
<tr><th colspan="2">Motor</th><th colspan="2">Motor Starter</th><th colspan="13">Circuit Breakers</th></tr>
<tr><th rowspan="2">Capacity
(kW)</th><th rowspan="2">Full-load current
(A)</th><th rowspan="2">Type</th><th rowspan="2">TOR Rated current
(A)</th><th rowspan="2">Rated current
(A)</th><th colspan="12">Breaking Capacity (sym kA)</th></tr>
<tr><th>2.5</th><th>5</th><th>7.5</th><th>10</th><th>15</th><th>22</th><th>25</th><th>30</th><th>35</th><th>43</th><th>50</th><th>85</th></tr>
<tr><td>0.2</td><td>0.7</td><td>B) H8C-T
B) H10C-T
B) H11-T</td><td>0.6~1.0</td><td>15</td><td rowspan="8">F-30FB</td><td rowspan="11">S-60RB</td><td rowspan="11" colspan="2">F-60RB</td><td rowspan="9" colspan="7">F-50KB</td><td rowspan="9">L-50E</td></tr>
<tr><td>0.4</td><td>1.4</td><td>〃</td><td>0.9~1.5</td><td>15</td></tr>
<tr><td>0.75</td><td>2.3</td><td>〃</td><td>1.7~2.9</td><td>15</td></tr>
<tr><td>1.5</td><td>4.2</td><td>〃</td><td>2.8~4.4</td><td>15</td></tr>
<tr><td>2.2</td><td>5.6</td><td>〃</td><td>4~6</td><td>15</td></tr>
<tr><td>3.7</td><td>9.0</td><td>B) H10C-T
B) H11-T</td><td>7~11</td><td>20</td></tr>
<tr><td>5.5</td><td>14</td><td>B)H20-T</td><td>12~18</td><td>30</td></tr>
<tr><td>7.5</td><td>16</td><td>〃</td><td>〃</td><td>30</td></tr>
<tr><td>11</td><td>25</td><td>B)H25-T</td><td>16~24</td><td>50</td><td>S-50SB</td></tr>
<tr><td>15</td><td>33</td><td>B)H35-T</td><td>22~34</td><td>60</td><td rowspan="2"></td><td rowspan="5" colspan="3">F-100RB</td><td rowspan="5" colspan="4">F-100KB</td><td rowspan="5">L-100E</td></tr>
<tr><td>18.5</td><td>40</td><td>B)H50-T</td><td>32~48</td><td>60</td></tr>
<tr><td>22</td><td>45</td><td>〃</td><td>〃</td><td>75</td><td rowspan="3" colspan="4">S-100S
S-100SB</td></tr>
<tr><td>30</td><td>60</td><td>H65C-T</td><td>45~65</td><td>100</td></tr>
<tr><td>37</td><td>75</td><td>H80C-T</td><td>55~80</td><td>100</td></tr>
<tr><td>45</td><td>90</td><td>H100C-T</td><td>65~95</td><td>150</td><td rowspan="4" colspan="5">S-225SB
SXK225</td><td rowspan="4" colspan="3">F-225FB</td><td rowspan="4" colspan="3">F-225KC</td><td rowspan="4">L-225E</td></tr>
<tr><td>55</td><td>(110)</td><td>H125C-T</td><td>90~120</td><td>175</td></tr>
<tr><td>75</td><td>(150)</td><td>H150C-T</td><td>110~150</td><td>225</td></tr>
<tr><td>90</td><td>(180)</td><td>H200C-T</td><td>10~180</td><td>225</td></tr>
<tr><td>110</td><td>(220)</td><td>H250C-T</td><td>170~290</td><td>350</td><td colspan="6">S-400S</td><td colspan="3">SX400</td><td colspan="2">F-400R, FX400</td><td>L-400E</td></tr>
<tr><td>150</td><td>(300)</td><td>H300C-T</td><td>280~440</td><td>500</td><td rowspan="2" colspan="6">S-600S</td><td rowspan="2" colspan="3">SX600</td><td rowspan="2" colspan="2">F-600F
FX600</td><td rowspan="2">L-600E</td></tr>
<tr><td>190</td><td>(380)</td><td>H400C-T</td><td>〃</td><td>600</td></tr>
</table>

Note: (1) The starting conditions are set within 15 seconds at 500% (10seconds 600%) of full load current.

F Series

S Series

(b) Direct Starting 3-phase Motors (200-240V AC)

<table>
<tr><th colspan="2">Motor</th><th colspan="2">Motor Starter</th><th colspan="13">Circuit Breakers</th></tr>
<tr><th rowspan="2">Capacity
(kW)</th><th rowspan="2">Full-load current
(A)</th><th rowspan="2">Type</th><th rowspan="2">TOR Rated current
(A)</th><th rowspan="2">Rated current
(A)</th><th colspan="12">Breaking Capacity (sym kA)</th></tr>
<tr><th>2.5</th><th>5</th><th>7.5</th><th>10</th><th>15</th><th>22</th><th>25</th><th>30</th><th>35</th><th>43</th><th>50</th><th>85</th></tr>
<tr><td>0.2</td><td>0.7</td><td>B) H8C-T
B) H10C-T
B) H11-T</td><td>0.6~1.0</td><td>15</td><td colspan="2" rowspan="6">S-30E
F-30FB</td><td colspan="2" rowspan="8">S-60RB</td><td colspan="2" rowspan="8">F-60RB</td><td colspan="5" rowspan="7">F-50KB</td><td rowspan="7">L-50E</td></tr>
<tr><td>0.4</td><td>2.6</td><td>〃</td><td>1.7~2.9</td><td>15</td></tr>
<tr><td>0.75</td><td>4.2</td><td>〃</td><td>2.8~4.49</td><td>15</td></tr>
<tr><td>1.5</td><td>7.4</td><td>〃</td><td>5~8</td><td>15</td></tr>
<tr><td>2.2</td><td>10</td><td>〃</td><td>7~611</td><td>20</td></tr>
<tr><td>3.7</td><td>16</td><td>B) H20-T</td><td>12~18</td><td>30</td></tr>
<tr><td>5.5</td><td>25</td><td>B) H25-T</td><td>16~24</td><td>50</td><td colspan="2">S-50SB</td></tr>
<tr><td>7.5</td><td>33</td><td>B) H35-T</td><td>22~34</td><td>60</td><td colspan="2"></td><td rowspan="4">S-100SB</td><td colspan="3" rowspan="4">F-100RB</td><td rowspan="4">F-100KB</td><td rowspan="4">L-100E</td></tr>
<tr><td>11</td><td>45</td><td>B) H50-T</td><td>32~48</td><td>75</td><td colspan="4" rowspan="3">S-100EB</td><td colspan="2" rowspan="3">S-100S</td></tr>
<tr><td>15</td><td>60</td><td>H65C-T</td><td>45~65</td><td>100</td></tr>
<tr><td>8.5</td><td>75</td><td>H80C-T</td><td>55~80</td><td>100</td></tr>
<tr><td>22</td><td>90</td><td>H100C-T</td><td>65~95</td><td>150</td><td colspan="8" rowspan="4">S-225SB
SXK225</td><td colspan="3" rowspan="4">F-225FB
F-225KC</td><td rowspan="4">L-225E</td></tr>
<tr><td>30</td><td>(120)</td><td>H125C-T</td><td>90~120</td><td>200</td></tr>
<tr><td>37</td><td>(150)</td><td>H150C-T</td><td>110~150</td><td>225</td></tr>
<tr><td>45</td><td>(180)</td><td>H200C-T</td><td>110~180</td><td>225</td></tr>
<tr><td>55</td><td>(220)</td><td>H250C-T</td><td>170~290</td><td>350</td><td colspan="8" rowspan="2">S-400S</td><td colspan="2" rowspan="2">SX400</td><td rowspan="2">F-400R
FX400</td><td rowspan="2">L-400E</td></tr>
<tr><td>60</td><td>(240)</td><td>H250C-T</td><td>〃</td><td>400</td></tr>
<tr><td>75</td><td>(300)</td><td>H300C-T</td><td>200~400</td><td>500</td><td colspan="9" rowspan="2">S-600S</td><td rowspan="2">SX600</td><td rowspan="2">F-600F
FX600</td><td rowspan="2">L-600E</td></tr>
<tr><td>90</td><td>(360)</td><td>H400C-T</td><td>〃</td><td>600</td></tr>
</table>

Note: (1) The starting conditions are set within 15 seconds at 500% (10seconds 600%) of full load current.

(c) Y – △ Starting 3-phase Motor (380-415V AC)

Motor		Motor Starter		Circuit Breakers												
Capacity (kW)	Full-load current (A)	Type: Without enclosure	Type: With enclosure	Rated current (A)	Breaking Capacity (sym kA) 2.5	5	7.5	10	15	22	25	30	35	43	50	85
for a capacity of 15 kW or less, select the same breaker among those for direct-starting																
18.5	40	4Y-19	4SY-19	75												
22	45	4Y-22	4SY-22	75	S-100S				F-100RB		F-100KB					L-100E
30	60	4Y-30	4SY-30	10	S-100SB											
37	75	4Y-37	4SY-37	125												
45	90	4Y-45	4SY-45	150	S-225SB											
55	(110)	4Y-55	4SY-55	175	SXK225					F-225FB			F-225KC			L-225E
75	(150)	4Y-75	4SY-75	225												
90	(180)	4Y-90	4SY-90	350										F-400R		
110	(220)	4Y-110	4SY-110	400	S-400S						SX400			FX400		L-400E
150	(300)	–	–	600	S-600S						SX600			F-600F, FX600		L-600E
190	(380)	–	–	700	S-800S									FX800		L-800E

(d) Y – △ Starting 3-phase Motor (200-240V AC)

Motor		Motor Starter		Circuit Breakers												
Capacity (kW)	Full-load current (A)	Type: Without enclosure	Type: With enclosure	Rated current (A)	Breaking Capacity (sym kA) 2.5	5	7.5	10	15	25	30	35	50	85	125	175
for a capacity of 15 kW or less, select the same breaker among those for direct-starting																
18.5	75	Y-19	SY-19	125												
22	90	Y-22	SY-22	150	S-225SB						F-225FB					
30	(120)	Y-30	SY-30	200	SXK225						F-225KC				L-225E	
37	(150)	Y-37	SY-37	225												
45	(180)	Y-45	SY-45	350	S-400S									F-400R		
55	(220)	Y-55	SY-55	400	SX400									FX400	L-400E	
60	(240)	–	–	500	S-600S									F-600F		
75	(300)	Y-75	SY-75	600	SX600									FX600	L-600E	
90	(360)	–	–	700	S-800S, F-800R, FX800										F-800RH	L-800E

F Series | S Series

4.2 For lighting and heating branch

In case of resistance loads, it is not necessary to consider inrush current like motor circuits, so applied circuit breakers must be just suitable for permissible current of the wires.

It is necessary to consider regarding to margin between load currents of lighting, heating circuits and rated currents of Circuit breakers.

(1) As circuit breakers are adjusted in 40°C, reduce the load currents based on compensate curve if the temperatures in switchboard exceed 40°C.

