6. Outline of ELCB

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6 Outline of ELCB

6. 1 What is ELCB?

6. 1. 1 Definition of ELCB

ELCB is a molded case circuit breaker used in a low-voltage AC electrical circuit to provide electric shock protection and prevent fires from current leakages.

ELCB is called a “Circuit-breaker incorporating residual current protection” (IEC60947-2) or a “Residual current operated circuit breaker” (IEC61009-1). It is also referred to as a “Ground-fault circuit-interrupter” (UL943). There are two types of ELCB, a current-operated type and a voltage-operated type. In many countries, only the more beneficial current operating-type is manufactured. The Japanese Industrial Standards (JIS) apply only to the current-operated type. In terms of ELCB structure, the product is defined as a “device with integrated ground fault detector, tripping device and switch mechanism in an insulated body, and automatically shuts off the electric current in the event of a ground fault.”

6. 1. 2 History of ELCB

The low-voltage electrical circuit is originally a non-grounding circuit. However, after it became possible to use an alternating current to reduce a high-voltage to a low voltage with a transformer, the risk of contact of high and low voltages and the risk of double ground faults increased. Subsequently, the use of grounded systems became mainstream. Of course, there are still some non-grounding circuits, but most are grounded circuits.

In Japan and the United States, priority has been placed on preventing fires from ground faults. Most protective grounding systems reduce the voltage and ground the device frame. Conversely in Europe, 220 V voltage systems are used in homes, so there has been an interest in ELCB from an early stage.

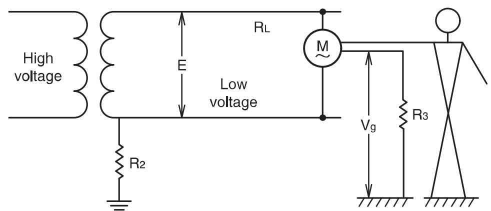
The initial ELCB was a voltage-operated type, and the protection range was small. There were many disadvantages in the use, etc. Today, most units adopt the current operating type.

Year	Worldwide trends	Trends in Japan	Trends at Mitsubishi
1912	○ Votage-operated type developed in Germany		
1930	○ Voltage-operated type standardized with VDE (Germany)		
1939	○ Voltage-operated type standardized with BS-842 (UK)		
1950	○ Current-operated type mass produced in Germany		
1957	○ Current-operated type released in France		
1962		○ Electric fire alarm standardized	
1963	○ Current-operated type		
1965	○ 30mA sensitivity developed in Germany and France		
1968	○ Current-operated type standardized with		○ Mitsubishi ELCB-1 approved by National Institute of Occupational Safety and Health, Japan
1969		○ Ministry of Labor mandates installation of current leakage prevention ○ Stipulated in Electrical Appliance and Material Control Law	
1970	○ Review of ELCB started at IEC	○ Use of 30mA product started widely throughout Japan	○ Mitsubishi ELCB released (up to 50 A frame)
1971			○ Up to 225A frame released, earth leakage relay released
1972	○ Standardized with UL934.1053 (USA)	○ Installation mandated with revision to Electric Equipment technical Standards ○ Standardized with JEM	○ Separated type earth leakage relay released
1973			○ Inverse time relay type released, Awarded the Minister of Construction award
1974		○ JIS-C8371 enacted	○ Shock wave withstand type released ○ Time-delay type released
1975			○ NV Series up to 600A frame released
1977		○ Time-relay type, time-delay type, high-speed type specified by Electrical Appliance and Material Control Law ○ Places requiring installation of earth leakage breakers increased due to revision of Indoor Wiring Regulations.	○ IC incorporated for all models ○ Large capacity NV-SA Series released (up to 1200A frame) ○ Earth leakage relay NV-ZS, NV-SU, NV-ZA Series released ○ NV-ZU awarded Minister of Construction award
1980		○ JIS-C8371 revised	
1983	○ IEC Publication 755 Current-operating type ground fault protection device enacted		
1986		○ Places requiring installation of earth leakage breakers increased due to revision of Indoor Wiring Regulations.	
1987			○ Super ELCB Released Rated voltage 100-200-415V AC common Sensitivity current 3-step changeover
1990	○ IEC 1008 “125A and smaller residual current circuit breaker without overcurrent protection for household and similar uses” enacted	○ Indoor Wiring Regulations revised	
1991	○ IEC 1009 “125A and smaller residual current circuit breaker with overcurrent protection for household and similar uses” enacted		○ New Super ELCB released Higher harmonics and surge compliance Same dimensions as MCCB
1992	○ IEC 60947-2 Annex B “Residual current circuit breaker” enacted	○ Equipment of single-phase 3-wire type electrical circuit ELCB with a neutral wire phase failure protection mandated through revision of Indoor Wiring Regulations. ○ JIS C 8371 revised * Applicable range increased * Coordination with IEC * Matters related to improvement of reliability improved	○ ELCB with single-phase neutral wire phase failure protection upgraded
1995			○ PSS released (30 to 255A frame)
1997			○ PSS released (400 to 800A frame)
2001			○ WSS released (30 to 255A frame), awarded the Minister of Land, Infrastructure and Transport award ○ Earth leakage relay upgraded
2004			○ Compact UL489 Listed no-fuse breaker with earth leakage protection released
2006			○ White & World Super Series released
2011			○ WS-V Series released, awarded the Minister of Land, Infrastructure and Transport award

6. 2 Why is ELCB needed?

Awareness toward electric shock injuries and short-circuit fires has increased in view of saving human life and assets. In addition, places requiring installation of ELCB has increased for legal reasons.

Conventionally, electric shocks were prevented only with protective grounding work. While this was effective, it was found to be insufficient when stricter conditions were considered.



R2: Class B grounding resistance (Ω)　E: Voltage (V)
R3: Class D grounding resistance (Ω)　Vg: Voltage to ground at ground fault point (V)
RL: Electrical Circuit resistance (Ω)

Fig. 6.1

In Fig. 6. 1 for example, if the motor Ⓜ insulation degrades and generates a potential at the motor frame, the voltage to ground Vg is expressed with the following expression.

$$Vg = \frac{R_3}{R_2 + R_3 + R_L} \cdot E \quad (1)$$

R_L is a low value that can be ignored compared to R_2 and R_3.
Thus,

$$Vg = \frac{R_3}{R_2 + R_3} \cdot E \quad (2)$$

With IEC60364-4-41, the contact potential must be 50V or less to protect humans against electric shock. In the 230/400V power distribution system, the maximum voltage to ground of an electric facility that could come in contact with humans is 230V, Thus, if Vg = 50 and E = 230, then expression (3) can be established from expression (2).

$$\frac{R_2}{R_3} = 3.6 \quad (3)$$

If R_2 is controlled to approx. 20Ω, R_3 must always be kept to 5.6Ω or less to enable electric shock protection with only the protective grounding method. This is not a complete electric shock completion method.

If a residual current circuit breaker is used, the "power supply breaking" means is added to the "protective grounding", and more complete electric shock protection measures are established.

The size of the ground fault current differs according to the grounding method so it is essential to select the appropriate overcurrent breaker that can detect a relatively large ground fault current (MCCB or fuse) or ELCB that can detect a minute ground fault current.

6. 3 Physiological symptoms of electric shocks

6. 3. 1 Effect of overcurrent passing through human body

When selecting the rated sensitivity current of ELCB used to prevent injury from electric shocks, it is necessary to understand the physiological symptoms of the human body in reception to electricity. According to Biegelmeier's report, the human's characteristics to electricity can be classified as shown in Table 6. 1.

When the passing current increases, the heart chamber (heart) starts fibrillating, the pulse is distributed, and the circulation of blood to supply fresh blood throughout the body stops. This is an extremely dangerous current that can lead to death. This current value requires medical experimentation, which were carried out (including animal experiments) in the United States and Germany, etc. The results were documented, and were usually several 10mA.

When intended to prevent electric shocks accidents, it is best to provide protective measures that limit the involuntary current (limit at which separation is possible). However, when the continuity of the power fed, etc., is considered in relation with the circuit's leakage current, providing protective measures for the ventricular fibrillation electrical current is unavoidable.

In various European countries (Germany and France, etc.), protective measures are applied using this ventricular fibrillation electrical current as a reference. Favorable results have been attained.

Dalziel (US) and Koeppen (Germany) are known for their research of the physiological symptoms in respect to currents on human bodies, such as ventricular fibrillation electrical currents. According to their papers, etc., the following type of current cases ventricular fibrillation.

According to Dalziel, the ventricular fibrillation electrical current I passing for an energizing time (Ts) within 5s is expressed as $I = \frac{116}{\sqrt{T}}$ (mA). The human's physiological symptoms are greatly affected by the current square time product. On the other hand, Koeppen found that even if the current value exceeds 50mA, human life can be saved if the energizing time is extremely short. The limit is current time product 50mA・s. The relation of these is shown in Fig. 6. 2.

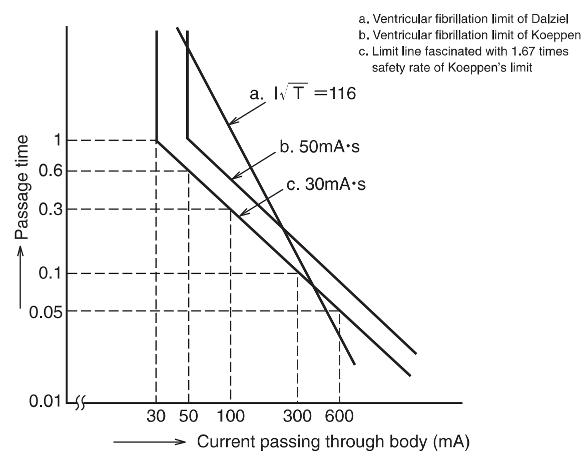


Fig. 6. 3 Ventricular fibrillation electrical current - passage time limit

When both are compared based on the characteristics in this figure, it can be seen that Koeppen's limits are less than Dalziel's limits, so using the safer 50mA・s as a reference is suitable.

Koeppen also writes about this, but using the reference of 50mA・s, 30mA・s is set as the safety factor in Europe. While there are no reports on the effect if a current of 50mA is continuously passed to the human body, typically if a current of 50mA or less is passed, the human would reflectively let go of the conductor. The size of the c urrent that passes through the human body is determined by the human body's resistance and the contact voltage. The human body's resistance varies by individual. It can be affected by race, dryness of skin, state of contact with electrode (contact area or contact pressure, etc.), and the size of the contact voltage. Freiberger (Germany) has reported that when the hand to foot, the most typical current path is looked at, the human resistance is within the range shown in Fig. 6.3. However, in adverse conditions where the skin surface resistance is ignored, the resistance drops to 500Ω. Thus, this value should be adopted when laying importance on safety.

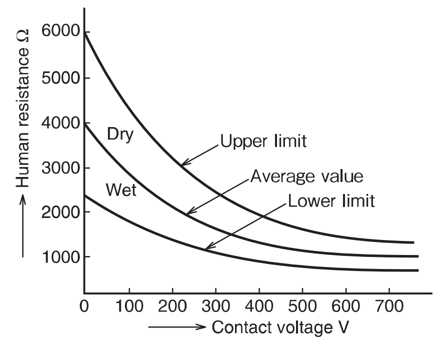


Fig. 6. 4 Relation of contact voltage and human resistance

Based on the above, when considering measures to prevent electric shock accidents, the human resistance in respect to contact voltage must be obtained from Fig. 6.3, and the size of the current passing through the human body must be estimated. In respect to the safe voltage, it is difficult to definitively set the danger voltage in the relation of the human resistance. If the environmental conditions or electrical conditions are poor, the contact voltage must be low. In the IEC Standards the voltage is a safe special low voltage. Within preset conditions, the maximum voltage must be 25VAC or less.

Table 6. 1 Electric shock current and physiological reaction on human body

50/60 Hz current effective value [mA]	Reaction time	Physiological reaction on human body
0 to 0.5	Not dangerous even when continued	Current cannot be sensed
0.5 to 5 (separation limit)	Not dangerous even when continued	Voluntary current range in which human starts to feel current, but does not have spasm. (Able to voluntarily separate from contact state, but feels pain in fingers and arms, etc.)
5 to 30	Several minutes is the limit	Involuntary current range (spasms prevent voluntary separation from constant state) Has trouble breathing, or blood pressure rises. Within tolerable range.
30 to 50	Several seconds to several minutes	Heart beat becomes irregular. Can faint, blood pressure rises, strong spasms occur. Ventricular fibrillation occurs after long time.
50 to several 100s	Less than heartbeat period	Receives extreme shock, but does not cause ventricular fibrillation
	Longer than heartbeat period	Ventricular fibrillation occurs. Faints, traces of current made at contact (heartbeat phase and start of current perception have no special relation)
More than several 100mA	Less than heartbeat cycle	Even if the reaction time is within the heartbeat cycle, ventricular fibrillation could occur if perception starts at a specific heartbeat Faints, traces of current made at contact
	More than heartbeat cycle	Ventricular fibrillation does not occur Recoverable heart failure, fainting occurs Burns could cause death

6. 3. 2 Electric shock protection, rated current sensitivity and operating time

As explained above, there are various theories on the physiological symptoms that occur to a human when currents pass through. If the safety standards were set following the IEC curve given in Fig. 6. 5, the following areas could be could be considered.

- In areas were secondary accidents could result because of electric shocks, the area of curve b and below
- Curve c_1 and below where secondary accidents would not result because of electric shocks.

(1) Taking measures using curve b as protection standard

As shown in Fig. 6. 4, usually there is no hazard to the human body if the passing current is 5mA or less. The 5mA current is a level at which a person generally feels tingling. The person could "let go" at his current, so normally the person can provide his/her own protection. If a person inadvertently and directly touches a 200mA voltage to ground liver wire, a 200mA (human resistance 1000Ω) current will flow through the body. In this case, based on curve b the operating time must be within 0.01 sec.

(2) Taking measures using curve c_1 as protection standard

In levels with a small current value, curve c_1 shows the drop from 50mA in one second and the drop from 40mA after three seconds. In levels with a high current level, curve c1 shows the drop from 500mA at 10ms or less, and from 400mA at 100ms. If the current passing to the human body exceeds 40mA, the risk of a serious physiological effect occurs as the current value and time increase.

(3) **Current passing through human body, time product 30mA・s**

Measures are often using the protection standard of 30mA・s based on Koeppen's ventricular fibrillation limit. However, even in this case the electric device must be grounded as a rule. If the electric device is improperly grounded (portable or movable device that easily generates a ground), the following two conditions must be satisfied to suppress the current to within the ventricular fibrillation limit even the human touches the high voltage.

- Rated current sensitivity 30mA or less
- Current/time product to ELCB operation Within 30mA・s

Note that grounding work is usually performed, so if the selection maintains the relation of (rated current sensitivity) × (grounding resistance value) ≤ (tolerable contact voltage), then the electric shock protection can be provided at 200mA or 500mA even if the rated current sensitivity is not 30mA.

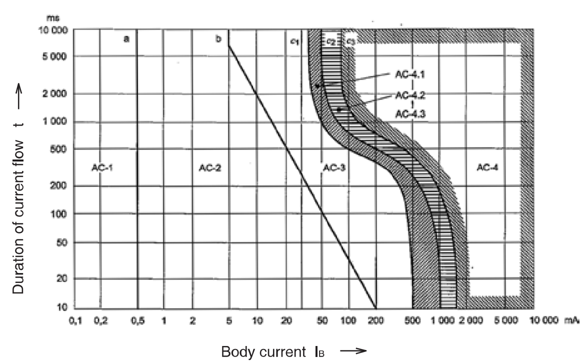


Fig. 6. 5 Effect of AC current (15Hz to 100Hz) on human body (IEC/TS60479-1)

The physiological effect in each zone is as follows.

Zone name	Range of zone	Physiological effect
AC-1	Below curve a	Normally imperceptible.
AC-2	Between curve a and curve b	Normally no harmful physiological effect.
AC-3	Between curve b and curve c_1	Normally, damage to organs not predicted. If the current continues for longer than 2 seconds, there is risk of muscular contraction or respiratory paralysis. Includes arterial fibrillation and temporary heart failure.
AC-4	Exceeding curve c_1	Increases with size and time. Possibility of pathophysiological effect such as hear failure, respiratory failure and severe burns.
AC-4.1	c_1 to c_2	In addition to effect of zone AC-3, possibility of ventricular fibrillation increases by 5%.
AC-4.2	c_2 to c_3	In addition to effect of zone AC-3, possibility of ventricular fibrillation increases by 50%.
AC-4.3	Exceeding curvec_3	In addition to effect of zone AC-3, possibility of ventricular fibrillation increases by more than 50%.

Curves c_1, c_2 and c_3 are the statistical evaluation of the result of animal experiments, and estimate the flow of current from the left hand to right foot.