(2) And furthermore, It is need margin of 10% due to fluctuation of power supply and so on.

4.3 For main circuit

4.3.1 For motor load

current of circuit breakers applied for main circuit of motor branch circuits are as follows;

(1) In case of sequential start

$$Ib = Ibmax + \sum I\ max$$

Ib: rated current of circuit breakers

Ibmax: maximum rated current of circuit breakers correspondence maximum motor which is selected in selection table

Imax: full load current of motor.

For example

$$Ib = 150 + (45+16+60) = 271(A)$$

Higher-nearest rated current of Ib must be selected, so the circuit breaker whose rated current is 300A will be applied.

(2) In case of simultaneous start

It is necessary to select circuit breakers regards total amount of capacities as one motor's capacity.

For example

Total amount of capacity is

$$22 + 11 + 3.7 + 15 = 51.7\ (kW)$$

and select 350A rating correspond to 55 (kW)

(Please refer to 4.1.5)

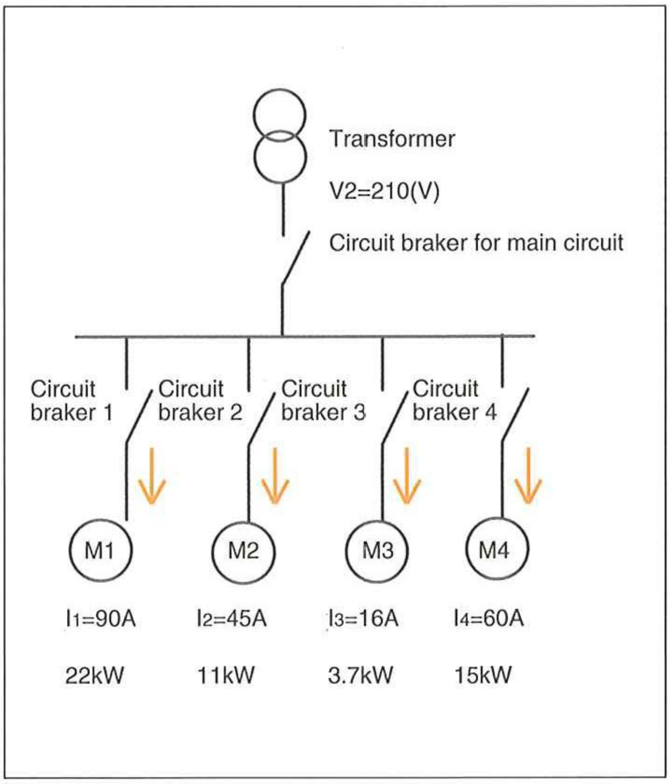


Fig. 4.3.1 Motor circuit

4.4 For welding circuit

4.4.1 Spot welders

Currents of spot welders are short and intermittent by switching primary side of transformers. The following point must be considered on circuit breakers selection.

(1) There are no nuisance trip caused by intermittent current, so it is necessary to calculate equivalent continuous current.

(2) There are no nuisance trip of instantaneous caused by transient surge in primary side of the transformer.

To convert the welder intermittent current into thermal-equivalent continuous value Ie, consider the current waveform which is shown Fig 4.4.2.

$Ie = Ip \times \sqrt{u}$

Ie: thermal-equivalent continuous value

Ip: current value

u: duty factor defined as

u = total conducted time/ total time

In case of Fig. 4.4.2

$Ie = 1000 \times \sqrt{(3/(3+45))} = 250A$

In practice the instantaneous temperature will fluctuate and maximum value of it is greater than the average temperature caused by Ie and power supply fluctuates, so it is necessary to leave a margin around 15%. Therefore rated currents of circuit breakers Ib are as follows;

$Ib=1.15 \times Ie = 1.15 \times 250 = 288A$

Selected circuit breakers will be the nearest rated current value above 288A.

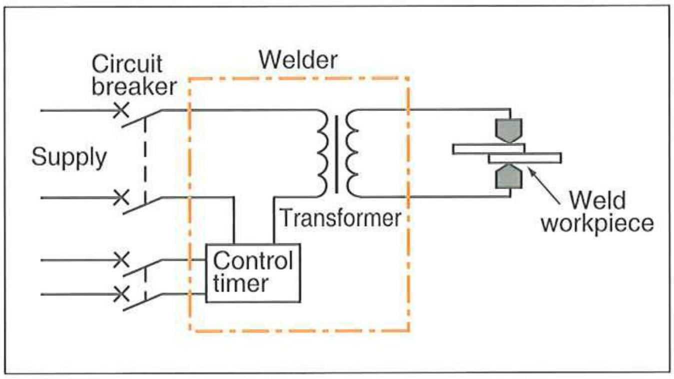


Figure 4.4.1 Internal circuit of spot welder

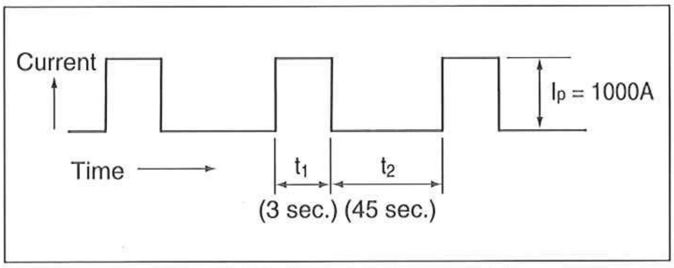


Figure 4.4.2 Current of spot welder

Transient surge

If circuit breakers close the primary side of transformer, transient current flows which is larger than regular currents.

Fortunately, recent welders are equipped synchronous making circuit system, so peak values of transient surges of primary circuit Imax are less than following value.

$Imax = VAmax / V \times 1.3$

VAmax: maximum input (VA)

V: rated voltage

1.3 : margin

-------------------------------- Example --------------------------------

Selection of circuit breakers for following spot welder.

Specifications (1) Rated current: 400V AC
(2) Rated capacity: 75kVA
(3) maximum input: 219kVA
(4) duty factor: 0.5

Equivalent continuous current

$Ie = Ip \times \sqrt{u} = 75000/400 \times \sqrt{0.5} = 133$ (A)

$Ib = 1.15 \times Ie = 153$ (A)

Transient inrush current peak value

$Imax = 2 \times 219000/400 \times 1.3 = 1424$ (A peak)

Instantaneous trip value Ii are shown in catalogs of our circuit breakers as r.m.s, so

$Ii = Imax / \sqrt{2} = 1007$ (A)

As a result of this calculations,

The selected MCCB will be 175 A

4.5 For transformer-primary use

4.5.1 Excitation surge current

If power supply is connected transformers, excitation surge current may be flow sometimes and its peak value exceed 10times as large as rated current sometimes and it may occur nuisance trip of circuit breakers.

The excitation surge current values are depends on making timing of making circuit and the magnitude of residual magnetism and so on.

If making circuit point is zero volt of power supply, maximum excitation surge current occurs.

After 1/2 cycle following switch on the core flex will reach the sum of the residual flex Φre plus the switching surge flex $2\Phi m$.

The total $2\Phi m + \Phi re$ is far bigger than saturation value of iron core of transformers and excitation surge current will flow.

As it is the instantaneous trip function of the circuit breakers that respond to the transient current, thermal-magnetic types circuit breakers ,which can more easily be made to handle high instantaneous trip currents, are advantageous over full-magnetic circuit breakers, which the instantaneous trip currents are relatively small multiple of the rated current.

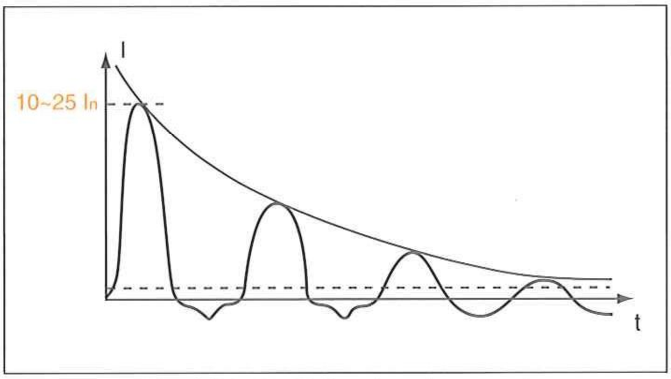


Fig. 4.5.1 Excitation inrush current

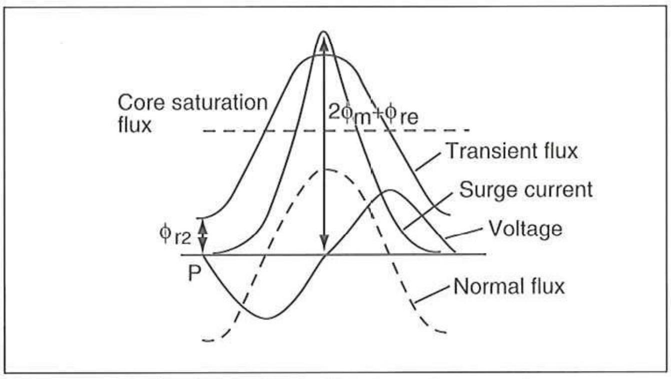


Fig. 4.5.2 Excitation inrush current

4.5.2 Selecting Circuit breakers

Selecting MCCBs

In case of 420V AC 3-phase 75kVA
Rated r.m.s current of the transformer I is

$I = \text{Capacity} / \sqrt{3}\,\text{voltage} = 75000/\sqrt{3} \times 420 = 103\ (A)$

The excitation surge current peak value Ip is maxmum 20 times rated current

$Ip = 20 \times \sqrt{3} \times I = 2913\ (A)$

The minimum instantaneous trip peak value of 225AF Ii is

$Ii = \sqrt{2} \times 225 \times 10 = 3182\ (A)$

Ii exceeds Ip, so 225AF can be applied this transformer.
Selecting circuit breakers above-mentioned way are shown in table 4.5.2 and it is necessary to decide the breaking capacity in the 1circuits.

Table 4.5.2 Circuit breakers for primary of transformer

Transformer Capacities and Primary-Side circuit breakers

Tran.	Type of circuit breakers (rated current (A))			
(kVA)	1-phase 240V	1-phase 415V	3-phase 240V	3-phase 415V
5	S-225SB (125A) SXK225 (125A) F-225FB (125A) F-225KC (125A)	S-100S (75A) S-100SB (75A) F-100RB (75A)	S-100S (75A) S-100SB (75A) F-100RB (75A)	S-50SB (50A) S-60RB (50A)
7.5	F-225FB (125A) F-225KC (125A)	S-225SB (125A) SXK225 (125A) F-225FB (125A) F-225KC (125A)	S-100S (100A) S-100SB (100A) F-100RB (100A)	S-50SB (50A) S-60RB (50A)
10	S-225SB (175A) SXK225 (175A) F-225FB (150A) F-225KC (150A)	S-225SB (150A) SXK225 (150A) F-225FB (125A) F-225KC (125A)	S-225SB (125A) SXK225 (125A) F-225FB (125A) F-225KC (125A)	S-100S (75A) S-100SB (75A) F-100RB (75A)
15	F-225FB (225A) F-225KC (225A) SX400 (200A) FX400 (200A)	S-225SB (175A) SXK225 (175A) F-225FB (150A) F-225KC (150A)	S-225SB (150A) SXK225 (150A) F-225FB (125A) F-225KC (125A)	S-225SB (125A) SXK225 (125A) F-225FB (125A) F-225KC (125A)
20	SX400 (200A) FX400 (200A)	S-225SB (175A) SXK225 (175A) F-225FB (150A) F-225KC (150A)	S-225SB (175A) SXK225 (175A) F-225FB (150A) F-225KC (150A)	S-225SB (125A) SXK225 (125A) F-225FB (125A) F-225KC (125A)
30	SX400 (200A) FX400 (200A)	S-225SB (225A) SXK225 (225A) F-225FB (200A) F-225KC (200A)	F-225FB (225A) F-225KC (225A) SX400 (200A) FX400 (200A)	S-225SB (175A) SXK225 (175A) F-225FB (150A) F-225KC (150A)
50	SX600 (300A) FX600 (300A)	SX400 (200A) FX400 (200A)	SX400 (200A) FX400 (200A)	F-225FB (225A) F-225KC (225A) SX400 (200A) FX400 (200A)
75	FX1000 (500A)	SX600 (300A) FX600 (300A)	SX600 (300A) FX600 (300A)	SX400 (200A) FX400 (200A)
100	FX1000 (600A)	FX1000 (500A)	SX600 (400A) FX600 (400A)	SX400 (200A) FX400 (200A)
150	FX1200 (800A)	FX1000 (500A)	FX1000 (500A)	SX600 (300A) FX600 (300A)
200	F-1600CB (1200A)	FX1000 (600A)	FX1000 (700A)	SX600 (400A) FX600 (400A)
300	–	FX1200 (800A)	F-1600CB (1000A)	FX1000 (600A)
500	–	F-2500E (1400A)	–	FX1000 (800A)

4.6 Selecting for DC system

The tripping characteristics of circuit breakers adjusted for AC circuits are not be the same in a DC circuit, so use circuit breakers adjusted for DC circuit.

Breaking circuit is harder in DC circuits than in AC circuits because there is no zero crossing point in DC circuit. The circuit voltage with 2 poles connected in series up to 250VDC, but be sure to use 3 poles or 3 poles connected in series if the circuit voltage is higher than 250VDC.

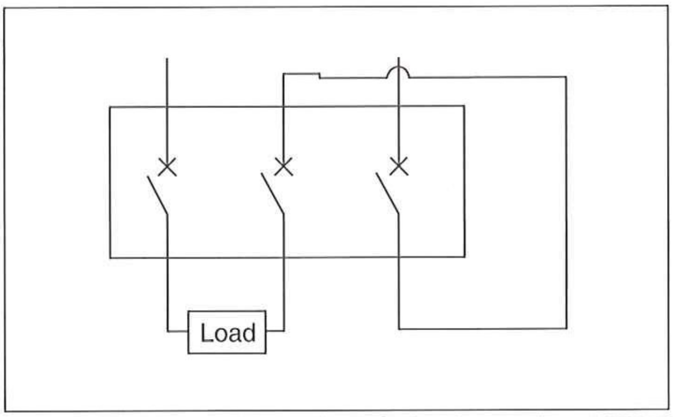


Fig 4.6.1 Connecting diagram for DC circuit over than 250V DC

Table 4.6.1 Circuit breakers for 125VDC and 250VDC circuit

Tripping device	Types of circuit breakers	DC load application	Ui	Icu (kA)	
				125V DC	250V DC
Full-magnetic	F-30FB	Specially designed circuit breakers is required (standard type circuit breakers cannot be used).	250V DC	5	2.5
	S-50SB			5	2.5
	F-50KB			40	40
	S-60RB			5	2.5
	F-60RB			7.5	5
	S-100EB			5	2.5
	S-100S			7.5	5
	S-100SB			7.5	5
	F-100KB			40	40
Thermal-magnetic	S-225SB	Standard type circuit breakers can be used.	250V DC	15	10
	SXK225			15	10
	F-225FB			25	25
	F-225KC			40	40
	F-250R			40	40
	S-400S			25	25
	F-400R			40	40
	S-600S			40	40
	F-600F			40	40
	S-800S			40	40
	F-800R			40	40
Instantaneous trip type	F-1000K	Specially designed circuit breakers is required (standard type circuit breakers cannot be used).	250V DC	40	40
	F-1200K			40	40

Notes: * The time constant is 10ms or less.

Table 4.6.2 Circuit breakers for 350VDC and 500VDC circuit

Tripping device	Types of circuit breakers	DC load application	Ui	Icu (kA)
Full-magnetic	F-60RB	Specially designed circuit breakers is required (standard type circuit breakers cannot be used).	350V DC	2.5
	S-100SB			2.5
	F-50KB		500V DC	10
	F-100KB			10
Thermal-magnetic	F-225KC	Specially designed circuit breakers is required (standard type circuit breakers cannot be used).	500V DC	20
	F-250R			20
	F-400R			20
	F-600F			20
	F-800R			20
Instantaneous trip type	F-1000K	Specially designed circuit breakers is required (standard type circuit breakers cannot be used).	500V DC	20
	F-1200K			20

Notes: The time constant is 10ms or less.

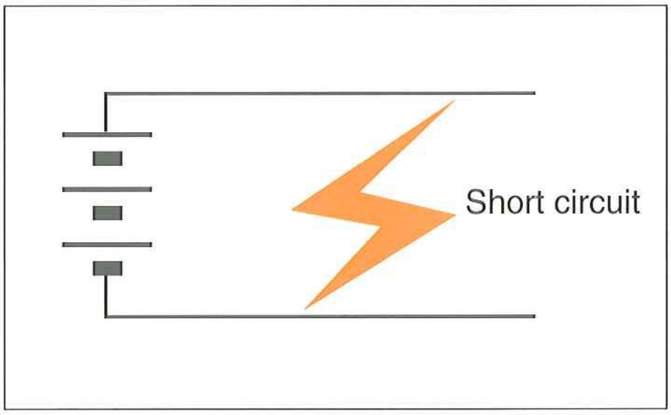
4.7 Calculation the short circuit current of batteries

If short circuit occurs in batteries, the batteries discharge currents I are given by following;

$I = Vb/Ri$

Vb: maximum discharge voltage

Ri : Internal resistance of batteries



What is the short circuit current of the battery with following characteristics

Capacity = 500 (Ah)

Discharge voltage = 230 (V)

Number of cells = 115 cells

Internal resistance = 0.5 (mΩ/cell)

$Ri = 115 \times 0.5 \times 10^{-3} = 57.5 \times 10^{-3}$

$I = 230/57.5 \times 10^{-3} = 4kA$

4.8 Selecting for 400Hz circuit

Tripping characteristics is influenced by high frequency of the circuit. The magnitude of the influence depends on the types of tripping device.

(1) Full-magnetic type

The temperature of full-magnetic tripping device will extremely increase and due to iron loss of the parts which are made of iron like the yoke, the armature and the movable iron core and the device will be broken. And furthermore, circuit breakers will not be tripped because the tripping device is not able to get the enough force to tripping due to eddy current loss. Therefore full-magnetic tripping type circuit breakers can not applied circuit which include high frequency.

For reference

Iron loss P is given following expression;

$P = Pe + Ph$

$Pe = K1 \times t^2 \times f^2 \times Bm^2$

$Ph = K2 \times f \times Bm^2$

P : Iron loss K1, K2 : Constant
Pe : Eddy current loss f : frequency
Ph : Hysteresis loss Bm : magnetic-flux density
t : Thickness of parts

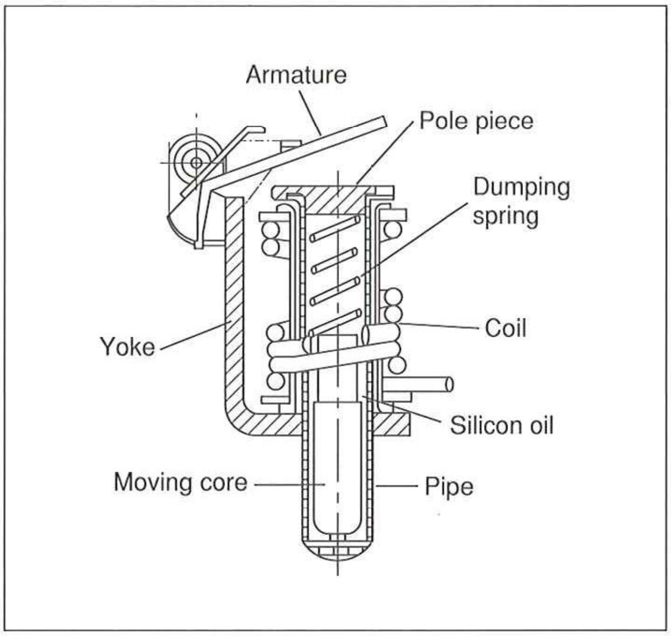


Fig 4.8.1 Structure of full magnetic type tripping device

(2) Thermal-magnetic type

Internal temperatures will increase due to skin effect of conductors and temperature rise due to Iron loss of the parts which are made of steel and the conductor capacity and the tripping current will decrease. The ratios depend on the circuit breakers but the ratio at 400Hz will be around 80%, therefore circuit breakers will be able to used up to 400Hz by decrease rated currents to 80% of the circuit breakers

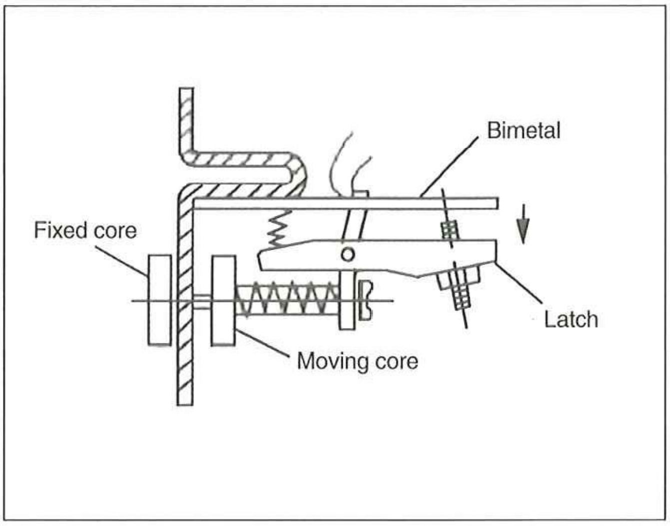


Fig 4.8.2 Structure of thermal-magnetic type tripping device

(3) Electronic type

The use of electronic type offers the advantage of greater tripping characteristics stability when the frequency is varied. However, the devices are still subjected to frequency related temperature effects, so circuit breakers will be recommended decrease rated currents to 80% the same as above.