6. 4 Types of ground fault protection

6. 4. 1 Comparison of ground fault protection methods

Table 6. 2

Protection method	Merits	Demerits
Earth leakage breaker method	◎The high-speed high-sensitivity type is extremely effective for electric shock protection. ◎The optimum sensitivity can be selected according to the working conditions and environment, scale of electrical circuit and importance, etc . ◎The current-operated type can protect all electrical circuits past the installation point. ◎Labor-saving as the electrical circuit insulation resistance measurement can be omitted, and the inspection cycle can be extended.	○If there is a ground fault accident, that circuit will be opened and the power will fail. ○Can be expensive if installed on each branch circuit to maintain the continuous power feed.
Protective grounding method	◎Economical if soil, where protective grounding is to be provided, has a low resistance value. ◎The contact voltage will not exceed the tolerable value. ◎Relatively high reliability in terms of chronological degradation.	○To limit the equipment's contact voltage to less than the tolerable value with the TT method, the protective grounding resistance value must be much less than the power side's grounding resistance value. However, since it is difficult to confirm the power side's grounding resistance value, the low resistance grounding work is difficult. Thus, this method is not practical for low voltages. ○The ground fault accident itself cannot be detected or removed, and thus, fires cannot be prevented.
Overcurrent breaker method	◎Highly reliable MCCB can swiftly and accurately remove ground fault accident circuits. ◎Cost feasible as the electrical circuit's metal pipes or building's steel frame can be used for the grounding dedicated wire.	○The tolerable contact voltage could be exceeded in the duration between generation of the ground fault accident to when MCCB functions and opens the circuit. ○Caution must be paid to the relation of the metal pipe and steel frame impedance and MCCB rated current.
Insulated transformer method (non-grounded)	◎With the secondary side non-grounded method, there is no contact voltage to the human body during a ground fault or when the live section is contacted. ◎There is no risk of power failure or fires caused by the ground fault accident.	○Can be hazardous if the ground fault accident is not detected and a double insulation breakdown occurs for a long time. ○If a high voltage is reached due to the effect of the induction, or if there is a ground fault in one wire, the voltage to ground for the other wires may become higher than the grounded type electrical circuit. This is not suitable for large capacity applications.
Earth leakage warning method	◎Economical if soil, where protective grounding is to be provided, has a low resistance value. ◎The contact voltage will not exceed the tolerable value. ◎Relatively high reliability in terms of chronological degradation.	○There is no self-protection function in respect to electric shocks. ○Not effective if the load electric device is not grounded. ○Not effective if there is no communicant or administrator when alarm is issued.

6. 4. 2 Ground fault protection method and application

The types of accidents that could occur in a ground fault accident can largely categorize into the three types shown in Table 6. 3. The main purpose must be understood when selecting the ground fault protection method and devices.

Table 6. 3 Types of damage caused by ground fault accidents

Type	Symptoms	Size of ground fault current
Electric shock	When a human body directly touches an electrical circuit or device's conductive section, or touches a frame onto which voltage is inducted due to degradation of motor insulation, etc., the current passes through the human body and a ground fault current flows.	Current that causes death is several 10mA or more.
Fire	When the insulation of the building where the wire passes through degrades and the ground fault current passes through the thin easily heated conductor, such as the metal truss, the conductor heats and can cause the building material to ignite.	Current that causes fires is several A or more.
Device burning	When the insulation of the electrical circuit or device is partially damaged and a large ground fault current flows, in most cases an arc occurs and burns the devices.	The current that causes arcs is several 10A or more.

(1) Electric shock damage protection

a. Contact state and tolerable contact voltage

If a ground fault occurs in the low-voltage electrical circuit, the contact voltage must be suppressed to the values shown in Table 6. 4 according to the human contact state.

① Places where Class 1 contact state occurs

If the human body is shocked in a swimming pool, measures against ventricular fibrillation current may lead to secondary accidents such as drowning. Thus, the tolerable current flowing through the human body (minimum involuntary current value) must be 5mA.

A double protection with the earth leakage breaking method and another method should be incorporated instead of just relying on the earth leakage breaking method.

A practical effect cannot be anticipated with the other ground fault protection methods.

② Places where Class 2 contact state may occur

The human resistance is set at 500Ω when the human body is extremely wet. In this case, the contact voltage must be 25A and the current/time product must be suppressed to within 50mA・s, and the current passing through the human body must be suppressed to the Koeppen tolerable limit of 50mA.

ELCB with a rated current sensitivity of 30mA and current/time product within 30mA・s (operating time 0.1 s or inverse time-delay type) must be used to provide protective grounding.

If the leakage current in the electrical circuit is large and it is difficult to use a high-sensitivity type, the device frame's grounding resistance value R_3 and rated current sensitivity must be selected with the following expression.

$$R_3 \leq \frac{25\text{ (V)}}{\text{ELCB rated sensitivity current (A)}}\ (\Omega) \quad \cdots\cdots (1)$$

As shown in expression (1), even if the rated current sensitivity is not 30mA or less, if the protective grounding resistance value is suppressed, it may be possible to achieve a sufficient effect even with a 100mA or 200mA sensitivity product.

③ **Class 3 contact state**

In the normal state in which the hands and feet are not wet, the human resistance is set to be 1000Ω. To suppress the current passing through the human body to below Koeppen's tolerable limit of 50mA, then the contact resistance must be limited to 50V or less, or the current/time product must be suppressed to 50mA・s or less.

Use ELCB with a rated current sensitivity of 30mA or less and operating time within 0.1s, or one with inverse time-delay characteristics together with protective grounding.

If the leakage current in the electrical circuit is large and it is difficult to use a high-sensitivity type with rated current sensitivity of 30mA, etc., the same state as Class 2 contact can be attained by selecting the device frame grounding resistance value R_2 and rated current sensitivity that satisfies the following r relation.

$$R_3 \leq \frac{50\text{ (V)}}{\text{ELCB rated sensitivity current (A)}}\ (\Omega) \quad \cdots\cdots (2)$$

③ **Class 4 contact state**

Normally, sections that will not contact human bodies do not require special electric shock protection. However, measures must be take for fire protection, etc.

Table 6. 4 Tolerable contact voltage (JEAG8101-1971)

Types of contact states		Tolerable contact voltage
Class 1	○Most of human body is submerged in eater.	2.5V or less
Class 2	○Human body is very wet. ○Part of metal electric device or system or structure is in constant contact with human body.	25V or less
Class 3	○Cases other than Class 1 or Class 2 where there is a high risk if contact voltage is applied in normal body state.	50V or less
Class 4	○Cases other than Class 1 or Class 2, where risk of contact voltage being applied in normal human body state is extremely low. ○When there is no risk of contact voltage being applied.	No limits

b. Application of various ground fault protection methods

Applications of the various ground fault protection methods for electric shock protection are shown in Table 6. 5. Even if ELCB is installed, there is a risk of electric shock accidents if two live places are touched.

Table 6. 5 Application of ground fault protection methods (JEAG8101-1971)

Protection method \ Contact state		Class 1	Class 2	Class 3	Class 4
Protective grounding	Tolerable contact voltage 25V	×	×	○	○
	Tolerable contact voltage 50V	×	×	○	○
	No limits	×	×	×	○
Overcurrent breaking		×	×	○	○
Earth leakage breaking	Current-operated type	○ (limited to high-speed high-sensitivity type)	○ (limited to high-speed high-sensitivity type)	○	○
Earth leakage alarm		×	×	○	○
Insulating transformer	Non-grounded type	×	○ (Working voltage on primary side 600V or less)	○	○
	Middle point grounded type	×	○ (Working voltage on secondary side 50V or less)	○ (Working voltage on secondary side 50V or less)	○

Remarks (1) ○ indicates that the protection method can be used independently in each contact state. × indicates that the independent use is not possible.
(2) The combination methods shown the same level as the minimum protection level.
(3) These applications do not apply to the double insulation structure load device.
(4) In the Class 1 or Class 2 contact state, if the current passing through the human body might be several mA such as when using a portable device, a protection method that operates at approx. 50mA is required.
(5) The types of contact states are shown in Table 6. 4.

(2) Earth leakage fire protection

Generally, fires caused by electrical leaks occur when the insulation sheath of the wire is damaged, and the electricity flows through the structure's metal body resulting in heating or spark discharge. In residential homes, it is essential to provide protection against earth leakage accidents caused when the metal truss contacts a stable or when the wire sheath is damaged in an earthquake, etc. If the ground fault occur is small, the risk of fires is small. However, if not repaired, the fault could develop and cause a fire. The size of the ground fault current that causes a fire differs according to various conditions, but is said to be several A.

The rated current sensitivity of ELCB is thought to have sufficient protection against fires when 1A or less.

The earth leakage alarm method is effective if it is in the constant monitor state. However, when using the protective grounding method or insulating transformer method, the ground fault current cannot be detected, and thus sufficient protection against earth leakage fires cannot be anticipated.

(3) Protection against arc ground fault damage

A well-known example of a fire that started with an arc ground fault is a large apartment fire in New York in 1964. The arc accident continued for an hour completely destroying a 480/277V distribution panel. The two 5000A bus wires were completely melted to the point of origin.

It took several days to recover the situation. Water, lighting and electric service to 10,000 people were stopped during that time.

There are many cases of arc accidents in load centers, distribution panels, bus wires, control centers and cables that resulted in serious damage.

Arc ground fault accidents cannot be prevented with just an overcurrent breaker. In other words, the arc short-circuit limits the short-circuit current with the arc resistor and prevents the overcurrent protector from functioning or taking a long time to function. Even in indirect arc accidents, there are cases when the overcurrent breaker does not function even through the damage is sequentially increases. Thus, an arc accident protection device is required in addition to the overcurrent breaker.

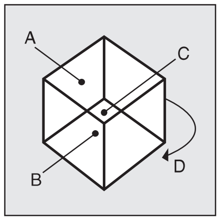
The arc ground fault current can extend over the range of several A to several 1000A, so protection using the earth leakage breaker method is the most appropriate.

6. 5 Types and features of ground fault protection devices and ground fault monitor dvevices

The ground fault protection device and ground fault monitor device for low-voltage electrical circuits must be selected carefully according to the purpose, cost efficiency and functions, etc. If an appropriate device is selected, optimum protection and monitoring can be provided for a long time. The features of the most commonly used main ground fault protection devices and ground fault monitoring devices are listed below. Refer to this table when selecting the devices.

Table 6. 6 Types and features of ground fault protection devices and ground fault monitor devices

	ELCB	Earth leakage relay	Ground fault relay	4E relay	Earth leakage fire alarm
Rated sensitivity current	Applicable from 15mA high sensitivity to several A. Also available as rated sensitivity current switching type for use according to electrical circuit state.	Applicable from 30mA high sensitivity to several A. Also available as rated sensitivity current switching type for high universality.	Typically available in 200, 400, 600mA switching type. 5-step switching from 100 to 600mA also available, but not available as high-sensitivity type.	100mA is standard.	Generally available in 100mA to 400mA. Some special products with low sensitivity (400 to 700mA) are available.
Operating time	Both high-speed and time-delay types are available enabling selective breaking.	In addition to high-speed and time-delay types, available in models for a wide range of applications such as automatic recovery types and selective coordination.	0.1 to 0.3 s at 130% of sensitivity current. 0.1 to 0.2 s at 400%. (JIS C4601 stipulation)	Only high-speed type.	Differs according to maker as there are no special stipulations.
Electrical Circuit breaking function	Equipped with capability to break load current and abnormal overcurrent, so capable of automatically breaking the accident circuit.	Earth leakage breaker itself does not have a main circuit breaking capability. However, a breaking circuit can be easily structured using the built-in contact.	Ground fault relay itself does not have a breaking capability, but equipped with built-in contact.	Same as earth leakage relay.	Typically, most do not have a breaking function. However, a breaking function can be provided.
External alarm function	Possible by incorporating earth leakage alarm (EAL) switch.	Optical or audio alarm can easily be created using built-in contact.	Some products have built-in alarm circuit in addition to built-in contact.	Same as earth leakage relay.	Equipped with device to sound 70 phons or more with Class 1 and 60 phons or more with Class 2 using audio device.
Overcurrent protection combination	Most products typically have short-circuit and overload protection functions, so three functions are covered with a single unit.	None	None	Protection corresponding to the load device possible as the overcurrent protection mechanism is electronic.	None
Energizing capacity	Mitsubishi's maximum frame is 1200A.	Mitsubishi's maximum frame is 3200A. Generally, a larger capacity than other devices can be manufactured.	Manufactured for the highest voltage. Available in 50 to 1000A class with zero-phase converter.	Typically available in 150A class. 1000A class available when specified.	Approximately available in 200A class or lower.
Handling Construction	Easy	Zero-phase converter and relay must be converted. A little more complicated than ELCB.	Same as earth leakage relay.	In addition to 3E relay, zero-phase converter must be mounted.	Same as earth leakage relay.
Overcurrent strength	Up to rated breaking current.	100,000A	40-times of more than rated primary current.	Overcurrent strength of zero-phase converter is 100,000A.	2,500A



7. Structure and Operation

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7 Structure and Operation

7. 1 Earth leakage circuit breakers

7.1. 1 Outline of structure

ELCB consist of the following major parts.

- Switching mechanism that opens and closes the contacts
- Earth leakage tripping device which trips the circuit breaker according to short circuit current
- Earth leakage indication device which is interlocked with the overcurrent protection device and indicates that it has operated owing to ground fault
- Overcurrent trip device which trips the circuit breaker according to overload or ground fault current
- Arc extinguishing device which extinguishes arc generated when current is interrupted
- Terminals for connecting wires and conductors
- Contacts which open and close the circuit
- Test button for checking that the breaker operates upon occurrence of ground fault
- Molded case in which the above parts are contained compactly

Fig. 7. 1 shows an example of arrangement of the above parts.

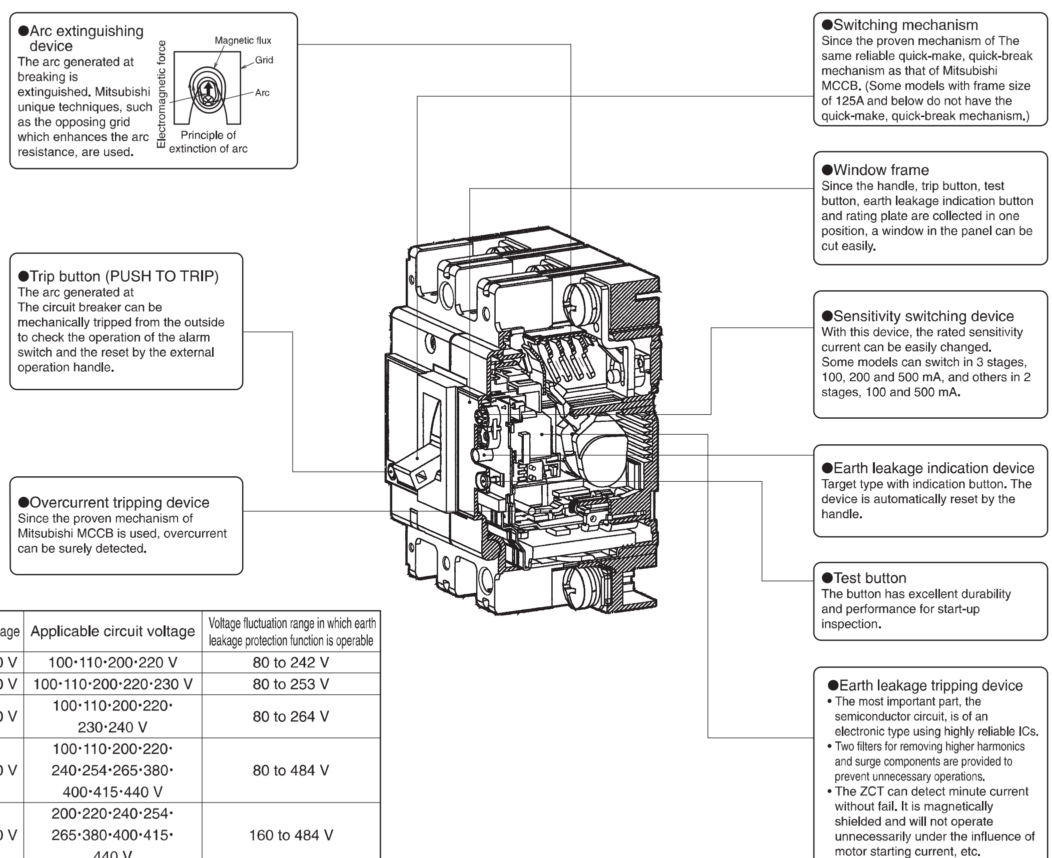
The earth leakage trip device is a current operation type device which detects directly the ground fault current and consists of a primary winding of each phase on the core, a zero-phase current transformer (hereinafter, referred to as ZCT) for detecting zero-phase current (ground fault current), an electronic circuit for amplifying the ZCT output and an electromagnetic device for tripping the circuit breaker.

The operating principle is explained below. See the input/output of ZCT on the circuit shown in Fig. 7. 2. If the circuit is sound, the magnetic fluxes generated by the forward current and return current cancel each other, and voltage is not induced on the secondary winding.

However, if a ground fault occurs, the forward current $\dot{I}_A$ is divided into current $\dot{I}_g$ which returns to the transformer through the earth and currents $\dot{I}_B$ and $\dot{I}_C$ which return through the ZCT. Therefore, the vector sum of the currents which pass through the ZCT is $\dot{I}_A + \dot{I}_B + \dot{I}_C = \dot{I}_g$, and a magnetic flux $\dot{I}_g$ depending on ϕg is generated on the core of ZCT, thereby inducing voltage on the secondary winding.

This signal enters the gate circuit of the thyristor on the electronic circuit to drive the thyristor, and the electromagnetic device connected with the thyristor in series operates to trip the circuit breaker.