5. ENVIRONMENT

Special environments may affect performance, service life, insulation and other aspect of circuit breakers. Normal environment of MCCB are as follows;

- Ambient temperature range: 10°C ~ 40°C (max temperature is 50°C)
- Relative humidity: up to 80%
- Altitude: up to 2000 m
- Atmosphere: There are no corrosive gas, inflammable gas, dust, vapor salt contents.

5.1 High temperature

If the temperatures exceed the above normal condition, the load current has to be reduced not to over the permissible temperature of the case and terminals.

Excessive temperatures of the terminals may cause deterioration in insulation of wire skin.

Parts	Permissible temperature (°C)
Cases	100
Terminals	100

5.2 Low temperature

If the temperatures is extremely low like less than –5°C, the tripping characteristics will be changed, so it is necessary installation heaters in switchboard in this case.

There are no harmful effects even extremely low temperature like –30 ~ –40°C in case of short period like shipping.

5.3 High humidity

It may occur deterioration in insulation and shortening electric service life, so it is necessary to apply protective structure, maintenance and inspection.

5.4 Bad environment

If circuit breakers are used in bad atmosphere like dust, corrosion gas, inflammable gas, salt contents, it is necessary to apply dust- proof and corrosion-proof structure in switchboard.

5.5 Altitude

If circuit breakers are used at high altitude over 2000 m above see level, the effect of a drop in pressure of atmosphere and fall in temperature will affect breaking performance of circuit breakers.

Therefore it is necessary to reduce rated current and rated voltage. ANSI (American national standard Institute) also proposal following correction regarding rated current and rated voltage.

Altitude (m)	Rated current	Rated voltage
2000	1.0	1.0
2600	0.95	0.99
3900	0.8	0.96

5.6 Vibration and shock

Avoid direct installation on machines and facilities which give out particularly large shock exceeds 2G and vibration exceeds 15G. In this case, it is necessary to consider the use of a vibration.

Environment	Fault	Measure
High temperature	Deterioration in insulation of case of circuit breakers and wire due to exceeding permissible temperature.	Reducing loads current. Using high heat-resistance wire
Low temperature	Abnormal tripping characteristics	Installing heater in switchboard
High humidity	Deterioration in insulation Shortening electric service life	Applying protective structure Maintenance and inspection
Bad environment	Deterioration in insulation Shortening electric service life	Applying protective structure against dust, corrosion and so on
Vibration and shock	Nuisance trip Breaking	Applying protective structure against vibration
High altitude	Deterioration in insulation of the air due to falling atmospheric pressure.	Reducing loads current and the voltage

6. SHORT CIRCUIT CALCULATION

6.1 General

To protect wires against over current and fire, it is necessary to choose the suitable circuit breakers for the distribution systems. Japanese and international standards like IEC standard require that over current protector must be capable of interrupting the short circuit current. Therefore it is necessary to establish practical method of calculating short circuit current on low voltage systems.

6.2 Circuit condition to determine the short circuit current

The value of a current flowing through a normal circuit is a determined by the capacity of its loads. However, when short circuit trouble in this circuit, a large faulty current flows independently the capacity of its loads. Circuit breakers provide the function of breaking this faulty current. The major factor for determining the value of this fault current are as follows;

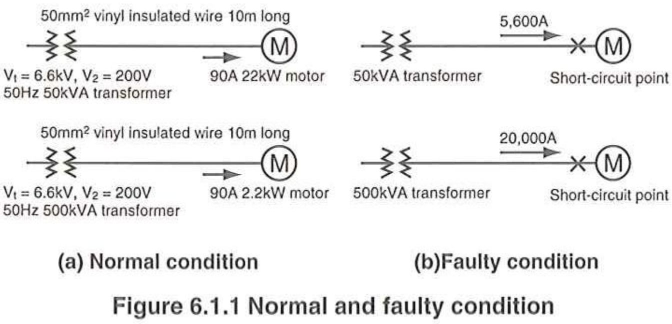
- Capacity of transformers and the impedance (it's may often given as percent impedance)
- Secondary voltage of transformers.
- Impedance of bus ducts and /or conduct wires capacity of the motor connected to systems under consideration

if short circuit occurs, the motors operate as a generator and flow a current backward toward the short circuit point and this current is called a "motor contribution current"

By considering the above factors, the formula for calculating a 3–phase short circuit current in an three phase circuit is given as

$$Is = V/\sqrt{3}Z$$

Is : symmetrical short circuit current
V : Line voltage of three phase systems
Z : Impedance



(a) Normal condition (b)Faulty condition

Figure 6.1.1 Normal and faulty condition

6.3 Faulty current

For instance, assume that 22kW motor is connected to 200 VAC circuit, as shown in Fig. 6.1.1 Under normal condition, the load current of the 50kVA and 500kVA transformers circuit are both 90A. If a short circuit occurs a faulty current of 5600A flows through the 50kVA transformer circuit and a faulty current of 20000A flows through the 500kVA transformer circuit. The values of these faulty currents being entirely different from those of normal currents. Accordingly, it is required that the circuit breakers, as a protective device, have the ability to positively and safely interrupt this faulty current.

For these reasons, HITACHI produces circuit breakers in 3 series, F,S, and L series which are classified according to their breaking capacity.

In addition to the above mentioned calculation method, termed the "Ohm method", there is another method which represent impedance, not in ohms but "in percent" or "per unit", whose convention formulas are as follows

6.4 Terms

Percent impedance

Percent impedance = Vd/Vc × 100(%)

Vd : Drop voltage at capacity at rated road
Vc : Criteria voltage 3ϕ : Phase voltage
1ϕ : Line-line voltage

Per unit impedance

Expression percent impedance In decimal

per unit impedance=Vd/Vc

Contribution current of motors

If motors is rotating and short circuit occurs, their act as generators and they increase the short circuit value.

It is necessary to consider this contribution current of motors.

It can be assumed as follows;

(a) There is a same capacity motor whose capacity is same as total capacities of the motors.

(b) Percent impedance is roughly 25% and X/R is 6

6.5 Calculation method of the short circuit current

6.5.1 General

In selection circuit breakers, short circuit current is liable to be neglected and there is a tendency to lay stress only on rated voltage and rated current. This had been caused primarily by the absence of definite information on the method calculating short circuit current values. The most effective method at present is that proposed and published by NEMA Joint Sections Committee. The method, described blow, is based mainly on the NEMA, and by adapting various impedance values suitable for domestic situations, has been devised in a form of actual materials which enable the calculation of short circuit current values easily.

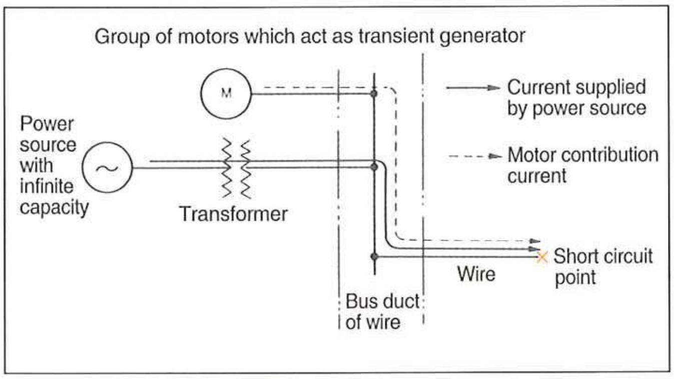


Fig. 6.5.1 Basic circuit of short circuit calculation

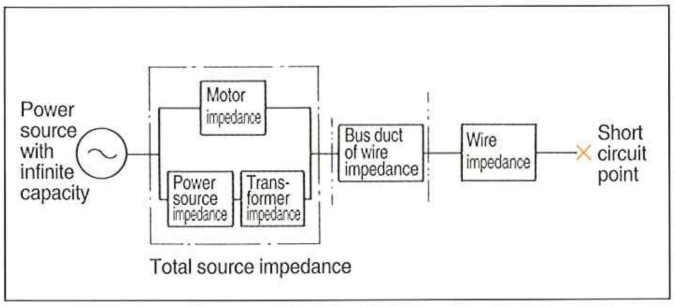


Fig. 6.5.2 Equivalent circuit of short circuit calculation

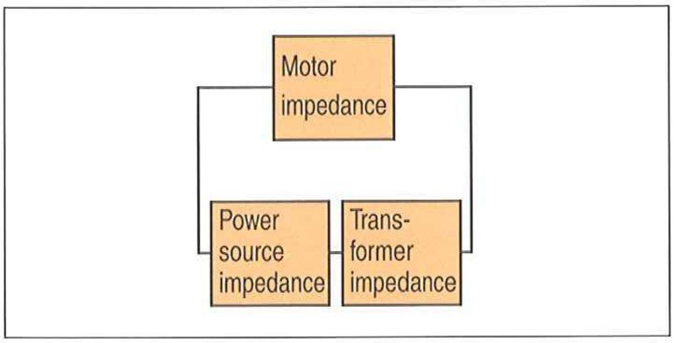


Fig. 6.5.3 Total source impedance Ze

6.5.2 Each impedance

(a) Power supply Zs

Impedance from the power supply to the transformers primary terminals can be calculated from the short circuit capacity specified by the power company, if known. Otherwise it should be defined, together X/R as 1000MVA and X/R=25 for a three-phase supply and it can be ignored completely if significantly smaller than the remaining circuit impedance.

(b) Motors Zm

Impedance of motors depend on kinds and capacities and so on but it can be considered percent impedance is roughly 25% and X/R is 6.

(c) Transformers Zt

Transformer impedance is the largest factor in determining the short circuit current values. Transformer impedance is designated as a percent impedance for the transformer capacity, so it must be converted to a criteria capacity values. If it is use Ohm's low, it must be converted to ohmic values.

The impedances are shown in table 6.5.1~6.5.3

(d) Wires and bus duct Zl, Zb

Wires and bus duct impedances depend on the size , length, kinds, distance between conductors, wiring method and so on. The impedances are shown in table 6.5.4~6.5.6

(e)Total source impedance Ze

The total source value is a value of parallel circuit of power supply impedance, transformers impedance and motors impedance.

$$Ze = (Zs + Zt) \cdot Zm / (Zs + Zt \cdot Zm)$$

The impedances are shown in table 6.5.7~6.5.9

Calculation formula

Resistance R = Total source Re + Bus duct Rb + Wire Rl

Reactance X = Total source Xe + Bus duct Xb + Wire Xl

Impedance $Z = \sqrt{(R^2 + X^2)}$

Short circuit $Is = V / (\sqrt{3} \times Z)$

6.5.3 Values of impedance of transformers whose secondary voltage is 200VAC

Table 6.5.1 Using three standard type single phase

Transformer Capacity (kVA)	Impedancc (mΩ)			Peicent Impedanoe
	R_T	X_T	Z_T	$\%Z_T$ (%)
20	40.0	22.2	45.7	2.3
30	25.3	17.3	30.7	2.3
50	14.4	11.2	18.2	2.3
75	8.00	10.7	13.3	2.5
100	6.00	8.00	10.0	2.5
150	4.00	6.93	8.00	3.0
200	2.80	5.40	6.08	3.0
250	2.24	5.92	6.33	4.0
300	1.87	5.33	5.65	4.2
400	1.30	4.00	4.21	4.2
500	1.04	3.36	3.52	4.4
750	0.69	2.29	2.40	4.5
1000	0.52	1.92	1.99	5.0
1500	0.32	1.57	1.61	6.0
2000	0.24	1.28	1.30	6.5

Table 6.5.2 3-phase transformer primary voltage 3kV or 6kV

Transformer Capacity (kVA)	Impedancc (mΩ)			Peicent Impedanoe
	R_T	X_T	Z_T	$\%Z_T$ (%)
10 × 3	28.0	12.0	30.5	2.3
20 × 3	11.3	10.0	15.1	2.3
30 × 3	6.67	7.56	10.1	2.3
50 × 3	3.73	5.60	6.73	2.5
75 × 3	2.49	4.27	4.94	2.8
100 × 3	1.87	3.20	3.70	2.8
150 × 3	1.07	2.22	2.46	2.8
200 × 3	0.80	1.80	1.97	3.0
300 × 3	0.49	1.57	1.63	3.5
500 × 3	0.29	1.96	1.00	3.8

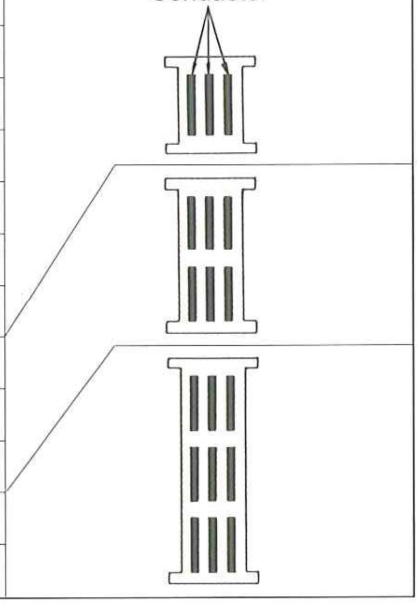
Table 6.5.3 Non standard type transformer which is increased the percent impedance

Transformer Capacity (kVA)	Impedance (mΩ)								
	Percent Impedance 5%			Percent Impedance 7%			Percent Impedance 10%		
	R_T	X_T	Z_T	R_T	X_T	Z_T	R_T	X_T	Z_T
10	112.0	165.6	200	112.0	256	280	112.0	384	400
15	72.0	110.7	133.3	72.0	172.0	186.7	72.0	257	267
20	52.0	85.2	100.0	52.0	130.0	140.0	52.0	193.0	200
30	33.3	59.1	66.7	33.3	27.1	93.3	33.3	129.0	133.3
50	17.60	35.9	40.0	17.60	53.2	56.0	17.60	78.0	80.0
75	10.67	24.4	26.7	10.67	35.7	37.3	10.67	52.3	53.4
100	7.20	18.63	20.0	7.20	27.0	28.0	7.20	39.3	40.0
150	4.27	12.64	13.33	4.27	18.13	18.67	4.27	26.4	26.7
200	3.00	9.52	10.00	3.00	13.68	14.00	3.00	19.77	20.0
250	2.24	7.68	8.00	2.24	10.98	11.20	2.24	15.83	16.00
300	1.733	6.45	6.67	1.733	9.16	9.33	1.733	13.22	13.33
400	1.200	4.85	5.00	1.200	6.90	7.00	1.200	9.92	10.00
500	0.960	3.88	4.00	0.960	5.52	5.60	0.960	7.95	8.00
750	0.587	2.61	2.67	0.S87	3.68	3.73	0.587	5.30	5.34
1000	0.440	1.952	2.00	0.440	2.76	2.80	0.440	3.97	4.00
1500	0.267	1.306	1.333	0.267	1.848	1.867	0.267	2.66	2.67
2000	0.200	0.980	1.000	0.200	1.388	1.400	0.200	1.99	2.00

Remarks: When secondaiy voltage (V') is other than 200V, the impedance value listed in the above table shall be multiplied by $(\frac{V'}{200})^2$.

6.5.4 Values of impedance of wires and bus duct

Table 6.5.4 Impedance of bus duct 1n case of 50Hz (Unit: mΩ/m)

Rated current (A)	Size of conductor (mm)	R_B	X_B	Z_B	Distribution of conductors
600	6 × 50	0.1243	0.0312	0.1282	
800	6 × 75	0.0837	0.0221	0.0866	
1000	10 × 75	0.0515	0.0317	0.0605	
1200	10 × 00	0.0396	0.0249	0.0468	
1500	10 × 125	0.0326	0.0206	0.0386	
2000	10 × 175	0.0243	0.0153	0.0287	
2500	10 × 250	0.0180	0.0110	0.0211	
3000	10 × 150 × (2)	0.0139	0.0088	0.0164	
3500	10 × 175 × (2)	0.0122	0.0076	0.0144	
4000	10 × 200 × (2)	0.0109	0.0068	0.0128	
4500	10 × 150 × (3)	0.0093	0.0058	0.0110	
5000	10 × 175 × (3)	0.0081	0.0051	0.0096	

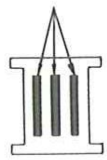
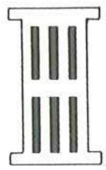
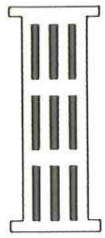
Remarks: The values listed above table are in case of Aℓ-Fe insulated bus duct.

Table 6.5.5 Impedance of wires

Cable size (mm²)	Resistance (mΩ/m)	Reactance (mΩ/m)					
		50Hz			60Hz		
		2-or 3-core cables	1-core cable (close-spaced)	1-core cable (6m-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	4.60	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	0.0884	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

Note : 1. Resistance values as par IEC 60228
2. Resistance par the equation: L (mH/km) = 0.05 + 0.4605$\log_{10}$ D/r (D= core separation, r = conductor radius)

Table 6.5.6 Impedance of bus duct in case of 60Hz (Unit: mΩ/m)

Rated current (A)	Size of conductor (mm)	R_B	X_B	Z_B	Distribution of conductors
600	6 × 50	0.1247	0.0374	0.1302	Conductor
800	6 × 75	0.0844	0.0265	0.0885	
1000	10 × 75	0.05 22	0.0381	0.0646	
1200	10 × 100	0.0405	0.0299	0.0503	
1500	10 × 125	0.0334	0.0247	0.0415	
2000	10 × 175	0.0250	0.0183	0.0310	
2500	10 × 250	0.0182	0.0132	0.0227	
3000	10 × 150 × (2)	0.0143	0.0105	0.0177	
3500	10 × 175 × (2)	0.0125	0.0092	0.0155	
4000	10 × 200 × (2)	0.0112	0.0081	0.0138	
4500	10 × 150 × (3)	0.0095	0.0070	0.0118	
5000	10 × 175 × (3)	0.0083	0.0061	0.0103	

Remarks: The values listed above table are in case of Aℓ-Fe insulated bus duct.

6.5.5 Values of impedance of total source whose secondary voltage is 200VAC

Table 6.5.7 In case of three-phase transformer whose primary voltage is 3kV or 6kV

Transformer Capacity (kVA)	Impedance (mΩ)		
	R_E	X_E	Z_E
20	36.3	23.3	43.1
30	22.7	17.7	28.8
50	12. 8	11.3	17.1
75	6.92	10.1	12.3
100	5.19	7.60	9.20
150	3.35	6.39	7.22
200	2.34	4.95	5.48
250	1.80	5.20	5.51
300	1.49	4.63	4.87
400	1.04	3.48	3.63
500	0.828	2.91	3.02
750	0.548	1.98	2.06
1000	0.408	1.64	1.69
1500	0.250	1.29	1.32

Table 6.5.8 In case of three standard type single phase transformer

Transformer Capacity (kVA)	Impedance (mΩ)		
	R_E	X_E	Z_E
10 × 3	25.7	13.4	29.0
20 × 3	10.0	9.91	14.1
30 × 3	5.87	7.32	9.38
50 × 3	3.22	5.28	6.19
75 × 3	2.11	3.98	4.50
100 × 3	1.59	2.99	3.38
150 × 3	0.909	2.07	2.26
200 × 3	0.674	1.67	1.80
300 × 3	0.403	1.41	1.46
500 × 3	0.239	0.870	0.902

Table 6.5.9 In case of non standard type transformer which is increased the percent impedance

Transformer Capacity (kvA)	Impedance (mΩ)								
	Percent Impedance 5%			Percent Impedance 7%			Percent Impedance 10%		
	R_E	X_E	Z_E	R_E	X_E	Z_E	R_E	X_E	Z_E
10	84.8	146.4	169.2	77.4	206	220	71.1	278	287
15	54.6	96.9	111.8	49.9	138.2	147.0	46.0	186.0	191.6
20	39.3	74.6	84.3	36.1	104.1	110.2	33.5	139.5	143.5
30	25. 1	51.2	57.0	23.2	69.6	73.4	21.6	93.1	95.6
50	13.33	30.9	33.7	12.41	42.3	44.1	11.72	56.2	57.4
75	8.11	20.9	22.4	7.61	28.3	29.3	7.27	39.6	38.3
100	5.50	15.86	16.79	5.21	21.4	22.0	5.04	28.2	28.7
150	3.29	10.72	11.21	3.14	14.32	14.65	3.09	18.91	19.16
200	2.32	8.08	8.40	2.23	10.80	11.02	2.21	14.17	14.34
250	1.745	6.51	6. 74	1.687	8.67	8.83	1.686	11.34	11.47
300	1.361	5.47	5.64	1.326	7.23	7.35	1.336	9.47	9.56
400	0.952	4.12	4.23	0.934	5.46	5.54	0.951	7.10	7.17
500	0.761	3.31	3.39	0.747	4.38	4.44	0.761	5.69	5.74
750	0.471	2.24	2.29	0.466	2.93	2.97	0.480	3.79	3.82
1000	0.353	1.688	1.723	0.350	2.21	2.24	0.360	2.84	2.87
1500	0.218	1.148	1.168	0.218	1.496	1.511	0.227	1.903	1.917
2000	0.1637	0.875	0.899	0.1642	1.135	1.147	0.1697	1.425	1.435

Remarks: When secondaiy voltage (V') is other than 200V, the impedance value listed in the above table shall be multiplied by $(\frac{V'}{200})^2$.

6.5.6 Example of calculation

Calculating short circuit if a short circuit occurs in the circuit in Fig. 6.5.4.

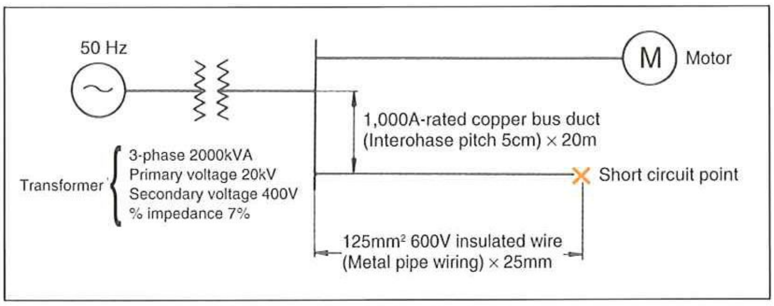


Fig 6.5.4 Example of calculation

(1) The value of impedance 7% in table 6.5.9 is read as the total source impedance and convert 400V.