In the case of 3-phase, if the circuit is sound even under unbalanced loading under which the currents of the phases are not equal to one another, the sum of currents of the phases is $\dot{I}_A + \dot{I}_B + \dot{I}_C = 0$, and ELCB will not malfunction. (Fig. 7. 3)



Rated voltage	Applicable circuit voltage	Voltage fluctuation range in which earth leakage protection function is operable
100-200 V	100･110･200･220 V	80 to 242 V
100-230 V	100･110･200･220･230 V	80 to 253 V
100-240 V	100･110･200･220･230･240 V	80 to 264 V
100-440 V	100･110･200･220･240･254･265･380･400･415･440 V	80 to 484 V
200-440 V	200･220･240･254･265･380･400･415･440 V	160 to 484 V
380-550 V	380･400･415･440･480･500･550 V	342 to 600 V

Fig. 7. 1 Construction of ELCB

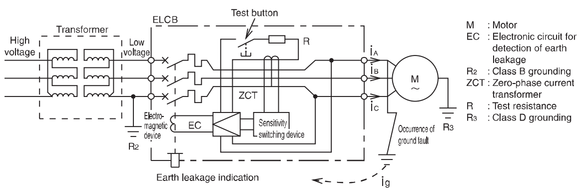


Fig. 7. 2 Circuit configuration of ELCB (TT system)

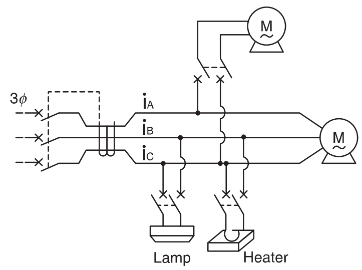


Fig. 7. 3 Unbalanced loads

7.1. 2 Earth leakage tripping device

(1) ZCT (zero-phase current transformer)

The ZCT is a current transformer for detecting minute ground fault current and shall be distinguished from general current transformers (CT). For the ZCT, mainly permalloy, a special material with high magnetic permeability, is used. It consists of a permalloy core, a primary conductor which feeds the main circuit current and a secondary winding on the core. The magnetic fluxes generated by the currents of the phases of the primary conductor are vector-synthesized by the core, and electromotive force is generated on the secondary winding by the magnetic flux according to the difference among the magnetic fluxes of the phases. Therefore, if the vector-synthesized current of the phases is 0, the magnetic fluxes cancel with one another in the core, and electromotive force is not generated on the secondary winding regardless of the magnitude of the primary current. On the other hand, if a ground fault occurs, the current balance among the phases is disturbed, the core is excited by the magnetic flux corresponding to the magnitude of the ground fault current, and electromotive force is generated on the secondary wiring.

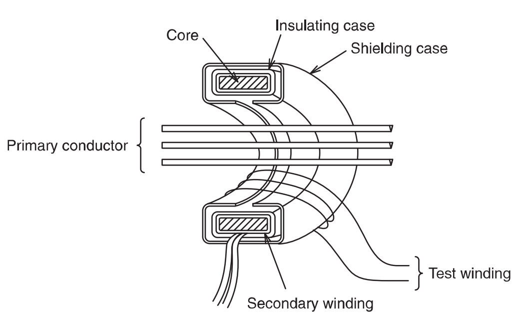


Fig. 7. 4 Structure of ZCT

(2) Electronic circuit

The circuit diagram is shown in Fig. 7. 5. The control power of almost all ELCB is 100 to 440VAC for facilitating selection, storage and maintenance. In addition, models with 100 to 200VAC, 100 to 230VAC, 200 to 415VAC and 200 to 440VAC and with fixed voltage of 100VAC are available.

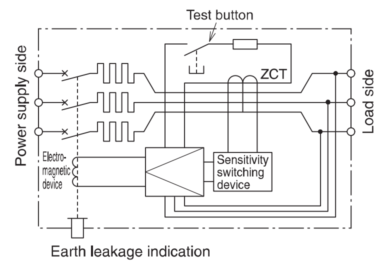


Fig. 7. 5 Internal connection diagrams

① Detection of ground fault on secondary side of inverter

As an example method of detecting the ground fault current on the inverter primary side and secondary side with ELCB installed on the inverter primary side, below is explained the method of detecting ground faults on the inverter secondary side where the waveform distortion is the largest.

a. Spectrum of leakage current on inverter secondary side

Fig. 7. 6 shows the spectrum (200V, Δ connection, one-line grounding, the same hereinafter) of ground fault current caused by the resistance on the inverter secondary side in the case of use of Mitsubishi inverter FR-Z220. The spectrum consists of commercial frequency, inverter operation frequency and carrier frequency components and their harmonic components. The spectrum contains commercial frequency and inverter operation frequency components at the same rate as that of the content of carrier frequency components.

Fig. 7. 7 shows the spectrum of ground fault current on the inverter secondary side including the leakage current caused by earth capacitance in the case of use of FR-Z220. This example simulates a case where the electric circuit on the inverter secondary side is long and its earth capacitance is large. Since the earth impedance caused by capacitance is inversely proportional to the frequency, the content of harmonic components in the carrier is higher compared to in Fig. 7. 6. This content increases in proportion to the earth capacitance and carrier frequency. The content of commercial frequency and inverter operation frequency components is identical to that in Fig. 7. 6.

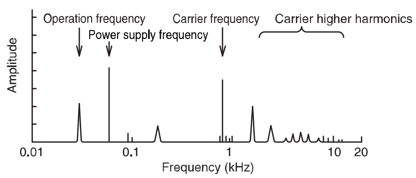


Fig. 7. 6 Spectrum of ground fault current (current caused by ground fault)

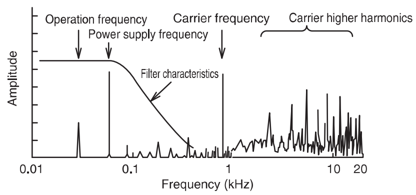


Fig. 7. 7 Spectrum of leakage current (by current caused by earth capacitance and ground fault current)

b. Concept of detection of ground fault on inverter secondary side

To detect ground fault on the inverter secondary side, it is necessary to reduce the influence of leakage current caused by earth capacitance on the secondary side. For this purpose, we used a method to remove the carrier frequency and harmonic content of the carrier which change depending on the earth capacitance and may cause unnecessary operations and unstable sensitivity current with a low pass filter. The filter characteristics are shown in Fig. 7. 7.

IEC 60479-2 presents the frequency characteristics of current value at which ventricular fibrillation is caused by the current passing the human body shown in Fig. 7. 8.

This curve shows that, at frequencies higher than 1kHz used as the inverter carrier frequency, the current value at which ventricular fibrillation occurs to expose the human body to hazardous situation is 14 times or more the value at 50/60 Hz and there is a low risk of electrical shock. Therefore, it is possible to realize stable detection of ground faults while ensuring the safety of human body against electrical shock by removing carrier frequency and the harmonic content of the carrier upon detection and detecting ground faults based only on the fundamental wave components. On inverters, the fundamental wave content is approx. 70% in the ground fault current. This percentage is less affected by the earth capacitance and is in proportion to the magnitude of ground fault current. Therefore, stable detection of ground faults can be realized by judging based on the fundamental wave content.

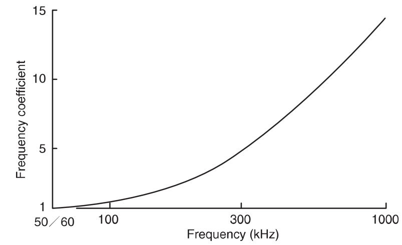


Fig. 7. 8 Current value at which ventricular fibrillation is caused by current passing human body (IEC 60479-2)

c. Structure and operation of ground fault detection circuit

As the low pass filter for removing carrier frequency and harmonic components of carrier, a digital filter was used. On ELCB applicable to higher harmonics and surge, signals from the ZCT are input to the input circuit and converted from analog to digital by the A/D converter. The digitalized signals are input to the low pass filter that is a digital filter. The digital filter is used because the filter provides sharp attenuation necessary for fundamental frequency components and carrier frequency (depending on the inverter type, approx. 800 Hz on low-frequency products) and filter characteristics without attenuating minute ZCT signals, and the filter constant for obtaining a low cutoff frequency can be set without influence on stability of ZCT and electronic circuit characteristics.

Fig. 7. 9 shows the structure of electronic circuit, and Fig. 7. 10 shows the digital filter block diagram. The ground fault current discriminating circuit detects the magnitude of ground fault current and the duration of signal. Fig. 7. 11 shows the function block diagram for explaining the operation. When the ground fault signal level exceeds the detection level, charging of the capacitor is started, and the occurrence of ground fault is detected after a lapse of a certain time. Therefore, relatively small surge current components which are leaked by the earth capacitance are removed. These circuits are contained in one chip as an IC for ELCB.

Fig. 7. 12 shows the effect of digital filter in detection of ground fault current. Comparing the waveforms before and after the digital filter, it is found that the fundamental wave components can be effectively extracted from the leakage current on the secondary side masked by the high frequency components. That is, not only on the primary side, but also on the secondary side, ground faults can be stably detected through the digital filter.

However, for a circuit containing harmonic components, the filter shall be used with load device leakage current distortion of 10kHz or less and at 3A or less because the zero-phase current transformer (ZCT) of the circuit breaker is overheated by iron loss. For circuit breakers with frame size of 800A and above, it is necessary to use the filter with load device leakage current distortion of 5kHz or less and at 3A or less.

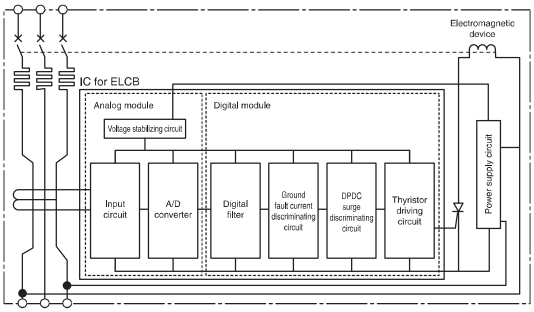


Fig. 7. 9 Structure of electronic circuit

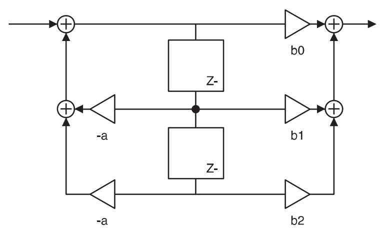


Fig. 7. 10 Block diagram of digital filter

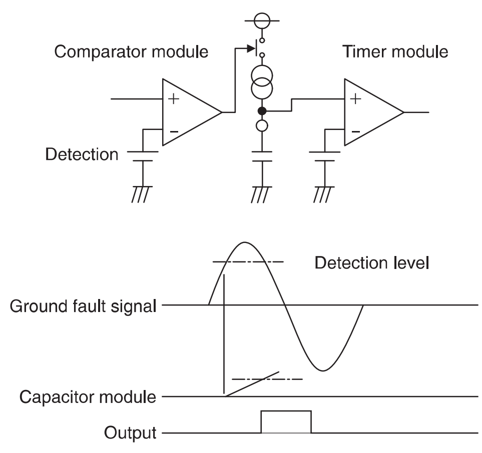


Fig. 7. 11 Function block diagram of ground fault current discriminating circuit

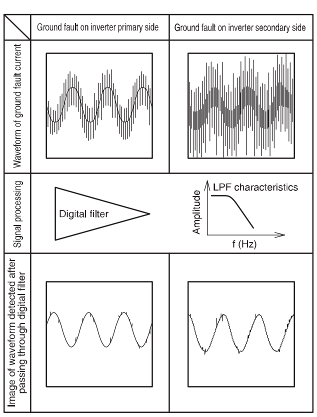


Fig. 7. 12 Effect of digital filter

② **Technique for prevention of unnecessary operations caused by surge**

As an example method of detectings the ground fault current on the ino higher harmonics and surge, signals from the ZCT are input to the input circuit and converted from analog to digital by the A/D converter. The digitalized signals are input to the low pass filter that is a digital filter. The digital filter is used because the filter provides sharp attenuation necessary for fundamental frequency components and carrier frequency (depending on the inverter type, approx. 800 Hz on low-frequency products) and filter characteristics without attenuating minute ZCT signals, and the filter constant for obtaining a low cutoff frequency can be set without influence on stability of ZCT and electronic circuit characteristics.

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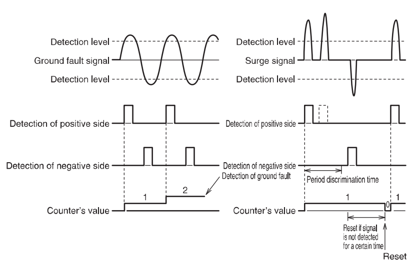


Fig. 7. 13 Operation of DPDC surge

Fig. 7. 14 shows the improvement of the performance to prevent unnecessary operations of ELCB applicable to higher harmonics and surge comparing with that of a conventional model. It was confirmed that no unnecessary operation was caused in any case of gap-less surge absorber and discharge gap type surge absorber. According to the waveforms verified in Fig. 7. 14, the performance to prevent unnecessary operations is improved as stated below.

(1) Resistance to leakage current caused by surge: Three times or more as peak value

(2) Leakage electric power energy (I^2t) caused by surge: 100 times or more

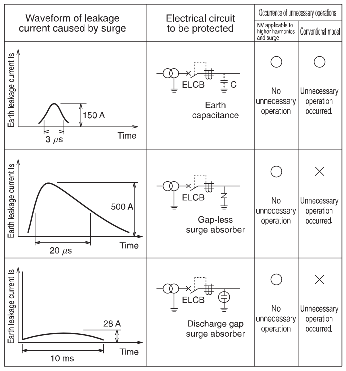


Fig. 7. 14 Performance to prevent unnecessary operations caused by surge

③ Improvement of leakage protection function by type A leakage characteristics

Recently, more machines are provided with inverters and servos to improve the performance and accuracy of drive control. Inverters and servos have rectifier circuits, and if the rectifier circuits go down, leakage current with half-wave rectified waveform or phase-controlled waveform may occur. To detect this leakage current and trip the circuit breakers to prevent electric shock and fire caused by earth leakage, type A (specified by IEC 60947-2) leakage protection characteristics for detection of half-wave rectified and half-wave phase controlled waveforms of leakage current shown in Fig. 7.15 must be provided. Then, we enlarged the leakage protection range by adding a function with the type A leakage characteristics to CE-marked and UL-listed circuit breakers with frame size of 250A and smaller (except some models).

Operation characteristics at ground fault current		
Ground fault waveform / Classification according to IEC 60947-2	AC ground fault	Half-wave rectified ground fault
Type A	○ Detectable	○ Detectable
Type AC	○ Detectable	× Not detectable

Note: Not applicable to complete DC ground faults

Fig. 7.15 Leakage detection characteristics

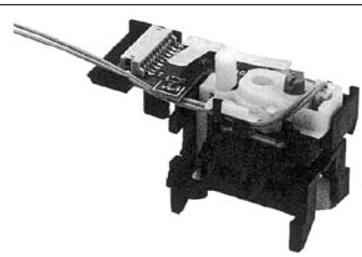


Fig. 7. 16 Example of electromagnetic device

7. 1. 3 Test device

Since electric shock may cause loss of life, it is necessary to check the operation of circuit breaker. The test device forms a ground fault simulation circuit as shown in Fig. 7. 17. Current is applied to the circuit by pressing the test button to make sure that the circuit breaker can operate surely upon occurrence of ground fault. All ELCB circuit breakers are provided with this test device.

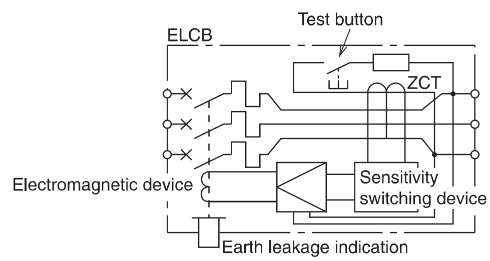


Fig. 7. 17 Circuit of test device

7. 1. 4 Earth leakage indication device

After ELCB operates owing to earth leakage, the earth leakage indication button shows that it has operated not owing to short circuit caused by overload. As shown in Fig. 7. 18, the earth leakage indication button is lower than the surface in the normal state and after the circuit breaker operates owing to overcurrent, but it is protruded when the circuit breaker operates owing to earth leakage.

The button is reset automatically by the handle.

The button will not be damaged even if it is pushed down accidentally. Furthermore, it is designed not to hinder operation owing to earth leakage even if it is pushed down for any reason.

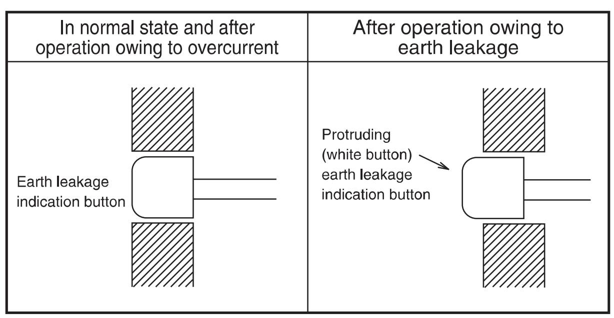


Fig. 7. 18 Indication with earth leakage indication button

7. 1. 5 Trip button

Models with a trip button can be mechanically tripped by pressing this button.

With an alarm switch (AL), it is possible to check the operation of the alarm circuit for tripping owing to overcurrent and, if it has an operation handle, check that the circuit breaker has been reset by the operation handle.

Trip button

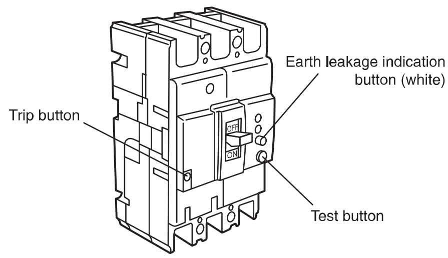


Fig. 7. 19 Example of button positions

7. 1. 6 Sensitivity switching device

With the sensitivity switching device, the rated sensitivity current can be easily and reliably switched.

Some models can switch in 3 stages, 100, 200 and 500mA, and others in 2 stages, 100 and 500mA.

JIS prescribes that a device which can switch the sensitivity between high (30mA or 15mA, operation within 0.1 s) and medium (50mA to 1000mA) levels should not be provided. ELCB of 100AF and smaller do not have this device. Fig. 7. 20 shows an example of the sensitivity switching device circuit.

The sensitivity can be switched by switching the adjusting resistances on the secondary size of the ZCT. The sensitivity on the high level is set by the adjusting resistance R_1, and the sensitivity on the low level is set by connecting the adjusting resistances R_2 and R_3 in series with the switching device. This system ensures safety against contact failure between R_2 and R_3 owing to nonconformity of the switching device because the sensitivity current is determined by R_3 and ELCB operates with high sensitivity.

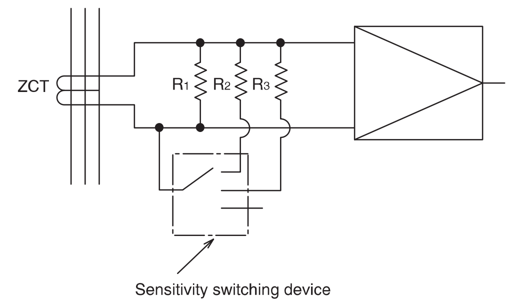


Fig. 7. 20 Example of sensitivity switching device circuit

7. 1. 7 Operating time switching device

The time delay circuit breakers have an operating time switching device in addition to the sensitivity switching device, which can switch the operating time to three stages, 0.45, 1.0 and 2.0 s or to two stages, 0.3 and 0.8 s. With this device, a ground fault protection coordination system can be easily configured.

7. 1. 8 Others

The parts not stated in this section have the same structures as those of MCCB.

7. 2 Earth leakage relays

The major components of earth leakage relays include a ZCT, amplifier, built-in relay, test button, earth leakage indication device dsdssds

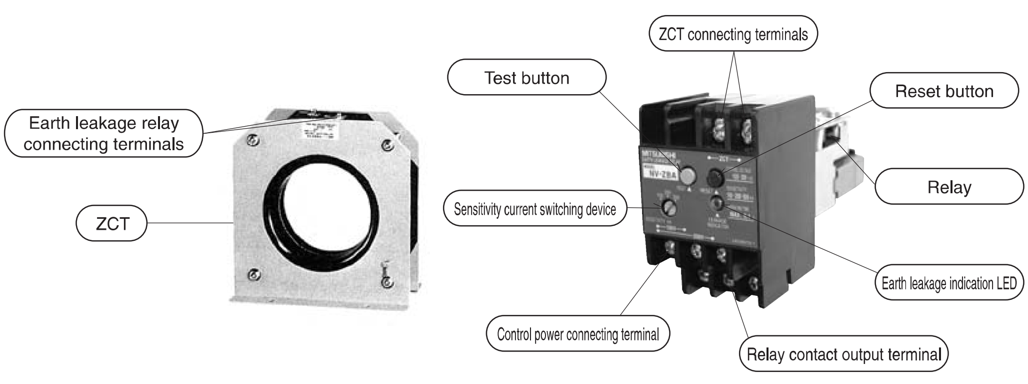


Fig. 7. 21 Structure of earth leakage relay

7. 2. 1 Zero-phase current transformer (ZCT)

The ZCT is designed to detect the zero-phase current on a line and consists of a core made of a magnetic material with high magnetic permeability and a secondary winding on the core. In addition, it is provided with a shield case to prevent changes in sensitivity current under the influence of external magnetic field.

7.2.2 Amplifier

When ground fault current flows, electromotive force is generated on the secondary winding of ZCT. However, this electromotive force is very minute. The amplifier amplifies this minute signal and drives the built-in relay.

7.2.3 Built-in relay

The amplified signal level is compared by the comparison circuit in the amplifier, and, if the level is higher than the specified value, the coil of a small relay is excited. The relay has a built-in contact, which can retrieve an external signal when actuated. An alarm circuit or a breaking circuit can be configured with the aid of this contact.

7.2.4 Test button

The operation upon occurrence of earth leakage can be simulated and checked by pressing the test button. The button is intended to periodically check that the earth-leakage relay can operate correctly.

7.2.5 Earth leakage indication device

When the earth leakage relay operates owing to ground fault, this device indicates the operation. An electric (LED) type and a mechanical (button) type are available. On the electric device, the lamp lights up when the relay operates. On the mechanical device, the indication button protrudes over the cover surface.

7.2.6 Connecting terminals

On the separate type, the relay and ZCT modules are separated. Therefore, it is necessary to electrically connect them. They are provided with connecting terminals.

7.2.7 Structure of each model

Mitsubishi earth leakage relays are classified into the following 6 types according to function and into two types of combination, a compatible type in which any relay and ZCT can be combined and an incompatible type in which the relay and ZCT with the same product number should be combined although the ZCTs of both types have the same appearance. The relay modules vary depending on the function.

(1) NV-ZBA (small-size economical product)

This type has terminals for connecting the two terminals of ZCT to the ZCT terminals on the relay. The relay module has a sensitivity switching device, and the sensitivity can be switched in three stages. On the time delay type, not only the rated sensitivity current, but also the operating time can be switched in three stages.

When a ground fault occurs, the relay will operate according to the signal from the ZCT, the built-in small-size relay will be driven, the signal at the relay output terminal will be switched, and simultaneously the earth leakage indicator lamp (LED) will light up (self-holding type). If the ground fault has been removed, the relay will return to the initial state by pressing the reset button.

If the control power supply is connected to the load side of MCCB to break MCCB by the operation of the earth leakage relay, the reset operation is not required.

(2) NV-ZSA (general-purpose product)

Like NV-ZBA, this type consists of ZCT and relay modules.

The releasing electromagnetic device in the relay module has been developed by Mitsubishi’s unique technology. Since it is a mechanical self-holding device, it can be reset by pressing the reset button serving also for indication of earth leakage. Like NV-ZBA, this model is characterized by the indication of earth leakage left even if the control power is turned off after it operates owing to earth leakage. It cannot be reset by turning off the control power.

(3) NV-ZHA (applicable to higher harmonics and surge)

The fundamental operation and structure of this model are the same as those of NV-ZBA. This earth leakage relay is provided with ICs applicable to higher harmonics and surge having an active filter circuit and a DPDC surge discriminating circuit. It can detect ground faults on the inverter secondary side to improve the performance of prevention of unnecessary operations caused by surge.

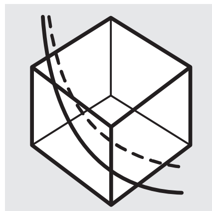
This type complies with various standards (US UL Standard, Canada CSA Standard and European CE Marking).

(4) NV-ZLA (applicable to higher harmonics and surge)

The fundamental operation and structure of this model are the same as those of NV-ZSA. This earth leakage relay is provided with ICs applicable to higher harmonics and surge having an active filter circuit and a DPDC surge discriminating circuit. It can detect ground faults on the inverter secondary side to improve the performance of prevention of unnecessary operations caused by surge.

This type complies with various standards (US UL Standard, Canada CSA Standard and European CE Marking).

It can be used also on 480V circuits.



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ELCB

8 Characteristics and performance

8. 1 Characteristics and types

ELCB are classified into the types shown in Table 8.1 according to the operating characteristics. Select the operating characteristics and sensitivity current depending on the purpose of use.

Table 8. 1 Classification of ELCB according to operating characteristics (IEC)

Operating characteristics		Rated sensitivity current		
Type	Operating time			
Fast-acting type	Within 0.04 sec. at current of 5 times the rated sensitivity current	6m A 10 30 100	300mA 500 1000	3A 10 30
Time delay type	Inertial non-operating time at current of twice the rated sensitivity current: 0.06 sec. – 0.1 sec. – 0.2 sec. – 0.3 sec. – 0.4 sec. – 0.5 sec. – 1 sec.	100mA 300 500 1000	3A 10 30	

8. 2 Impedance and power consumption

Table 8. 2 Impedance and power consumption of Mitsubishi ELCB Model

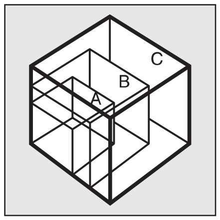
Model	Rated current (A)	Resistance R (mΩ)	Reactance X (mΩ)	Impedance Z (mΩ)	Powerconsumption Pw (W)
NV63-CV	5	105	14.5	106	9.88
	10	7.8	1.69	7.98	4.34
	15	5.6	1.59	5.82	5.78
	20	4.8	1.44	5.01	7.76
	30	3.9	1.20	4.08	12.5
	40	2.8	0.67	2.88	15.4
	50	2.1	0.46	2.15	17.8
	60	1.5	0.39	1.55	18.2
	63	1.49	0.35	1.53	19.7
NV125-CV	60	1.6	0.51	1.68	19.3
	75	1.15	0.31	1.19	21.4
	100	0.68	0.29	0.74	22.4
	125	0.64	0.23	0.68	32.0
NV250-CV	125	0.53	0.15	0.55	26.8
	150	0.51	0.14	0.53	36.4
	175	0.40	0.13	0.42	38.8
	200	0.33	0.12	0.35	41.6
	225	0.30	0.11	0.32	47.6
	250	0.28	0.11	0.30	54.5
NV400-CW	250	0.30	0.14	0.33	58.3
	300	0.22	0.15	0.26	61.4
	350	0.19	0.11	0.22	71.8
	400	0.16	0.11	0.19	78.8
NV630-CW	500	0.12	0.23	0.26	92.0
	600	0.10	0.38	0.39	110
	630	0.10	0.38	0.39	121.1
NV32-SV	5	105	14.5	106	9.88
	10	7.8	1.69	7.98	4.34
	15	5.6	1.59	5.82	5.78
	20	4.8	1.44	5.01	7.76
	30	3.9	1.20	4.08	12.5
	32	3.8	1.11	3.96	13.7
NV63-SV	5	137	16.6	138	12.3
	10	7.8	1.69	7.98	4.34
NV63-SV NV63-HV	15	5.6	1.59	5.82	5.78
	20	4.8	1.44	5.01	7.76
	30	3.9	1.20	4.08	12.5
	40	2.8	0.67	2.88	15.4
	50	2.1	0.46	2.15	17.8
	60	1.5	0.39	1.55	18.2
	63	1.49	0.35	1.53	19.7
NV125-SV NV125-HV	15	16.0	2.54	16.2	12.8
	20	9.0	1.41	9.11	12.8
	30	5.2	1.26	5.35	16.0
	40	2.5	0.64	2.58	14.0
	50	1.8	0.51	1.87	15.5
	60	1.6	0.51	1.68	19.3

Model	Rated current (A)	Resistance R (mΩ)	Reactance X (mΩ)	Impedance Z (mΩ)	Powerconsumption Pw (W)
NV125-SV NV125-HV	75	1.15	0.31	1.19	21.4
	100	0.68	0.29	0.74	22.4
	125	0.64	0.23	0.68	32.0
NV125-SEV	50	0.32	0.29	0.43	4.40
	60	0.32	0.29	0.43	5.46
	75	0.32	0.29	0.43	7.40
	100	0.32	0.29	0.43	11.6
	125	0.32	0.29	0.43	17.0
NV250-SV NV250-HV	125	0.53	0.15	0.55	26.8
	150	0.51	0.14	0.53	36.4
	175	0.40	0.13	0.42	38.8
	200	0.33	0.12	0.35	41.6
	225	0.30	0.11	0.32	47.6
	250	0.28	0.11	0.30	54.5
NV250-SEV	125-250	0.32	0.29	0.43	62.0
NV400-SW	250	0.31	0.25	0.40	60.1
	300	0.23	0.24	0.33	64.1
	350	0.19	0.26	0.32	71.8
	400	0.16	0.22	0.27	78.8
NV400-SEW NV400-HEW NV400-REW	200	0.10	0.31	0.32	14.0
	225	0.10	0.31	0.32	17.2
	250	0.10	0.31	0.32	20.8
	300	0.10	0.31	0.32	29.0
	350	0.10	0.31	0.32	38.8
	400	0.10	0.31	0.32	50.0
NV630-SW	500	0.1	0.38	0.39	92.0
	600	0.1	0.38	0.39	110
	630	0.1	0.38	0.39	121.1
NV630-SEW NV630-HEW	300	0.1	0.31	0.32	29.0
	350	0.1	0.31	0.32	38.8
	400	0.1	0.31	0.32	50.0
	500	0.1	0.31	0.32	77.0
	600	0.1	0.31	0.32	110.0
	630	0.1	0.31	0.32	121.1
NV800-SEW NV800-HEW	400	0.13	0.37	0.39	64.4
	450	0.13	0.37	0.39	80.9
	500	0.13	0.37	0.39	99.6
	600	0.13	0.37	0.39	142.4
	700	0.13	0.37	0.39	193.1
	800	0.13	0.37	0.39	251.6

Notes 1. Values at 50 Hz on front mounting type
2. For 60 Hz, multiply the reactance by 1.2.
3. There are differences depending on the connecting method and product.
4. The power consumption values of 3-pole products determined by the following formula are shown.

$Pw = I^2R \times 10^{-3} \times P + 2$ [W] P : Number of poles
2 : Power consumption of electronic circuit

Remark : 1J = 1W·s



9. Selection

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9 Selection

9. 1 Before selecting rated current sensitivity

The most important factor for selection of ELCB is the rated current sensitivity. The rated current sensitivity should be determined examining various conditions of environment of use of electricity. However, also legal restrictions and measures against unnecessary operations should be taken into consideration. This section describes the factors to be examined in the selection.

9. 1. 1 Legally regulated places

Technical standards for electrical equipment, Labor Safety and Health Regulations and Interior Wiring Regulation specify the rated current sensitivity for some places. When installing ELCB in such a place, select the rated current sensitivity according to the regulations.

9. 1. 2 Selection for prevention of electric shock

For protection from electric shock, in principle, ELCB and protective grounding should be used, and the contact voltage should be reduced to low voltage. Therefore, if two bare live parts are touched even when ELCB is installed, the contact voltage caused by current passing the human body exceeds the allowable contact voltage regardless of protective grounding, and a shock hazard may be caused. ELCB is a device to provide protection against indirect contact described in IEC 60364-4-41. Protection against indirect contact can be provided by appropriately selecting ELCB rated current sensitivity based on the contact voltage and the resistance value of protective grounding. Generally, since the rated current sensitivity is not regulated, it is determined by the formulas (1) and (2) in 6. 4. 2. However, the rated current sensitivity should be selected from 15, 30, 100, 200 and 500mA, and the protective grounding resistance should be controlled to prevent the contact voltage from exceeding the allowable value.

9. 1. 3 Consideration of constant leakage current

From the viewpoint of protection coordination, it is necessary to confirm that unnecessary operations are not caused by constant leakage current originating from earth floating capacitance. Particularly, when selecting a high-sensitivity model, it is necessary to take measures, for example, reducing the wiring length and increasing the distance from the earth, to reduce the constant leakage current.

9. 1. 4 Procedures for selecting rated current sensitivity

The three factors, rated current sensitivity, protective grounding resistance value and constant leakage current on electric circuit, have a relationship with one another. From the viewpoint of electric shock protection, the relationship between rated current sensitivity and protective grounding resistance value is critical, and, from the viewpoint of prevention of unnecessary operations, the relationship between rated current sensitivity and leakage current cannot be ignored. Fig. 9. 1 shows the relationship among them.

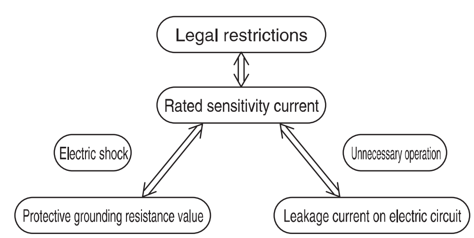


Fig. 9. 1

The factor to be defined first depends on various conditions. Generally, it is better to determine the relationship between rated current sensitivity and protective grounding and check for possibility of unnecessary operations caused by constant leakage current. It is not favorable, from the viewpoint of electric shock protection, to select a model with low rated current sensitivity for reasons of large leakage current on electric circuit except for unavoidable cases.

9. 2 Selection of rated current sensitivity

As a rule, the rated current sensitivity shall be selected based on the theories. However, since the theories contain many assumptions, it is necessary to select the rated current sensitivity referring to practical field data and experiences and observing the regulations if necessary. The actual selection procedures are described below.

9. 2. 1 Selection for electric shock protection

(1) The fundamental concept of prevention of risk of electric shock in the case of indirect contact is reduction of contact voltage value to reduce the passing current to the human body. Therefore, there is a close relationship between rated current sensitivity of ELCB and protective grounding resistance value of device.
If the allowable contact voltage (Table 6. 4 in 6. 4. 2 in "Outline of ELCB") is determined according to the

electrical environment conditions, the rated current sensitivity can be theoretically calculated by the following formula.

$$\text{Rated current sensitivity (mA)} \leq \frac{\text{allowable contact voltage (V)} \times 100}{\text{Protective grounding resistance value of casing of machines and devices } (\Omega)} \quad \cdots\cdots (1)$$

Actually, the protective grounding resistance value cannot be controlled finely. Therefore, the rated current sensitivity is selected from 30, 100, 200 and 500mA, and protective grounding work is performed to sufficiently meet the formula (1).