$Re = 0.1642 \times (400 / 200)^2 = 0.657$ (mΩ)

$Xe = 11.35 \times (400 / 200)^2 = 4.54$ (mΩ)

(2) The value of the impedance of the bus duct in table 6.5.4 is multiplied by 20

$Rb = 0.0515 \times 20 = 1.03$ (mΩ)

$Xb = 0.0317 \times 20 = 0.634$ (mΩ)

(3) The value of the impedance of the wire in table 6.5.5 is multiplied by 25

$Rl = 0.153 \times 25 = 3.83$ (mΩ)

$Xl = 0.0838 \times 25 = 2.1$ (mΩ)

(4) The total value of resistance and reactance

$R = 0.657 + 1.03 + 3.83 = 5.52$ (mΩ)

$X = 4.54 + 0.634 + 2.1 = 7.27$ (mΩ)

(5) Impedance Z is

$Z = \sqrt{(R^2 + X^2)} = 9.12$ (mΩ)

(6) Symmetrical short circuit current Is is

$Is = V / (\sqrt{3} \times Z) = 25323$ (A)

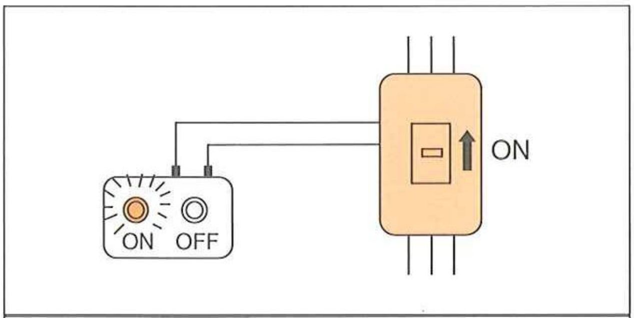
Therefore selected breaking capacity of circuit breaker is exceed 25323 (A) at 400V AC

7. ACCESSORIES

7.1 General

7.1.1 Auxiliary switch (AUX)

The auxiliary switch, a device interlocked with opening and closing position of circuit breakers and it is used to open or close control circuits as the breaker operates. It is used a micro switch equipped with C contact.



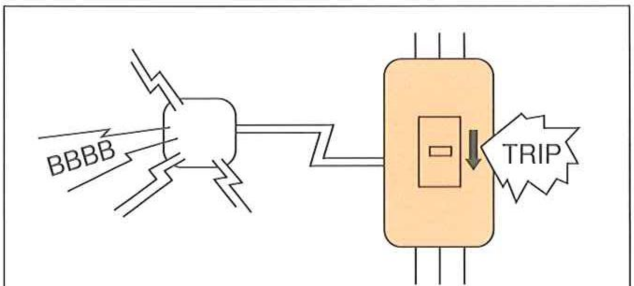
Condition of breaker	Connection condition of AUX switch
ON	A-1 (A-4) — A-2 (A-5) / A-3(A-6)
OFF or tripped	A-1 (A-4) — A-2(A-5) / A-3(A-6)

( ) : for 2C contacts

Symbol of AUX

7.1.2 Alarm switch (AL)

If the breaker tripped, the alarm switch will be closed to energize indicating lights or buzzers. It uses a micro switch equipped with C contact.



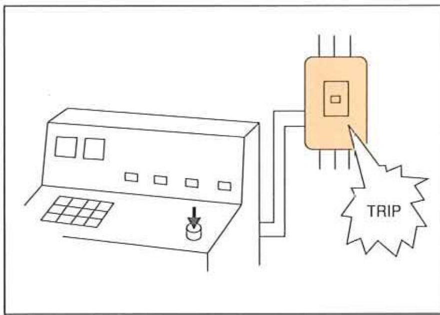
Condition of breaker	Connection condition of AL switch
ON or OFF	S-1 (S-4) — S-2(S-5) / S-3(S-6)
tripped	S-1 (S-4) — S-2(S-5) / S-3(S-6)

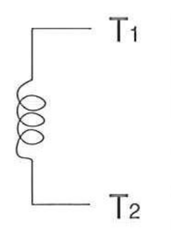
( ) : for 2C contacts

Symbol of AL

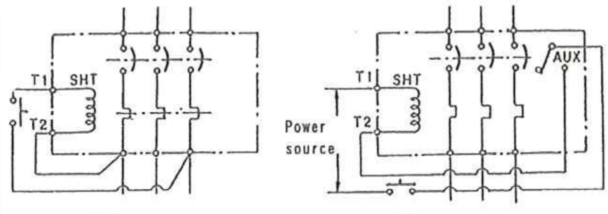
7.1.3 Shunt trip (SHT)

The shunt trip is used to trip circuit breakers electrically from remote point. The standard installation of the circuit breakers with this tripping device is on the vertical wall with its line end positioned upward.





Symbol of SHT



(a) Uni-power

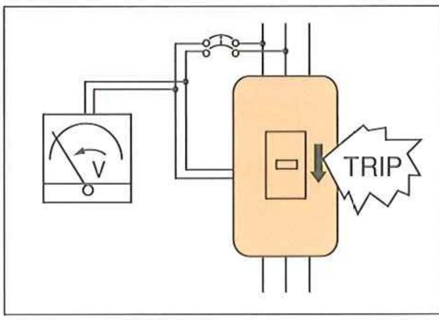
(b) Separate power (excepting DC for F-225FB, F-225KC)

Wiring diagram of shunt trip

7.1.4 Under-voltage trip (UVT)

The under voltage trip is used to automatically trip the circuit breakers if the line voltage drops to 35%~70% of its rated value.

The standard installation of the circuit breakers with this tripping device is on the vertical wall with its line end positioned upward.



Symbol of UVT

7.2 Rating

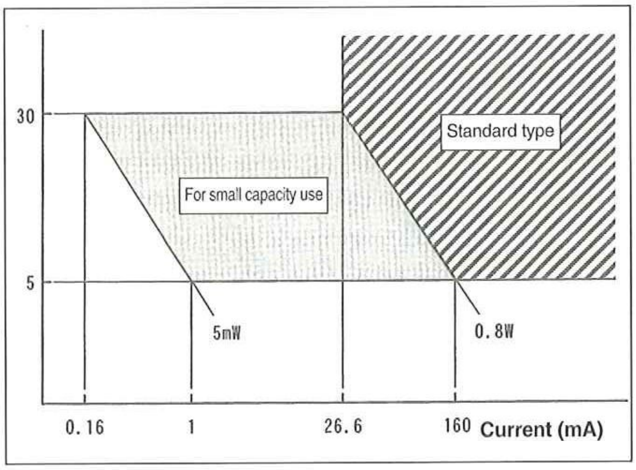
7.2.1 Rating of auxiliary and alarm switch

(a) Breaking capacity

Voltage (V)		Current (A)	
		Resistant load	Inductive load*
AC	500	1	1
	250	3	2
	125	5	3
DC	250	0.2	0.2
	125	0.4	0.4
	30	4	3

*Inductive load means power factor is more than 0.7 and time constant is less than 7ms

(b) Minimum rating



If voltage and current is very small, it may cause bad contact of auxiliary and alarm switch, so it is necessary to use within the area of standard type. If the small voltage and current are inevitable, For small capacity use which is a special product is also available.

7.2.2 Rating of coils of shunt and under-voltage trip

<table>
<tr><th rowspan="2">Type</th><th colspan="2">SHT</th><th colspan="2">UVT</th></tr>
<tr><th>Voltage</th><th>Input (VA)</th><th>Voltage</th><th>Input (VA)</th></tr>
<tr><td>S-30E, S-50EB
S-225SB, SXK225</td><td rowspan="5">AC 100-110V
AC 200-220V
AC 230-240V
AC 380V
AC400-440V
AC480V
(Common use
for 50 and 60HZ)

DC 100V
DC 110V</td><td>100
(for 400V: 200VA)</td><td>–</td><td>–</td></tr>
<tr><td>F-30FB, S-50SB, S-60RB, F-50KB
F-50E, S-100EB, S-100S, S-100SB
F-100S, F-100RB, F-100KB, L-100E</td><td rowspan="4">200</td><td>50Hz 60Hz
AC 100V AC 100V
200V 110V
230V 200V
240V 220V</td><td>20</td></tr>
<tr><td>S-225FB, F-225KC</td><td>–</td><td>–</td></tr>
<tr><td>F-250R, L-225E, S-400S, SX400
F-400R, FX400, L-400E</td><td rowspan="2">50Hz 60Hz
AC 100V AC 100V
200V 110V
230V 200V
240V 220V
400V 400V
415V 440V</td><td>20</td></tr>
<tr><td>S-600S, SX600, F-600F, FX600
L-600E, S-800S, SX800, F-800R
F-800RH, FX800, L-800E, FX1000
FX1200, F-1000C, F-1000K, F-1200C
F-1200K, F-1600CB, F-1600B
F-2000C, F-2000, F-2500C
F-2500, F-3200CB, F-3200E, F-4000E</td><td>30</td></tr>
</table>

A1 Short circuit current

General

Short circuit current is shown in Fig. A1 and the current consist of DC component and AC component. The magnitude of the DC component is determined by the voltage phase angle at the instant of short circuit and the power factor of the circuit. However, the DC component will be immediately gone but If circuit breakers or fuses will break the short circuit current quickly, it is necessary to consider the magnitude of short circuit current including transitional current.

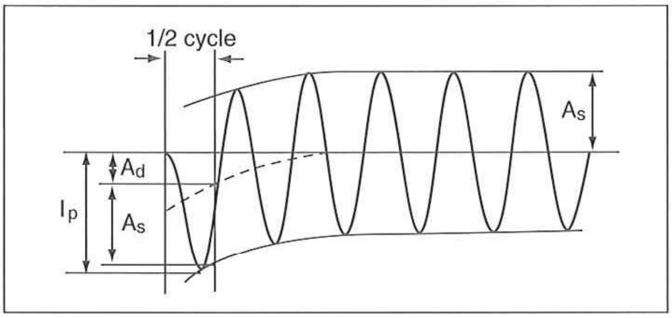


Fig. A1 short circuit current

R.M.S symmetrical short circuit current

The symmetrical short circuit current value is exclusive of the DC component. The magnitude is

$$As / \sqrt{2}$$

R.M.S asymmetrical short circuit current

The asymmetrical short circuit current value includes the DC component. Its magnitude is

$$Ias = \sqrt{(As / \sqrt{2})^2 + Ad^2}$$

If the value of DC component this value get maximum, R.M.S symmetrical short circuit current value get maximum value and the conditions is

$$\theta - \phi = \pm \pi/2$$

θ = voltage phase angle at the instant of short circuit occurs

ϕ = power factor of the circuit

After 1/2 cycles the value get in single-phase circuit

$$Ias = Is \times \sqrt{1 + 2e^{\frac{-2\pi R}{X}}} = Is \times K1$$

$$K1 = \sqrt{1 + 2e^{\frac{-2\pi R}{X}}}$$

K1 is the single-phase maximum asymmetrical coefficient and Ias can be calculated by the power factor of the circuit and symmetrical value.