From the viewpoint of protection coordination, it is necessary to confirm that unnecessary operations are not caused by constant leakage current originating from earth floating capacitance. Particularly, when selecting a high-sensitivity model, it is necessary to take measures, for example, reducing the wiring length and increasing the distance from the earth, to reduce the constant leakage current.

Table 9. 2 Relationship between contact condition and rated current sensitivity

Item \ Contact condition	Class 1	Class 2	Class 3	Class 4
Degree of total danger	Highest	Very high	High	Low
Contact condition	• Most of human body is in water.	• Human body is considerably wetted. • Part of human body is constantly in contact with metallic electric device.	• Degree of danger is high if contact voltage is applied to human body in normal state in cases other than Class 1 and Class 2.	• Degree of danger is low even if contact voltage is applied in the state shown left. • There is no risk of application of contact voltage.
Fundamental concept	• Since the environment of application of contact voltage is severe, it is improper to specify the rated sensitivity current only based on individual elements, such as contact voltage and current passing human body. It is necessary to examine based on the product of current × time. • In underwater environment, a secondary accident may be caused by electric shock, and it is difficult to escape from the environment. Therefore, it is necessary to take measures to quickly and automatically break the electric circuit.	• The degree of danger in the case of application of contact voltage is the same as stated on the left because the human body resistance is regarded as identical to that in class 1 condition. • The difference from class 1 is that the affected range in class 2 is a point while that in class 1 is a surface. The environment of class 1 is underwater, and we cannot easily escape from it, but that of class 2 is the air, and we can easily escape from it.	• The degree of danger in the case of application of contact voltage ranges widely and, in some cases, may be close to the degree in class 2. • The difference from class 1 and class 2 is that no one is in constant contact with an electric circuit even if dielectric breakdown occurs on the circuit. • Since the human body is in the normal state, the human body resistance is relatively high. Therefore, generally, the contact voltage is allowed to be 50V or less, and a circuit breaker which gives an alarm or automatically breaks a circuit upon occurrence of dielectric breakdown may be used.	• If there is no possibility of contact of human bodies with a low-voltage electric circuit and the contact with the circuit is not so hazardous, it may be considered that the protection is primarily unnecessary. But, from the viewpoint of prevention of fire, practically, grounding work corresponding to class 3 work is required.
Electric circuits to be protected	• Electric circuits installed in bathtubs, swimming pools, water tanks, ponds and rice fields	• Water tanks, swimming pools and facilities around ponds and rice fields • In tunnels • When handling metallic electric devices and structures in constant contact with them • Electric circuits in houses and shops • Vending machines and freezing display cases	• General plants • Offices • Buildings and schools	• Electric circuits in locations where no one will touch the circuits • Electric circuits which do not require protective grounding (for example, electrical facilities installed in hidden areas in general places of houses, plants and offices or in high places)
Operating time	Fast-acting type or inverse time type	Fast-acting type or inverse time type	Fast-acting type or time delay type	Fast-acting type or time delay type
Allowable contact voltage	2.5V	25V	50V	Not specified

9. 2. 2 Selection based on leakage current

In many cases, there is some leakage current on electric circuits even if the insulation resistance is normal because earth floating capacitance exists between wire and earth. This leakage current can be approximately calculated if the wire type, wire size and circuit length from ELCB installation point to load device are determined. It is necessary to determine the rated current sensitivity to prevent unnecessary operations of ELCB owing to this leakage current.

(1) Total leakage current on Δ connection 3-phase 3W 200V electric circuit

① Calculation of leakage current from wire
Determine the length of electric circuit, wire type and size on the load side of ELCB, and calculate the leakage current from Attached Tables 4 to 8 in Appendix 10.

② Calculation of leakage current from motor
Determine the motor capacity and the number of motors, and calculate the leakage current using the value shown in the “leakage current at start” column in Attached Table 11 in Appendix 10 for the number of motors to be simultaneously started (generally, 10% of total number of motors are selected starting from that with the largest capacity) or in the “leakage current during operation” column for other motors.
Leakage current from almost all machines, such as air conditioners and machine tools, using motors, may be calculated based on the motor capacity.

③ Leakage current from fluorescent lamp
When lamp is installed directly on steel frame (also when metallic fittings are used): 0.1mA/unit
When lamp is installed on wood or concrete: 0.002mA/unit

(2) Calculation of leakage current on electric circuits by other wiring methods
Determine the leakage current by multiplying the leakage current value obtained in 9. 2. 2 (1) “Total leakage current on Δ connection 3-phase 3W 200V electric circuit” by the multiplying factor shown in Table 9. 3.

Table 9. 3 Table of conversion of leakage current

Kind of electric circuit	Multiplying factor
Single-phase 100V circuit	0.3
Single-phase 3 wire 200V circuit	0.3
3-phase 400V circuit (star connection)	0.7

(3) Inrush current on capacitive circuit
To prevent unnecessary operations, it is important to examine not only the constant leakage current caused by earth floating capacitance of the line, but also the transient leakage current caused by switching surge generated when switches (Magnetic Contactors, MCCBs, etc.) are opened and closed. As an example, the ratio of steady-state value to transient value for a circuit shown in Fig. 9. 2 is determined.

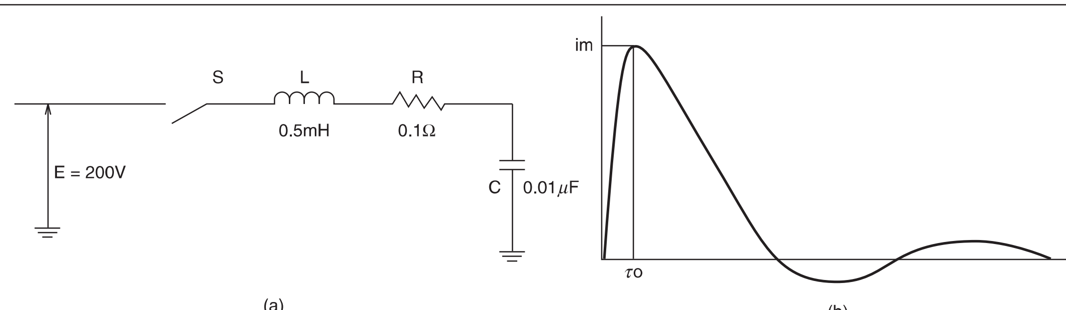


Fig. 9. 2 CapacitormAking current

im and τo in Fig. 9. 2 (b) are obtained by the following formulas.

$$im = \frac{\sqrt{2}\,E}{\sqrt{\frac{L}{C}}}\,\varepsilon - \frac{R}{\sqrt{(4L/C)-R^2}}\arctan\frac{\sqrt{(4L/C)-R^2}}{R} \quad \cdots\cdots \text{Formula (2)}$$

$$\tau o = \frac{2L}{\sqrt{4L/C-R^2}}\arctan\frac{\sqrt{\frac{4L}{C}-R^2}}{R} \quad \cdots\cdots \text{Formula (3)}$$

Assign the values shown in Fig. 9. 2 (a) to these formulas, and the following results can be obtained.

im = 1.26A τo = 3.5μS

Since the steady-state leakage current Ig in Fig. 9. 2 (a) is $R << \frac{1}{\omega c}$ $\omega L << \frac{1}{\omega c}$,

$$Ig = \frac{E}{\sqrt{R^2 + (\omega L - \frac{1}{\omega c})^2}} \fallingdotseq \omega CE = 0.754\text{mA} \cdots\cdots \text{Formula (4)}$$

im/Ig = 1670.

Since current of 1670 times the steady-state current flows to a circuit, it is necessary to examine whether or not ELCB will operate at this pulse current.

As is evident from this example, on a capacitance circuit, even if the constant leakage current is 0.754mA, current of 1670 times (1.26A) the steady-state leakage current may flow in a transient state depending on conditions. The resistance to the transient current varies depending on the manufacture and product. Mitsubishi circuit breakers with rated current sensitivity of 30mA will not operate if the capacitance is lower than the earth floating capacitance (= 0.04μF, 200V). In this case, the constant leakage current Ig is equal to $\sqrt{3}$ ωCE = 5.2mA (60Hz) on a 3-phase 200V Δ connectionn circuit, and unnecessary operations will not occur at a leakage current of 5.2mA or less. However, it is generally desirable that the leakage current is less than 1/10 of the rated current sensitivity to allow some margin.

(4) Selection of rated current sensitivity

After determining the constant leakage current by the above method and further examining the transient inrush current, finally determine the rated current sensitivity.

Table 9. 4 shows the relationship between constant leakage current (the insulation resistance to the earth is generally negligible, and the capacitance has a larger influence) and rated current sensitivity.

Table 9. 4 Selection of rated current sensitivity based on leakage current

Rated current sensitivity	Leakage current on electric circuit	
	200/400V circuit	100V circuit
15mA	1.5mA or less	3mA or less
30mA	3mA or less	6mA or less
100mA	10mA or less	20mA or less
200mA	20mA or less	40mA or less
500mA	50mA or less	100mA or less
1000mA	100mA or less	200mA or less

(5) Example of calculation and selection of leakage current

a. Conditions

① Steel-framed single story plant

② 3-phase 3W 200V Δ connection electric circuit

③ Electric devices

Machine tools (motor capacity of 0.75kW or less): 30 units

2.2kW compressor: 2 units

220W fluorescent lamp: 30 pcs.

④ Wiring with 600V vinyl-coated 14mm^2 wire, circuit length 50m, 2mm^2 × 100m, 1.6ϕ × 1km

⑤ One ELCB installed onmAin circuit

b. Leakage current

As shown in Table 9. 6, the total leakage current is approx. 13mA.

Table 9. 5 Leakage current

Electrical machine	Number of units	Leakage current per unit (mA)	Leakage current (mA)	Remarks
Compressor, 2.2kW	2	0.79	1.58	Value at start shown in Attached Table 11 in Appendix 10
Machine tool, 0.75kW	2	0.35	0.70	
Machine tool, 0.75kW	28	0.12	3.36	Value during operation shown in Attached Table 11 in Appendix 10
Fluorescent lamp	30	0.1	3.00	Value in the case of installation with fittings shown in 9. 2. 2 (1) ③
Electric wire, 14mm^2	50m	22.1/km	1.11	Wiring with vinyl tube along steel frame according to Attached Table 8 in Appendix 10. For 2mm^2 wire, the value for 5.5mm^2 wire in the table is used.
Electric wire, 2mm^2	100m	19.9/km	1.99	
Electric wire, 14mm^2	1km	1.29/km	1.29	Wiring at a distance of 10cm from steel frame according to Attached Table 7 in Appendix 10, value for 5.5mm^2 wire
Total			13.03	

c. Rated current sensitivity

The rated current sensitivity is 200mA from Table 9. 3.

In this case, the use of one ELCB with a sensitivity of 30mA on the main circuit is insufficient. It is necessary to install one circuit breaker on each of the power circuits of compressors and machine tools and lighting circuits.

9. 3 Analysis of unnecessary operations

While the operations of ELCB caused by the intended faults, such as earth leakage, electric shock and ground fault, are considered to be normal operations, the operations caused by other factors, such as surge and induction, are unnecessary operations (nuisance operations or nuisance trips). Many users may think that ELCB operates without reasons and causes troubles. This section analyzes the unnecessary operations of ELCB and describes the correct selection of ELCB.

9. 3. 1 Classification of ELCB operations

The operations are classified as shown below.

- Operations
  - Normal operations
    - (1) Operations owing to earth leakage, electric shock and ground fault
  - Unnecessary operations
    - Caused by ELCB
      - (2) Failure of earth leakage circuit breaker
      - (3) Improper sensitivity current (too sensitive)
    - Caused by circuits, etc.
      - (4) Surge
      - (5) Circulating current
      - (6) Induction
      - (7) Improper connection
      - (8) Improper grounding
      - (9) Influence of ground fault of branch circuit
      - (10) Overload or short circuit
      - (11) Environmental conditions (vibration, impact, etc.)
      - (12) Carrier phone
      - (13) Radio wave
      - (14) Inverter
      - (15) Others (operation of surge absorber, etc.)

9. 3. 2 Details of operations

(1) Normal operations

The normal operations of ELCB refer to the intended operations of ELCB. The major causes of the operations are shown below.

a. Deterioration of machine insulation
   Mainly, machines, such as washing machines, using water and machines, such as presses, receiving high impact.

b. Deterioration of wiring insulation
   Mainly, joints and terminals of temporary electric circuits.

c. Nonconforming work
   Ground fault caused by cables damaged during work and disconnection.

d. Careless handling
   Electric shock caused by submerging and ground fault caused by surge and drop of foreign substances.

(2) Defects of ELCB

Some parts of circuit breakers may be deteriorated and corroded to cause troubles, but the earth leakage detection module causes less defects. Wear of the electromagnet switching mechanism may cause unstable switching. Mitsubishi ELCB have sufficiently improved durability and can be used without concern for these problems. Besides these defects, circuit breakers with low equilibrium characteristics may operate at the start of motor. If the characteristics of the ZCT used in ELCB are inferior or the magnetic shield effect for the ZCT is low, the equilibrium characteristics of the ZCT are deteriorated by the influence of the residual current, and the circuit breaker may operate improperly because electromotive force is generated on the secondary winding of ZCT when the motor starting current (several times the full-load current) flows in the samemAnner as when an apparent ground fault occurs. As the bus-bar current increases, the absolute value of residual current becomes larger. Therefore, it is necessary to pay attention to the influence of residual current on a circuit with large load current. Care must be taken for circuits with unshielded ZCTs.

The residual current characteristics of ZCT vary depending on the coremAterial, conductor position and winding. It is not allowed that the circuit breakers on general circuits are operated incorrectly by the ZCTs. If a low-quality core is used or the ZCT shielding effect is insufficient, malfunction may be caused. For the ZCTs of Mitsubishi ELCB circuit breakers, high-quality Ni-based permalloy having good residual magnetic characteristics is used, and the outer surfaces of ZCTs are covered with a high-quality material having good magnetic characteristics for hydraulic magnetic shielding. Therefore, the influence of residual current on them can be minimized, and they will not malfunction. When unbalanced current occurs on a load, theoretically, ELCB will not operate. However, if a ZCT with low residual current characteristics is used, malfunction may be caused. malfunction at the start of motor or under unbalanced loading is caused owing to improper equilibrium characteristics of ZCT which are based on the residual current characteristics. It is necessary to use the product of a reliable manufacture.

(3) Improper current sensitivity

When the current sensitivity of ELCB is too high for the normal leakage current of a circuit, ELCB operates unnecessarily. This trouble is caused by improper selection of current sensitivity.

In most cases, circuit leakage current is caused by earth floating capacitance of electric wire. However, some electric furnaces and sheathed heaters decrease in insulation resistance at high temperatures although they have sufficient insulation resistance at low temperatures, and it

may take time to reveal the cause of the operation.
In addition to the leakage current in the steady state, the transient leakage current at the switching or start may activate ELCB. The transient leakage at the start is caused through the capacitance to the winding frame because the potential distribution on the winding at the start differs from that during operation.

(4) Operation caused by surge

For the surge caused by secondary shift of induced lightning in distribution line, fig. 9. 3 shows a circuit for test for non-operation at lightning impulse.
When a circuit is affected by induced lightning surge, high voltage is applied to the distribution device through the electric line. At this time, the electronic parts of ELCB may malfunction to trip ELCB or may be damaged to disable ELCB. ELCB for service entrance may be influenced by this high voltage. Special care must be taken for this influence.
The magnitude and frequency of surge voltage carried by the induced lightning significantly vary depending on the region also in Japan. Statistically, in most cases, the surge voltage is 5kV or less. Although large induced lightning surges corresponding to 6 to 7kV have been recorded several times a year, it is generally allowed to think the surge voltage is about 5kV. Mitsubishi ELCB use electronic parts which have sufficient characteristics to cope with such phenomena. However, in many cases, as shown in Fig. 9. 4, the switching surge generated when the circuit is opened or closed by the inductive load switch S is not a single pulse unlike induced lightning surge, but a continuous pulse. Since the non-operating performance for continuous pulse is different from that for single pulse, it is necessary to improve the performance for continuous pulse. Mitsubishi ELCB have sufficient non-operating performance for continuous pulse and can be used reliably. However, it may be helpful to be well acquainted with this property.

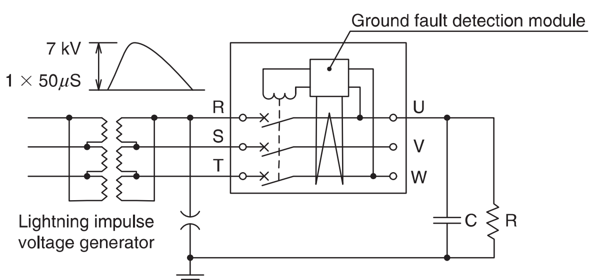


Fig. 9. 3 Test circuit for non-operation at lightning impulse

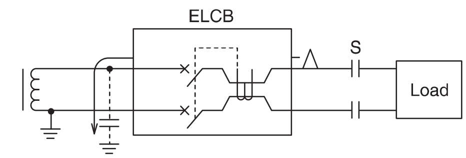


Fig. 9. 4 Switching surge

① The switching surge is not always caused when the current of inductive load is large. It occurs rather easier when the load current is low, 1 to 2A, and the load inductance is large. Attention must be paid to magnetic coil loads, such as magnetic switch coil current.
② The magnitude and repetition of surge depend on the performance of the switch S shown in Fig. 9. 4.
If the switch S causes chattering or a vacuum switch having too high breaking performance is used, surge is easily generated. Therefore, as the switch S, a device with less chattering and high current cutting performance is favorable. General magnetic relays are regarded as relatively useful.
③ To prevent switching surge, it is effective to add an arc reduction device, such as C or R, between the contacts of switch S or install a surge absorber on the load side.

Since the distribution line and load device have capacitance to the earth (earth floating capacitance), the charge current flowing through the earth floating capacitance may instantaneously increase when switches are closed under adverse conditions with non-simultaneous operations of contacts upon closing of switches and the above-mentioned surge voltage, and, if the charge current exceeds the rated non-operating current value, ELCB may operate. Electric circuits have various degrees of capacitance to the earth, but zero-phase current is not generated in the steady state if the capacities of the phases are well-balanced. However, switching surge is caused owing to contact chattering, the voltage phase will be disturbed, high-frequency voltage will occur, the impedance by the earth floating capacitance will decrease, and excessive charge current will flow, and, as the result, electromotive force will be generated on the ZCT secondary winding to activate ELCB. Therefore, a filter is provided on the ZCT secondary side to prevent the thyristor from responding to extremely short-time output of ZCT secondary winding owing to the surge voltage, and a surge absorbing circuit is installed to protect the electronic components against excessive leakage and large ground fault current. Most of Mitsubishi MCCB are provided with DPDC surge discriminating circuits for discriminating the ground fault current and the transient leakage current caused by surge to improve the performance to prevent unnecessary operations and will not malfunction on general circuits.

(5) Operation caused by loop circuit (circulating current)

As on parallel circuits connected on the load side as shown in Fig. 9. 5, the branch currents of each phase at the right and left branches are not always equal to each other. For example, when the current of phase A is divided into 11A and 9A, current of 1A is continuously flowing in this loop. This circulating current causes ELCB to operate. Therefore, use of two ELCB in parallel must be avoided. If earth leakage is detected on the ground wire of each transformer in the case of parallel operation of two transformers as shown in Fig. 9. 6, circulating current will flow through the ground wire owing to unequal division of current, thereby causing ELCB to operate. As a method to avoid this, the circuit may be configured as shown in Fig. 9. 6 (B).

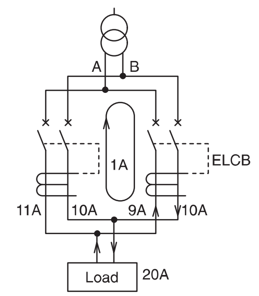


Fig. 9.5 Parallel circuit

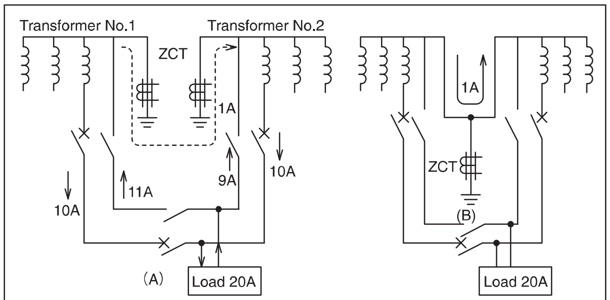


Fig. 9. 6 Parallel operation of transformers

(6) Operation caused by induction

A circuit contains a loop circuit as stated in (5) is easily affected by induction. That is, if the loop shown in Fig. 9. 5 is considered to be a loop antenna, the ZCT primary winding is connected to the antenna and easily generates induction. As an example, assume tha t the loop area is $1m^2$, and a 200A heavy current source is located at a distance of 5m (see Fig. 9. 7). When the circumference of a circle with a radius of 5m is the magnetic path length, the magnetic field strength H (AT/m) is:

$$H = \frac{AT}{2\pi R} = \frac{200}{31.4} = 6.37 \quad AT/m$$

Then, when $\mu = \frac{1}{800000}$,

$B = \mu H = 8 \times 10^{-6} Wb/m^2$ is the average magnetic flux density. The loop area is $S = 1\ m^2$, the total magnetic flux ϕ is:

$$\phi = BS = 8 \times 10^{-6} Wb.$$

The induced voltage E is $E = 4.44\ fN\phi$. However, since f = 60Hz and N = 1,

$$E = 2.12 \times 10^{-3}\ V.$$

Since the resistance R of 38-mm^2 wire 4m long is $R \fallingdotseq 1.92 \times 10^{-3}\Omega$, the circulating current I flowing in the loop is:

$$I' = \frac{E}{R} = 1.1A$$

This value is sufficient to activate ELCB with current sensitivity of up to 500mA. Actually, since the power supply is not isolated only in one direction, the influence of induction will be lower than the above calculation result. For example, when a single-phase power supply is used and other phases are at a distance of 5.2m from the power supply, the circulating current I' is $\frac{0.2}{5.2}$ of the above value:

$$I' = 0.04A.$$

This value is sufficient to activate ELCB with current sensitivity of 30mA.

As stated above, loop circuits are unfavorable from the viewpoint of induction. It is desirable to avoid such circuits.

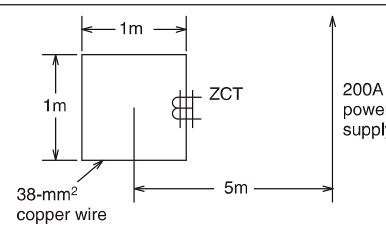


Fig. 9. 7 Loop antenna

If a ZCT is installed on the solid line in the figure when a common ground wire is used as shown in Fig. 9. 8, the primary conductor of the ZCT forms a loop. To avoid this, it is desirable to install the ZCT on the dashed line.

Induction can be caused also on the input circuit of an earth leakage relay. Therefore, the lead wires between the relay and ZCT must be twisted.

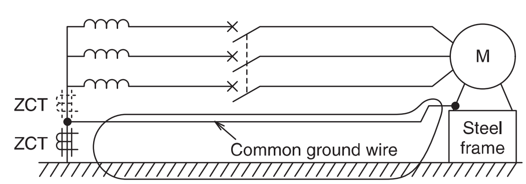


Fig. 9. 8 Detection of ground fault by ground wire

(7) Operation caused by improper connection

Simple errors, such as failure in passing the neutral line to the ZCT in Fig. 9. 9, can occur. In the case of Fig. 9. 9, ELCB will operate owing to single-phase load current.

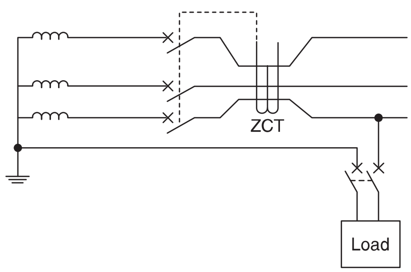


Fig. 9. 9 Improper connection of 3-phase 4-wire circuit

The TN-S system has the same circuit configuration as shown above. Care must be taken when using the system.
To the contrary, if a line not to be passed through the ZCT is passed through the ZCT, the circuit breaker may not operate when earth leakage occurs (see Fig. 9. 10). Therefore, do not pass the common ground wire through the ZCT.
The TN-C system corresponds to this.

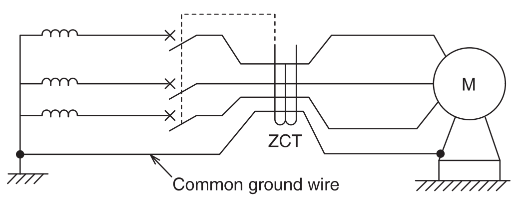


Fig. 9. 10 Improper connection of common ground wire

If grounding work has been performed for the metallic conduit or metallic shield of cable on the power supply side of the ZCT position as shown in Fig. 9. 11, ELCB may not normally operate when leakage occurs in the metallic conduit.
In this case, move the ground wire to the load side of the ZCT, or install the ZCT in a place other than the metallic conduit. If this is difficult, it is necessary to remove the metallic parts from the area of installation of the ZCT or take other proper measures.
If grounding is provided in two places, on the power supply side and the load side, in Fig. 9. 11, a loop as the primary conductor of ZCT is formed by the metallic conduit, ground wires and earth, and the circuit breaker may malfunction owing to the induction stated in (6).

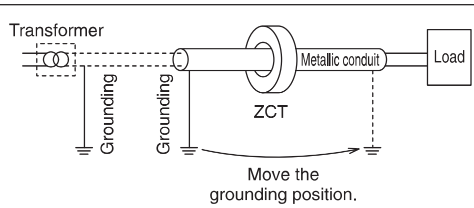


Fig. 9. 11 Grounding for metallic conduit

(8) Operation caused by improper grounding

The wire of a single-phase grounding delta circuit as shown in Fig. 9. 12 should not be grounded also on the load side.
In Fig. 9. 12, part of the load current is divided to I'_T by the voltage drop of the electric circuit on the grounding side, and ELCB is operated. (In addition, in Fig. 9. 12, the circuit breaker may not operate even if current leaks from the motor.)

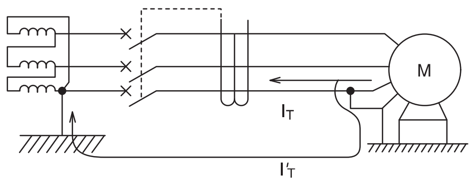


Fig. 9. 12 Improper double grounding

When the purchased power-private power line is switched, the neutral line must be switched simultaneously. If the line is not switched simultaneously as shown with the dashed line in Fig. 9. 13, the neutral line return current IN will be divided into IN and I'N shown in the figure, and ELCB on this circuit will operate.

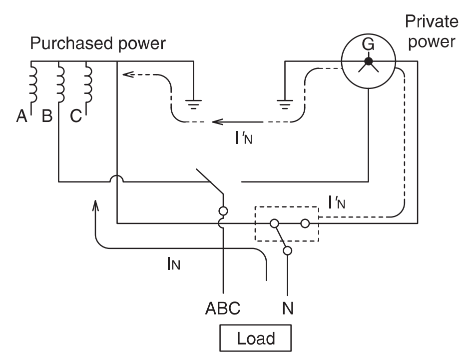


Fig. 9. 13 Simultaneous switching of neutral line

On machines (electronic calculators, numerically-controlled machine tools, etc.) using electronic circuits, filters are often used as measures against noise on the electronic circuits.
If a line filter is used as shown in Fig. 9. 14, current flows as shown with the dashed line to activate ELCB. To avoid this, an insulating transformer should be used in the power supply unit of the electronic machine.
On home-use audio equipment of auto transformer or transformer-less type, part of the return current I^2 leaks through the chassis earth as shown in Fig. 9. 15 to activate ELCB.

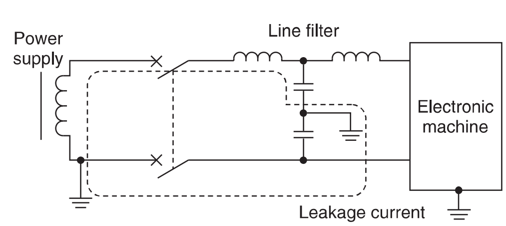


Fig. 9. 14 Line filter

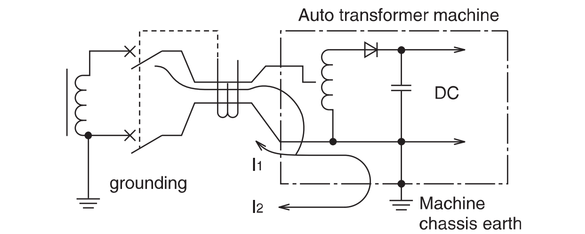


Fig. 9. 15 Chassis earth of transformer-less machine

On a system using a ZCT to detect zero-phase current for detection of ground fault, care must be taken for connection of neutral line. The neutral line on a single-phase 3-wire or 3-phase 4-wire circuit must pass through the ZCT without fail. In addition, the neutral line must be insulated from the earth, and the neutral line of each system must be electrically independent.
When a ZCT is installed at each of the branches A and B in Fig. 9. 16, it is necessary to configure the circuit so that the neutral lines are not electrically connsected directly or indirectly through the earth. If they are connected correctly, the current at the branch A is $i_{1a} + i_{1b} + i_{1c} + i_{1N} = 0$, and that at the branch B is $i_{2a} + i_{2b} + i_{2c} + i_{2N} = 0$. No electromotive force occurs in each ZCT, and the ZCT will detect ground fault current when ground fault occurs.
However, if the neutral lines at the branches A and B are connected through the earth, $i_{1a} + i_{1b} + i_{1c} + i_{1N} = i_{2a} + i_{2b} + i_{2c} + i_{2N} = i_{0N}$ unless they are in full balance, and the ZCTs will detect current of i_{0N} and operate even when ground fault current does not flow.
As stated above, for detection of ground fault, if the connection of neutral lines is improper, troubles can occur. Therefore, wiring work for ground fault detection shall be performed more carefully compared to that without ground fault detection.

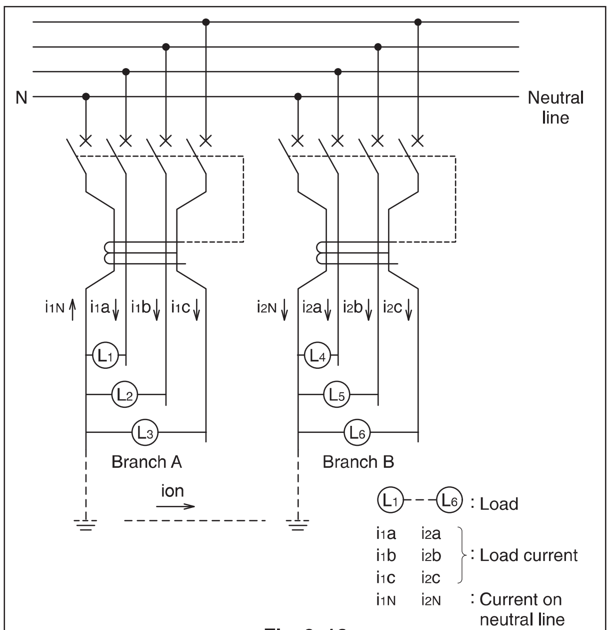


Fig. 9. 16

(9) Operation of sound circuit upon occurrence of ground fault of branch circuit

Circuits may be configured as shown in Fig. 9. 17, and ELCB not only on the ground fault circuit, but also on the sound circuit may operate. This can be prevented by using ELCB with current sensitivity appropriate to the leakage current caused by earth capacitance.

(10) Operation owing to overload or short circuit

It is normal that circuit breakers with overload and short circuit elements operate upon occurrence of short circuit. Most of ELCB are designed both for these factors, and you may forget that they can operate upon occurrence of overload or short circuit.
Furthermore, since the equilibrium characteristics of ELCB

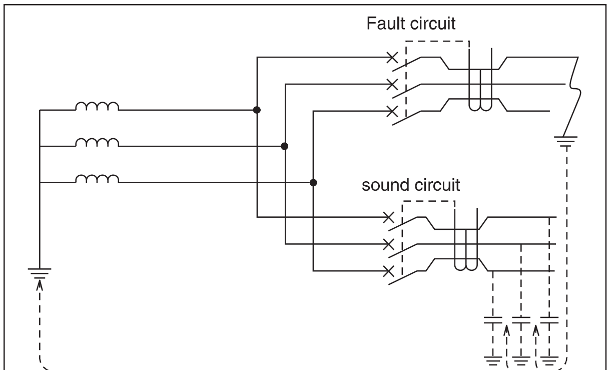


Fig. 9. 17 Operation on sound circuit owing to earth capacitance

are restricted, even those for ground fault may operate at large overload or short circuit. However, in this case, you will notice such a large overload or short circuit.

(11) Environmental conditions, such as vibration, impact and high temperature

The influence of these conditions on ELCB can be considered to be almost identical to that on MCCB. Although the heat resistance of electronic circuits is often regarded as unreliable, Mitsubishi ELCB have a sufficient margin for the rating of parts and use parts which can withstand high temperatures and is containing temperature compensation circuits to stably operate at various ambient temperatures.

(12) Operation caused by carrier phone

If ELCB is installed on an electric circuit where a carrier phone unit for communication through power line is installed, ELCB may malfunction.
Since the carrier phone unit is a unit which forcibly inserts high frequency signals (normally, 50 KHz to 400 KHz) between electric circuit and earth as shown in Fig. 9. 18, ELCB detects the high frequency signals as leakage current andmAlfunctions.
Whether or not ELCB malfunctions depends on the magnitude of high frequency signal and the high frequency characteristics and rated current sensitivity of ELCB.

To prevent this malfunction, it is effective to use ELCB whose current sensitivity for high frequency current has been intentionally reduced. For determination of the specifications, consult us.

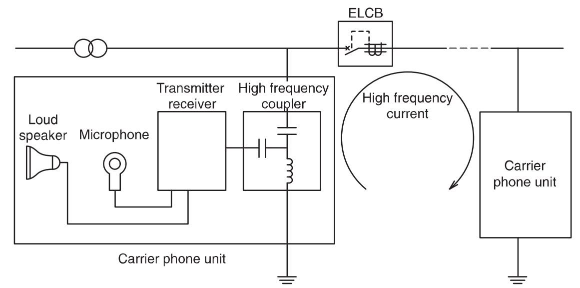


Fig. 9. 18 Example of installation of carrier phone unit

(13) Operation caused by radio wave

In the case where there is a large-output broadcasting station, taxi radio station or amateur radio station near a circuit with ELCB, ELCB may operate unnecessarily if the strength of radio wave, frequency, weather, landform and wiring method adversely affect them. Particularly, when signals from a portable transceiver are received near ELCB, high magnetic field strength is generated, and unnecessary operation can be easily caused.