In 3-phase circuit, it is necessary to consider the average values of 3 phases because the values of Ias are different among the each phase due to difference of the voltage phase angles

$$Ias = Is \times 1/3 \left(\sqrt{1 + 2e^{\frac{-2\pi R}{X}}}\right) + 2\left(\sqrt{1 + \frac{1}{2}e^{\frac{-2\pi R}{X}}}\right) = Is \times K3$$

$$K3 = \frac{1}{3}\sqrt{1 + 2e^{\frac{-2\pi R}{X}}} + 2\sqrt{1 + \frac{1}{2}e^{\frac{-2\pi R}{X}}}$$

Ias in 3 phases can be also calculated by the power factor of the circuit and the symmetrical value

Peak value of asymmetrical short circuit current (Ip in Fig. A1)

This value is depends on the phase angle at short circuit closing and the power factor of the circuit. It will be maximum in case of $\theta = 0$. It will get peak value $\omega t \fallingdotseq \pi/2 + \phi$ after short circuit occurs. It can be also calculated by the symmetrical value and the power factor of the circuit.

$$Ip = Is \times \sqrt{2} \times \left(1 + \sin\phi \times e^{-\left(\frac{\pi}{2} + \phi\right)\frac{R}{X}}\right)$$

$$Ip = Is \times Kp$$

$$Kp = \sqrt{2} \times \left(1 + \sin\phi \times e^{-\left(\frac{\pi}{2} + \phi\right)\frac{R}{X}}\right)$$

Kp is called the peak asymmetrical short circuit current coefficient and also called as the closing-capacity coefficient as Ip is called the closing capacity.
Therefore the asymmetrical values can be calculated by the power factors of the circuit and symmetrical values. These coefficients are shown in Fig. A2.

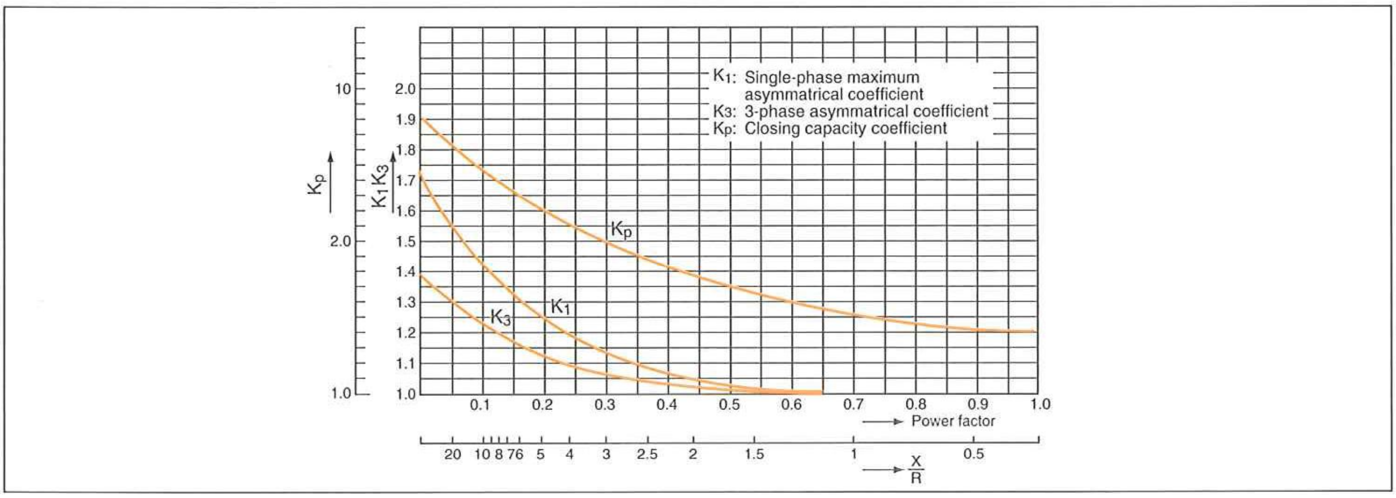


Fig. A2 short-circuit current coefficients

A2 Protection against electric shock

General

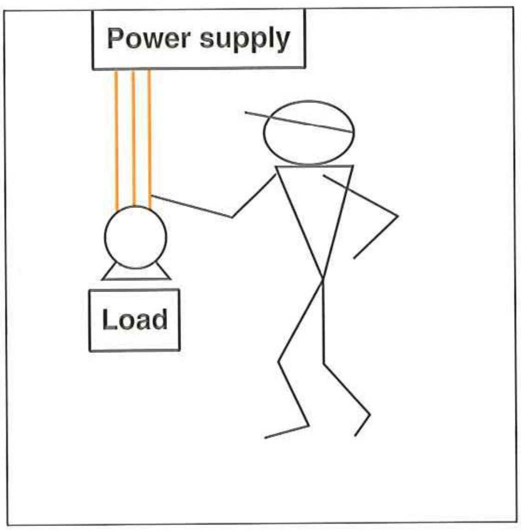
Protection against electric shock are stated in IEC60364-4-41

(1) Protection against direct contact

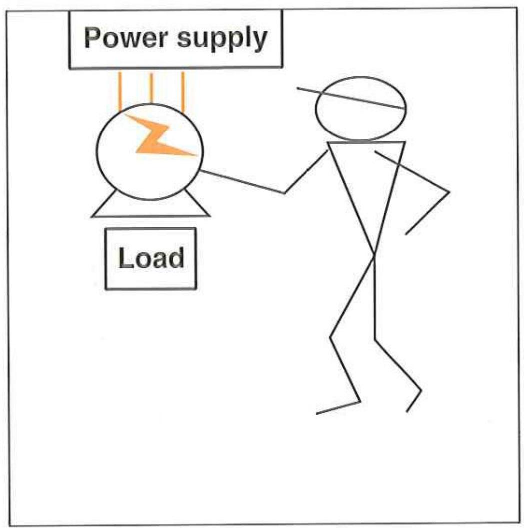
- Using very low safety voltage
  (AC voltage ≦50V, DC voltage ≦120V)
- Preventive measures to ensure that live parts cannot be touched.
  Residual current device whose rated sensitive current IΔn is 30mA or less may be used as a additional protection.

(2) Protection against indirect contact

- Protection without interrupting of the power supply.
  Using of class II equipments, insulation or physical isolation of load devices and so on.
- Protection by automatic interruption of the power supply.
  The following conditions must be satisfied for this measure
  (a) All frames and accessible conductive parts must be connected and earthed.
  (b) Automatic breaking time of the power source must be within not harmful time for human body.



Direct contact



Indirect contact

A3 Earthing systems and automatic breaking of power source for protection against indirect contact

A3.1 Classification of Earthing systems

There are 3 types earthing systems in low voltage distribution systems.

- TN multiple earthed neutral system
- TT directly earthed neutral system
- IT multiple earthed neutral system

A3.2 TN multiple earthed neutral system

(1) General

One point at the power source is connected to directly to the earth.

Exposed-conductive parts are connected to earth electrode through protective conductor.

TN-C system : In which neutral and protective functions are combined in a single conductor throughout the system

TN-S system : In which throughout the system, separate protective conductor is used

Necessary condition for protection against indirect contact is;

$$Zs \times Ia \leqq Uo$$

Zs : Fault loop impedance

Ia : Current causing the automatic operation of disconnecting protective device with in the time stated in table 41A in IEC60364

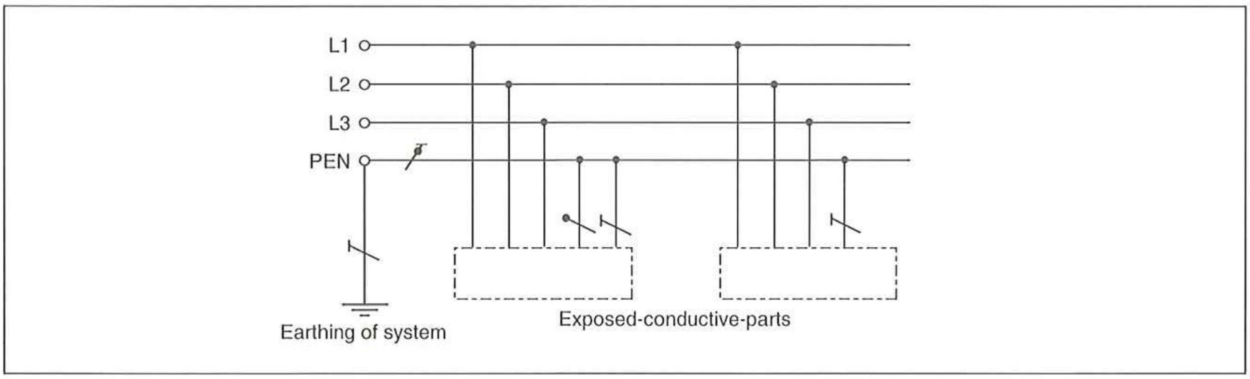
Uo : Nominal voltage between line to earth

The protection against indirect contact in TN system are stated in IEC60364 as follows;

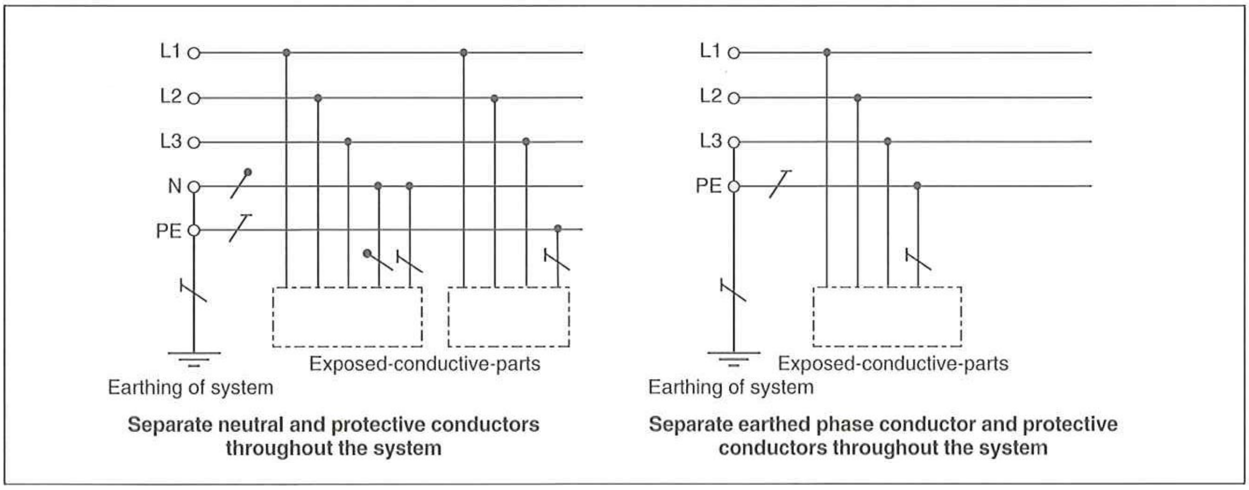
- Over-current protection device
- Residual current device

Over-current protection devices are generally used in the countries which apply IEC standards.