Generally, portable transceivers are used in frequency bands of 27/28MHz, 50/60MHz, 150MHz, 400MHz and 90MHz, and their output is about 0.5 to 5W. Mitsubishi ELCB have been confirmed to cause no unnecessary operations when various commercially available transceivers with output of 5W transmit signals at a distance of 1m from ELCB. If it is expected that a stronger magnetic field will be generated, house ELCB in an iron box, and ground the box. The unnecessary operations can be prevented by installing a capacitor of hundreds to thousands pF as shown in Fig. 9. 19.

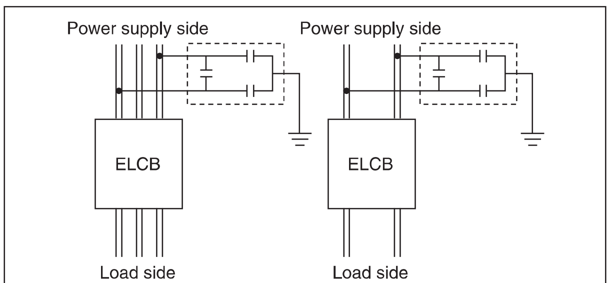


Fig. 9. 19 Installation of capacitor for prevention of unnecessary operations

(14) Operation caused by inverter

Since these high frequency components are constantly carried by the earth floating capacitance, ELCB may operate unnecessarily when the earth floating capacitance is increased. (Fig. 9. 20)

Therefore, when using a general ELCB on an inverter circuit, it is necessary to select one with current sensitivity lower than usual to prevent unnecessary operations.

To ensure high-sensitivity detection of ground fault on an inverter circuit and realize stable detection of ground fault on the primary and secondary sides of the inverter, it is suitable to use ELCB applicable to higher harmonics and surge which is hardly affected by high frequency components so that it can be used for inverter.

ELCB shall be installed on the inverter primary side. Never install it on the secondary side.

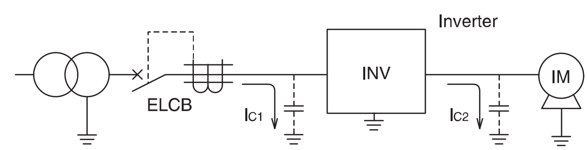


Fig. 9. 20 Circuit with inverter

(15) Others

As the electronics technologies are increasingly applied to load devices, in many cases, surge absorbers are installed in the devices or on the electric circuits to protect the devices from surge. The surge absorbers connected to the earth, which discharge surge to the earth, generate large transient leakage current although for a short time and may cause unnecessary operations of ELCB (Fig. 9. 21).

Most of ELCB are provided with DPDC surge discriminating circuits for discriminating ground fault current caused by faults, such as insulation failure, and the transient leakage current caused by surge to improve the performance to prevent unnecessary operations even if surge absorbers are installed between them and the earth.

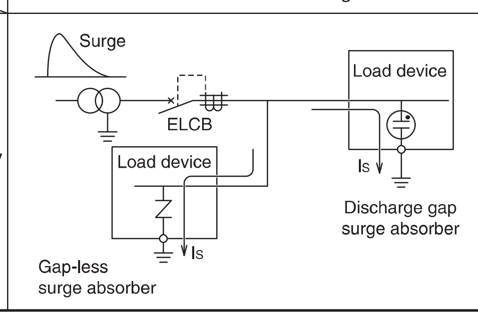
	Circuit and route of earth leakage current
When load devices are protected by surge absorbers	

Fig. 9. 21 Transient leakage current caused by surge absorbers

Selection ELCB

9. 3. 3 Summary of unnecessary operations

The unnecessary operations of ELCB are described above. We have taken all possible measures against unnecessary operations caused by ELCB. Therefore, they will not cause any problem under normal working conditions. Almost all unnecessary operations are caused by factors of circuits. Most of unnecessary operations can be prevented by taking special care when wiring and connecting ELCB and selecting their installation locations and current sensitivity.
It is desirable to carefully examine the earth floating capacitance to the earth and the rated current sensitivity at the stage of design.

9. 4 Protection from arcing ground fault

9. 4. 1 Actual condition of arcing ground fault

General ground faults are caused by contact of electric circuits or electrical equipment with the earth at a resistance value lower than the normal insulation resistance value and include faults caused by electric shock and earth leakage and ground fault, and the ground fault current ranges from several mA to thousands A depending on the earth voltage and ground impedance. For prevention of these ground faults, high speed type ELCB or earth leakage relays are used at branches, and a time delay type ELCB or earth leakage relay is used on the main line for coordination of operating time. This method is gradually coming into use. The method ensures protection from general ground faults and limits damage to the faulty parts, and the damage is relatively minimal.
To the contrary, upon occurrence of arcing ground fault, an electric circuit or device is connected with the earth through arc, the fault current value is restricted to about 30% of the 3-phase short circuit current owing to arc voltage drop and earth resistance. Therefore, on a circuit using only general circuit breakers, the arcing ground fault current does not reach the instantaneous tripping area of any circuit breaker, and the arc may be kept for a long time. When a time delay type ELCB is used, since its operating time is long, the arc is kept during the operating time. If arcing ground fault continues, the electric circuit and device will be significantly damaged by a large amount of thermal energy generated by the arc, and other sound devices may be affected because the arc point moves. The best-known accident caused by arcing ground fault is the fire accident of a large apartment house in New York. In this accident, arcing ground fault continued for 1 hour on a 480/277V distribution circuit, the distribution board is burned out, and the 5000A bus bar burned out to the starting point. As the result of this, the lifts, lamps and feed pumps were stopped, and approx. 10,000 residents of the apartment house were forced to live rough, and several days were taken to restore the facilities. As stated above, when arcing ground fault continues, unlike in the case of general ground fault, electric circuits and devices are considerably damaged, and there is a possibility of damage to other devices.

9. 4. 2 Damage to electric circuits and devices by arc

(1) Arc energy and damage to devices

The scale of arcing ground fault is indicated not only by the ground fault current value, but also by the arc energy determined by the ground fault current, arc voltage and sustaining cycle and can be determined by the following formula.

$$Pa = \frac{Ig \times Ea \times t}{1000} \quad \cdots\cdots (1)$$

Where, Pa : arc energy [kW-cycle]
Ig : Ground fault current RMS value [A]
Ea : Arc voltage [V]
t : Sustaining cycle of arc [cycle]

Table 9. 7 shows the arc energy obtained by the above formula and the degree of damage to devices determined according to the results of various tests.
The limit of arc energy is 2000kW-cycle.

Table 9. 7 Arc energy and damage to devices

Arc energy	Degree of damage to devices
100kW-cycle	Spots and traces of smoke are left on device mounting panel, but there is no real damage.
2,000kW-cycle	The mounting panel is melted but not holed. The conductor exposed surfaces are not fused. The device insulated parts are spoiled by arc, but the insulation can be restored by cleaning. It is necessary to limit the arc energy to this level.
10,000kW-cycle	The metallic fittings and conductor exposed surfaces are considerably melted and damaged by arc, but the arc is within the box and does not spread to other boxes or panels. The box or panel where the arc occurred loses its functions.
20,000kW-cycle	The arc cannot be contained within the box or panel, damages the case and spreads to adjacent boxes or panels.

(2) Minimum sustaining current of arcing ground fault

The minimum sustaining current of arcing ground fault is up to about 350A although it significantly changes depending on the gap, pole arrangement at arc point and shape. If the sustaining current lowers below this value, the arc will become unstable and spontaneously disappear.

(3) **Transition from arcing ground fault to phase-to-phase arcing short circuit**

In most cases of normal metallic panels, if arcing ground fault does not spontaneously disappear, arcing ground fault changes to phase-to-phase arcing short circuit. The transition time varies significantly from several ms to hundreds ms depending on the device layout, gap and arcing ground fault current. Fig. 9. 22 shows the oscillogram in a case of transition from arcing ground fault to phase-to-phase arcing short circuit. In this case, the ground fault arc energy is 215kW-cycle, and the phase-to-phase arc energy is 2250kW-cycle. The damage caused by the phase-to-phase arc is larger.

According to the above, it is found that:

○ The arcing ground fault can occur on electric circuits on which ground fault current of 350A or more flows.

○ It is necessary that electric circuits must be broken quickly while the arc energy is within 2000kW-cycle.

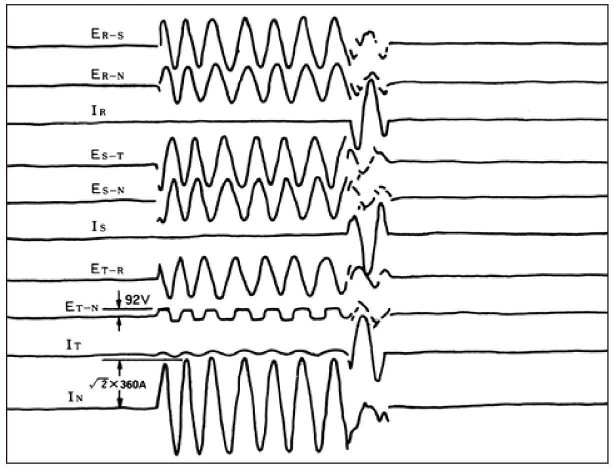


Fig. 9. 22 Example of MCCB breakng for phase to phase arcshort circuit caused by arc ground fault

9. 5 Ground fault protection coordination

Since the ground fault current changes from several mA to thousands A, the selective protection coordination shall be examined in the remarkably wide range. When a selective breaking system is used, coordination cannot be achieved only based on the difference in rated current sensitivity. Fig. 9.23 shows the operating characteristics of ELCB by single lines. Selective coordination between ELCB1 with sensitivity of 30mA and high-order ELCB2 with sensitivity of 200mA can be achieved at a ground fault current of 150mA or less. But, at a ground fault current exceeding 150mA, there is a strong possibility that both ELCB1 and ELCB2 will operate because they are high speed circuit breakers with operating time of 0.1 sec or less. Therefore, the selectivity shall be examined in consideration of the rated current sensitivity and operating time.

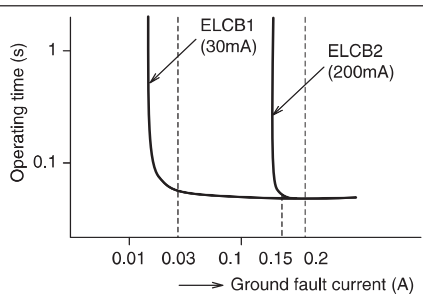


Fig. 9. 23 Operating characteristics of high speed MCCB

9.5.1 Ground fault protection coordination by time delay circuit breakers

In many cases of prevention of electric shock and ground fault at terminals, circuit breakers with high sensitivity (30mA or so) having the highest protection effect are used. For long systems, since faults between transformer and branches can occur, MCCB are often used also on the main lines for protection between them. In such a case, if selective coordination is not achieved on the whole circuit, the high-order ELCB will operate upon occurrence of ground fault, other sound circuits will be broken, and power supply cannot be continued. Therefore, it is necessary to examine the coordination.

Fig. 9. 24 shows an example of a coordination system using time delay circuit breakers, and Fig. 9. 25 shows the coordination diagram of ELCB1, ELCB2, ELCB3 and ELCB4 on the system shown in Fig. 9. 24. If a ground fault of several A occurs at the point A, ELCB4, which is a high speed circuit breaker, will operate within 0.1 sec. The high-order ELCB3 which is a time delay circuit breaker with operating time of 0.3 sec has a longer operating time than the total breaking time of ELCB4 at the branch. Therefore, selective trip can be ensured ly. On time delay circuit breakers, the inertial non-operating time is shown. The circuit breakers will not operate within the time even if ground fault current is flowing. The minimum value of the time is 0.1 sec. Therefore, coordination between the time delay and high speed types can be easily obtained as in this case.

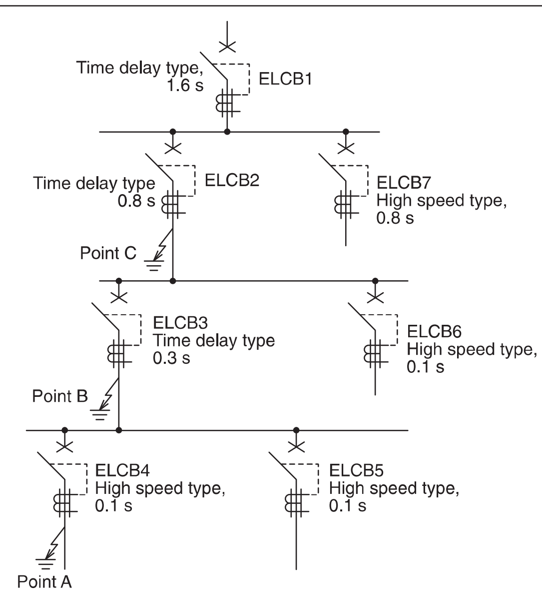


Fig. 9. 24 Example of coordination system with time delay circuit breakers

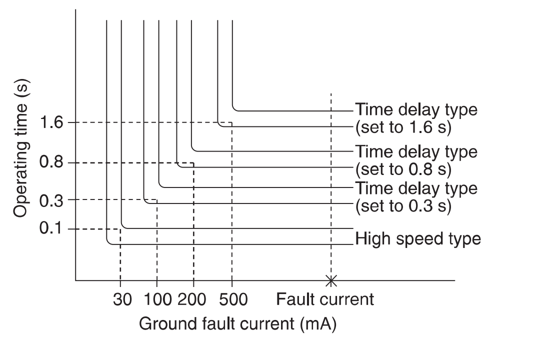


Fig. 9. 25 Coordination characteristics of time delay circuit breakers

Similarly, since the inertial non-operating time of ELCB1 and ELCB2 is longer than the total breaking time of ELCB4, ELCB3, ELCB2 and ELCB1 will not operate upon occurrence of fault.
When a fault occurs at the point B, since the inertial non-operating time of ELCB2 and ELCB1 is longer than the total breaking time of ELCB3, coordination between ELCB3 and ELCB2 and ELCB1 can be achieved, and power supply to ELCB6 can be continued.
Also when a fault occurs at the point C, coordination between ELCB2 and ELCB1 can be achieved, and power supply to ELCB7 can be continued.

9. 6 Application to concrete electric circuits

9. 6. 1 Branch circuits

Branch circuits are closest to devices and operators and, therefore, involve a high risk of electric hazard. Except for special cases, the use of high-sensitivity circuit breakers (30mA or so) is desirable. For outlets in western style bathrooms, vending machines, machines using midnight power and mobile and portable motor-driven machines, high-sensitivity high speed circuit breakers should be used.
Generally, since branch circuits are shorter and have lower earth floating capacitance, the risk of unnecessary operations is low even if high-sensitivity circuit breakers are used. However, if the earth floating capacitance is increased, it is better to reduce the constant leakage current through improvement of branch wiring method and use high-sensitivity circuit breakers.
Under some conditions, it is difficult to use high-sensitivity circuit breakers. In such a case, as stated in 9. 2. 2 "Selection for electric shock protection for general equipment," use medium sensitivity circuit breakers with sensitivity of 100mA, 200mA or 500mA reducing the class D grounding resistance value to prevent the voltage from exceeding the allowable contact voltage.

9. 6. 2 Main circuits

ELCB installed on main circuits shall be capable of providing selective coordination with ELCB on branch lines and protecting the electric circuits from ground fault of the main lines. The most common and simplest method is to use medium sensitivity time delay ELCB, and this method is economical.
Note that since the rated non-operating current of ELCB is 50% of the rated current sensitivity, the rated current sensitivity of ELCB for branch exceeds the rated non-operating current of ELCB for main line if the rated current sensitivity of ELCB for branch is too close to that of ELCB for main line, and selectivity cannot be obtained. Therefore, the current sensitivity of branch and that of main line shall be different desirably by 2.5 times.
Table 9. 8 shows the relationship between rated current sensitivity of ELCB for branch circuit and that for main circuit.

Table 9. 8 Relationship between rated current sensitivity of ELCB for branch circuit and that for main circuit

Rated current sensitivity of ELCB for branch	Rated current sensitivity of ELCB for main line
15 · 30	100 · 200 · 500
100 · 200	500 · 1000
500	1000

9. 6. 3 Detection of ground fault by ground wire

One of the methods for protecting the whole electric circuit from ground fault is detection of ground fault by ground wire. As shown in Fig. 9. 26, only the ground wire of power supply is passed through the ZCT. When the circuit is broken, it is protected by the earth leakage relay combined with MCCB with SHT.