Caution : The PEN conductor in TN-C system and PE conductor on TN-S system mustn't be opened.

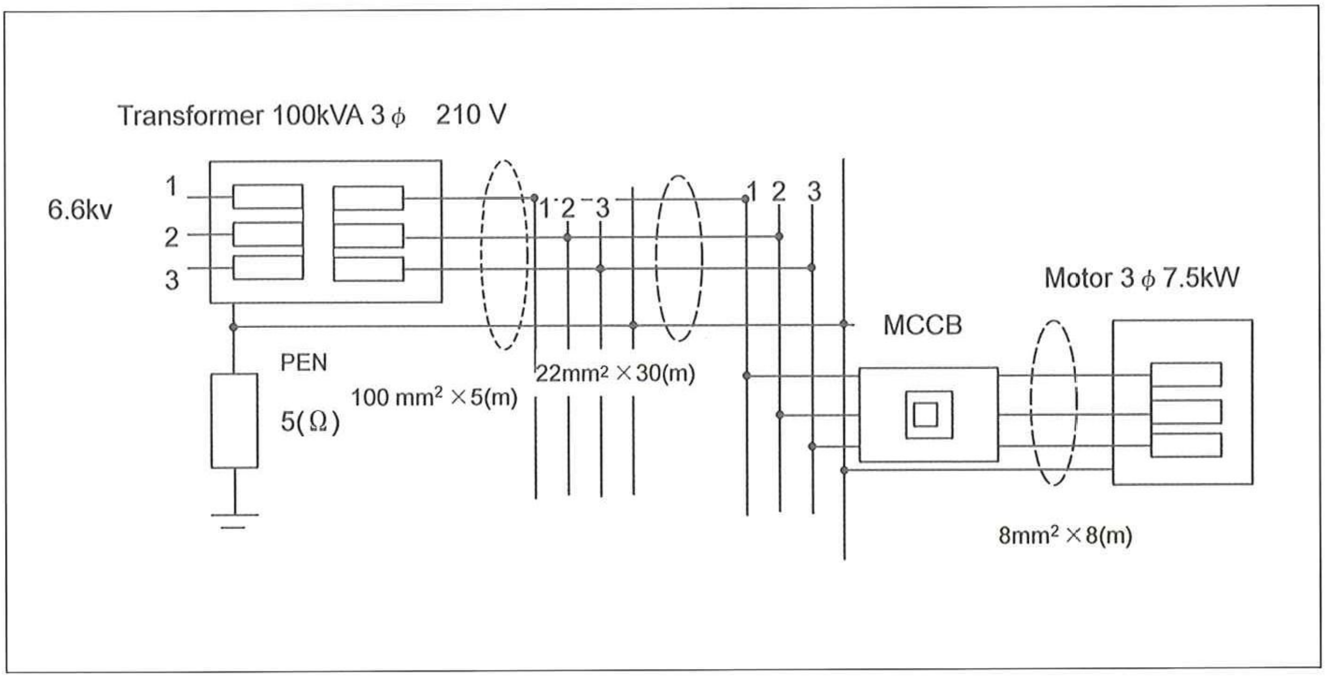


TN-C system



TN-S system

(2) Example of selection for protection against indirect contact



Selection of MCCB

(1) Condition of automatic interruption the power supply

$Zs \times Ia \leqq Uo$

Zs : Fault loop impedance

Ia : Current causing the automatic operation of disconnecting protective device within the time stated in table 41A in IEC60364

Uo: Nominal voltage to earth

(2) Condition of the system

% Impedance of transformer : 1.65% + j1.96%

Impedance of cables

$100mm^2$	0.18 + j0.13	(Ω/km)
$22mm^2$	0.83 + j0.15	(Ω/km)
$8mm^2$	2.3 + j0.2	(Ω/km)

Voltage line to earth : 210 (V)

(3) Calculation of Ia in case of the short circuit between line and line

(a) Transformer

Criterion impedance of transformer Zc

$Zc = Voltage^2 / rated\ capacity$

$= 210^2 / 100 \times 10^3 = 0.441(\Omega)$

$Zt = 0.441 \times (0.0165 + j0.0196) \times 2$

$= 0.015 + j0.017(\Omega)$

(b) Cables

$Zc1: (0.18 + j0.13) \times 5 \times 2/1000$

$= 0.0018 + j0.0013$

$Zc2: (0.83 + j0.15) \times 30 \times 2/1000 = 0.05 + j0.09$

$Zc3: (2.3 + j0.2) \times 8 \times 2/1000 = 0.037 + j0.003$

Fault loop impedance Zs is

$Zs = Zt + Zc1 + Zc2 + Zc3 = 0.1 + j0.03$

$Zs = \sqrt{0.1^2 + 0.03^2} = 0.108\ (\Omega)$

$Ia \leqq Uo/ Zs = 210 / 0108 = 1944\ (A)$

Selected MCCB's breaking time is as follows;

Breaking time is within 4 (ms) at 1944 (A)

(Refer to table 41A in IEC 60364-4-41)

A3.3 TT direct earthed neutral system

One point at the power source is connected to directly to the earth.
Exposed-conductive parts are connected to earth electrode through protective conductor.

Necessary condition for protection against indirect contact is;

$Ra \times Ia \leqq 50$ (V)

Ra : the sum of resistance of earth electrode and resistance between exposed-conductive parts and protection conductor

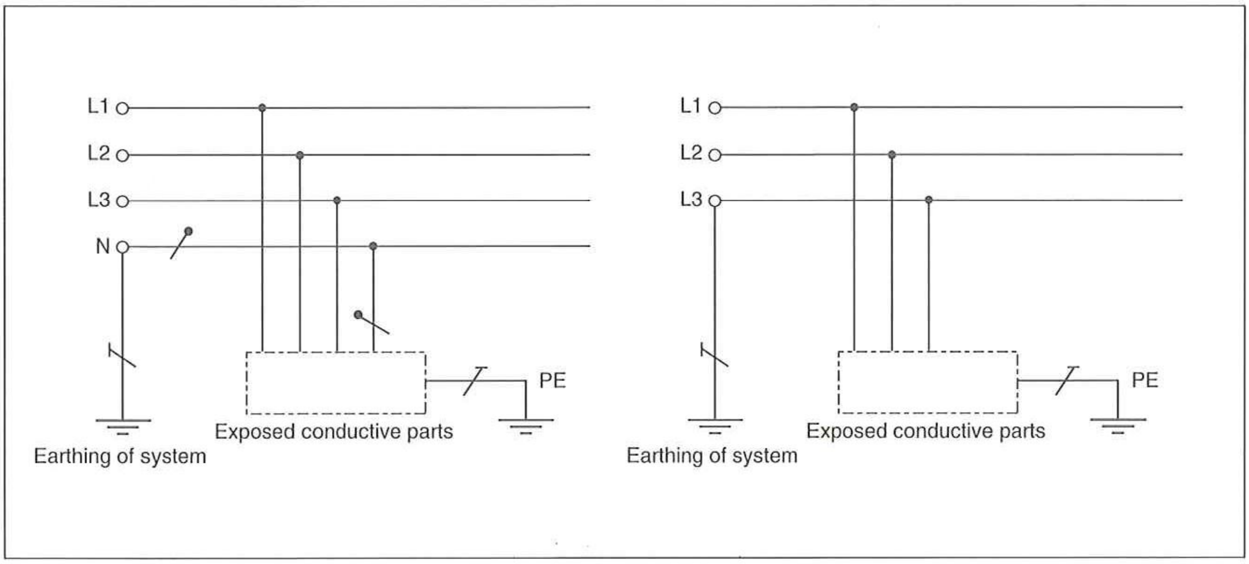
Ia : Current which trips a protective device

If protective device is residual current device, Ia is rated sensitivity current IΔn

The protection against indirect contact in TT system is stated in IEC60364 as follows;

- Over-current protection device
- Residual current device

If over-current protection device is used as a protection against indirect contact, it is necessary that Ra is very small, therefore residual current devices are recommended as a protection against indirect contact.



TT system

A3.4 IT unearthed neutral system

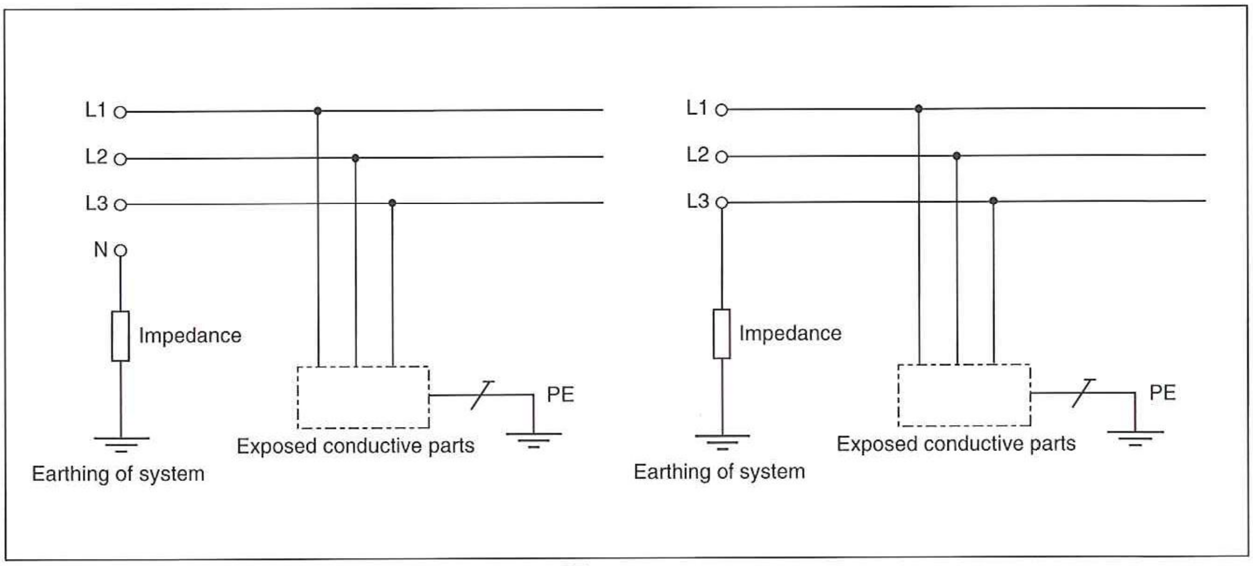
No connection is made between the neutral point of supply source and the earth or connect through high impedance.

IT system is unearthed system, so automatic breaking of the power source is no required in case of first insulation fault but if first insulation fault and second insulation fault occur coincidently, automatic breaking of the power source is required.

Condition of automatic breaking of power supply depend on the each earthed condition as follows;

If exposed-conductive parts are earthed individually : same as TT system

If exposed-conductive parts are earthed collectively with protection conductor: same as TN system



IT system

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