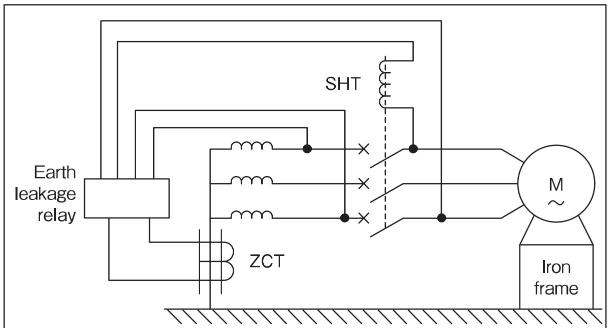


Fig. 9. 26 Ground fault protection by ground wire

9. 6. 4 Arc welder circuits

In many cases, an arc welder is moved in a working site during use. Therefore, there is a possibility that the workers may touch the insulated wires or movable cables on the primary side. In such a case, it is desirable to install ELCB.
Therefore, ELCB are used in many cases. ELCB for arc welders must not malfunction with an instantaneous transient phenomenon at the start of arc welding.
Therefore, some manufacturers separate the circuit breakers for arc welders from others. Mitsubishi ELCB of

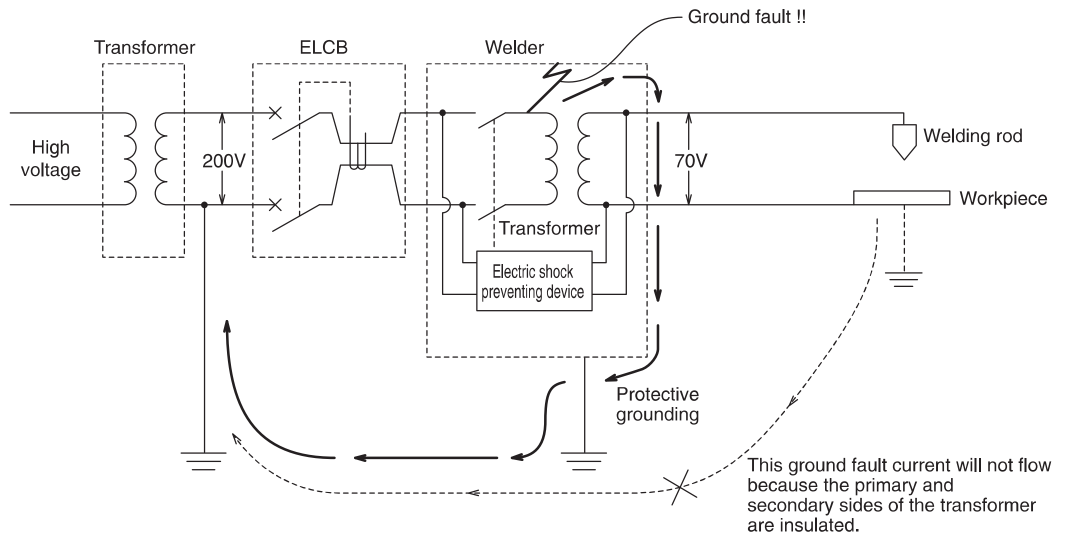


Fig. 9. 27 Arc welder circuit

standard type can be used for arc welders.

There are various kinds of welders, including arc welders and resistance welders. On welder electric circuits, as shown in Fig. 9. 27, the low-voltage circuit (primary circuit of welder transformer) is grounded, and the load circuit of the welder (secondary circuit of welder transformer) is insulated from the primary side.

When ELCB is installed on this low-voltage circuit, ELCB can protect only the range to the primary side of the welder transformer from electric shock and cannot protect the secondary circuit because the circuit is insulated from the primary side. For example, if insulation breakage occurs between the primary winding of the welder transformer and outer case, the "welder transformer → outer case → protective ground wire → earth → electric circuit ground wire → transformer" circuit will be formed as shown in Fig. 9. 27, and ground fault current will flow to operate ELCB.

However, even if the welding rod or workpiece is connected to the earth, ground fault current will not flow to the electric circuit ground wire because the primary side and secondary side of the welder transformer are insulated.

Therefore, it is unnecessary to take into consideration the leakage current which will be generated if the workpiece is connected to the earth, and ELCB rated current sensitivity of 30mA is allowed.

However, when one ELCB is installed for tens of welders or the wire between ELCB and welder is remarkably long, it may be desirable to install ELCB with medium sensitivity (200 or 500mA) in consideration of the earth floating capacitance.

The secondary circuit of the arc welder transformer has a voltage of about 70V while welding is suspended and can cause electric shock. Therefore, measures against electric shock must be taken for the circuit. To prevent the electric shock, an electric shock preventive device should be installed. The electric shock preventive device keeps open the primary side of the welder transformer while welding is suspended. Therefore, there is no possibility of electric shock on the secondary side. During welding, the voltage between welding rod and workpiece is reduced to several V, and there is no risk of electric shock.

✦Points for selection

(1) Operation with overcurrent trip element

The instantaneous tripping current value must be set larger than the transient inrush current value of welder.

The transient inrush current values of commercially available welders are 8 to 9 times.

(2) Operation with earth leakage trip element

Voltage may be generated on the secondary side of ZCT by the transient inrush current of welder, and a phenomenon similar to ground fault may occur.

Mitsubishi MCCB have excellent resistance to such transient phenomenon (equilibrium characteristics), and even the standard models will not malfunction.

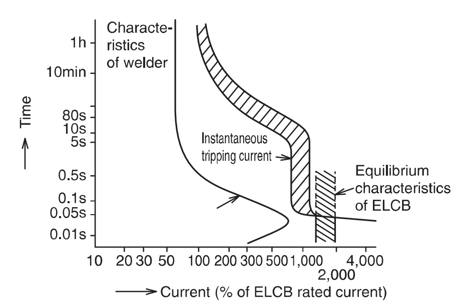


Fig. 9. 28 Overcurrent tripping characteristics of ELCB

(3) Rated current

Generally, calculate the rated current by the following formula in consideration of the use at the maximum output.

$$I_{ELCB} \geqq K \times \frac{P}{E} \times 10^3$$

I_{ELCB} : Rated current of ELCB (A)

P : Rated input o f welder (kVA)

E : Rated voltage of welder (V)

K : Constant for use at max. output, normally 1.2 or so

(4) Rated current sensitivity

Since the major purpose is protection from electric shock, it is recommended to select a circuit breaker with rated current sensitivity of 30mA. However, when the electric circuit is remarkably long, determine the rated current sensitivity carefully because a circuit breaker may malfunction owing to the earth floating capacitance sf the electric circuit.

In this case, calculate the current sensitivity by the following formula.

$$I_{\Delta N} \geqq K (L \times Ig_1 + n \times Ig_2)$$

$I_{\Delta N}$: Rated current sensitivity of ELCB (mA)

K : Safety factor for ingress of switching surge, normally 10 o r so

km) … According to Attached Tables 4 to 8 in Appendix 10

n : Number of welders

I_{g2} : Leakage current per welder (mA) (1 because the current is 1mA or less and negligible in the case of normal use)

9. 6. 5 Resistance welder circuits

Resistance welders are classified into several types according to voltage and capacity. All resistance welders used at 400VAC shall be provided with ELCB, and those used at 200VAC shall be provided with ELCB if they are water-cooled and may be exposed to moisture. In the case where workers may touch insulated wires or movable cables of welders, ELCB shall be installed on the welders used at 200VAC and 400VAC.

Fig. 9. 29 shows an example of a resistance welder circuit. Also on this circuit, ELCB can protect only the range to the primary side of the welder transformer from electric shock and cannot protect the secondary circuit. However, the voltage on the secondary side is normally 8V or so, and there is no possibility of electrocution at this voltage. (It is said that voltage of 25V or less is safe even in a sweating state.)

Mitsubishi ELCB (NV225-WEP and NV400-WEP) have built-in timers and can protect circuits even from abnormal weld flow.

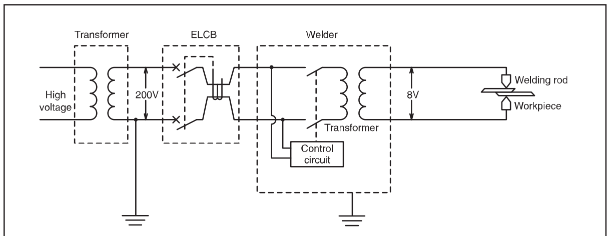


Fig. 9. 29 Resistance welder circuit

When welding is started, the timer detects the welder current and starts counting the time. If the welder current continues to flow after a lapse of the welding time set on the timer (continuous arc-through or abnormal weld flow), the built-in contact in the timer will close, the tripping coil will be excited, and the circuit breaker will automatically trip. In the case of normal weld flow, the welder current will be stopped within the welding time set on the timer, and the timer will be reset (the maximum reset time is 0.1 sec) and get ready for start of next welding.

The welding time shall be set on the timer somewhat longer than the welding time set on the welder control unit.

When earth leakage occurs, the ZCT will detect the leakage, the tripping coil will be excited through the leakage detector, and the circuit breaker will trip. At a welder circuit a large inrush current will flow owing to the transient phenomenon at the start of welding, and the ZCT may detects it as earth leakage and cause malfunction (the magnitude of inrush current at which the circuit breaker does not malfunction is indicated as the RMS value referred to as an equilibrium characteristic). Mitsubishi ELCB have an equilibrium characteristic improved by reinforced magnetic shield and will not malfunction.

When short circuit occurs, the instantaneous trip device will function, and instantaneously the circuit breaker will trip automatically.

✦Points for selection

(1) Selection of rated flowing current

The rated flowing current is 225A or 400A. Select the current based on the thermally equivalent current of the welder primary current. Actually, the welder primary current varies depending on the welding conditions, such as the material and thickness of workpiece. However, the welder primary current determined based on the current value obtained from the rated capacity of welder can be used without problem. Since the rated capacity of welder is prescribed as input at a service factor of 50%, the thermally equivalent current Ie can be obtained by the following formula.

$$Ie = \frac{P}{V} \times \sqrt{\beta}$$

Where, P is the rated capacity of welder, V is the rated voltage of welder, and β is the service factor and expressed by the formula β = weld time/weld cycle.

For example, when the rated capacity is 100kVA and the rated voltage is 415V:

$$Ie = \frac{100 \times 10^3}{415} \times \sqrt{0.5} = 170A.$$

The rated flowing current is determined by allowing a margin of about 15% for this value in consideration of supply voltage fluctuation. Therefore, 170A × 1.15 = 19A, and a circuit breaker with rated flowing current of 225A should be selected.

Table 9. 9 Table of selection of rated flowing current

Rating of resistance welder		ELCB rated flowing current (A)
Rated voltage (V)	Rated capacity (kVA)	
200	50 or less	225
	Over 50 to 100	400
415	100 or less	225
	Over 100 to 200	400

Table 9. 9 shows the relationship between welder rated capacity and rated flowing current of ELCB determined by the above calculation formulas.

(2) Selection of rated current sensitivity

The standard current sensitivity of ELCB for inverter welders is 30mA.

If the electric circuit between ELCB and welder is increased, ELCB may malfunction under the influence of earth floating capacitance. It is necessary to install ELCB in such a way that the circuit length is less than the value shown in Table 9. 10. For cases where the circuit length is longer and circuit breakers with sensitivity of 30mA cannot be used, 100mA, 200mA and 500mA circuit breakers are available as special models.

Table 9. 10 Rated current sensitivity and maximum electric circuit length (m)

Rated voltage	Applicable wire size mm²	For wiring with 600V vinyl coated wire (1V)						For wiring with chloroprene cabtyre cable (2RNCT)		
		Wiring work with vinyl tube			Wiring work with metallic conduit					
		30mA	(200mA)	(500mA)	30mA	(200mA)	(500mA)	30mA	(200mA)	(500mA)
200	38	125m	1250m	3100m	25m	250m	630m	45m	450m	1100
	60	100	1000	2500	20	200	500	37	370	910
	100	90	900	2300	18	180	440	36	360	890
415	100	78	780	1990	15	150	380	31	310	770
	150	70	700	1750	14	140	355	26	260	650
	200	68	680	1710	13	130	340	28	280	710

(3) Setting of instantaneous tripping current

The instantaneous tripping current must be determined in consideration of the maximum input current of welder and the inrush current at the start of welding. The maximum input current can be obtained from the standard maximum input of welder, but, when the welder secondary side is completely shorted, the maximum input current will be higher by about 30% than the current value determined from the standard maximum input. Therefore, the instantaneous tripping current Iinst in consideration of the inrush current at the start of welding can be determined by the following formula.

$$Iinst > \frac{Pmax}{V} \times 1.3 \times K$$

Where, Pmax is the standard maximum input of welder, V is the rated voltage of welder, and K is the margin ratio for inrush current and 1 to 1.5 for models with synchronous peak control, 1.4 to 3 for models without synchronous peak control and 2 to 6 for models with asynchronous soft start. Table 9. 11 shows examples of selection of instantaneous tripping current determined by the above formula.

Table 9. 11 Examples of selection of instantaneous tripping current

Welder specifications			ELCB rated flowing current (A)	Instantaneous tripping current (A)		
Rated voltage (V)	Rated capacity (kVA)	Standard max. input (kVA)		With synchronous peak control K = 1.0	Without synchronous peak control K = 1.4	With asynchronous soft start K = 2
200	35	69	225	900	1200	2250
	50	144	225	2250	2250	3000
	70	144	400	2400	2400	4400
	100	240	400	4400	4400	4400
415	35	69	225	900	900	900
	50	144	225	900	1200	1200
	70	144	225	900	1200	1200
	100	240	225	1200	2250	2250
	120	295	400	1200	2400	2400
	150	455	400	2400	4400	4400
	200	875	400	4400	6000	6000

Note: In the above table, the instantaneous tripping current values determined based on inverter welder specifications are shown. When selecting the instantaneous tripping current, it is necessary to ensure the coordination so that the surge current capacity of control element (thyristor stack) is not exceeded.

9. 6. 6 Inverter circuits

(1) Influence of higher harmonics and countermeasures

Higher harmonics can be caused by CVCF units with thyristors and transistors used as computer power supply units, various rectifiers and VVVF units for motor control for meeting the recent trend toward energy conservation.

These units are used to make AC power using the semiconductor switching function. In this process, a current chopping phenomenon occurs, and wide-range higher harmonics and high frequency noises are generated. Below is described the influence of higher harmonics and high frequency noises on ELCB and proper selection of ELCB for the VVVF inverters which are widely used as a major method for motor control.

(2) Selection of ELCB

①Selection of rated current

Since the harmonic content is very high on inverter circuits, select the rated current to ensure the following relationship between ELCB rated current I_{ELCB} and load current I.

$I_{ELCB} \geqq 1.4 \times I$

②Selection of rated current sensitivity

When a motor is driven by an inverter, the output voltage of the inverter contains harmonic components, and leakage current is constantly generated by the earth floating capacitance of the electric circuit from the inverter to the motor and the floating capacitance between the motor winding and core. Although the leakage current value varies depending on the wire type, wire thickness, length of wire from ELCB to inverter and wire from inverter to motor and inverter output frequency, calculate the approximate value of leakage current based on the values in the case of commercial power supply (50Hz or 60Hz).

1) Leakage current from wire

Determine the length of electric circuit from ELCB to inverter input terminal and the wire type and size, and calculate the leakage current according to Attached Tables 4 to 8 in Appendix 10. (Use the values at the commercial frequency. Ignore the high-frequency components.)

Determine the length of electric circuit from inverter output terminal to motor and the wire type and size, and calculate the leakage current according to Attached Tables 4 to 8 in Appendix 10. Then, multiply the calculated value by K_2 in consideration of high-frequency components. (Average multiplying factor K_2 depending on inverter output frequency)

2) Leakage current from motor

Determine the motor capacity and the number of motors, and calculate the total leakage current using the leakage current value during operation shown in Attached Table 11 in Appendix 10. Then, multiply the calculated value by K_2 in consideration of harmonic content. (Average multiplying factor K_2 depending on inverter output frequency)

3) When radio noise filters for inverter (FR-BIF) are used, take into consideration leakage current of approx. 4mA per filter.

● Selection of rated current sensitivity

Determine the constant leakage current by the method stated as above, and set the rated current sensitivity to 10 times or more the constant leakage current in consideration of transient inrush current.

According to the above, the following formula (1) for selection of rated current sensitivity can be obtained.

Rated current sensitivity $I\Delta n \times K_1 [Igc_1 + Ign + K_2 (Igc_2 + Igm)]$ (mA) ··· (Formula 1)

Igc_1 : Constant leakage current from electric circuit between ELCB and inverter (mA)

Igc_2 : Constant leakage current from electric circuit between inverter and motor (mA)

Igm : Constant leakage current from motor (mA)

Ign : Leakage current from noise filter from inverter input side (mA)

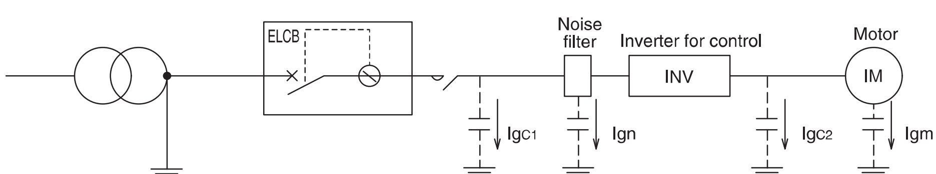
Ig : Total leakage current

K_1 : Constant for transient inrush current, 10

K_2 : Constant for harmonic content

Remarks (1) Models applicable to higher harmonics and surge can detect ground faults on the inverter secondary side at a working frequency of 120Hz or less. In the case of star connection neutral grounding, the current sensitivity to ground fault on the inverter secondary side is reduced, the protective grounding of load device shall be class C grounding (10Ω or less).

(2) ELCB shall be installed on the imerter primary side (power supply side).



9. 7 Ground fault protection for non-grounded circuits

The non-grounded system is used in plants where power failure must be prevented for operation. Particularly, in many petrochemical plants, where explosive gas may catch fire owing to ground fault current and serious accidents may be caused, this system is used to reduce the ground fault current.

On non-grounded circuits, the ground fault current is remarkably low even if one line falls down on the earth, and the current cannot be easily detected. Therefore, note that the protection effect of ELCB may not be expected only by installing it.

9. 7. 1 Circuit insulation detector (MEGMONITOR)

Mitsubishi circuit insulation detector, MEGMONITOR, has an excellent feature that enables constant monitoring of circuit without necessity of power interruption because it can monitor the whole electric circuit in the live state with low-voltage small current and detect deterioration of insulation of circuit to the earth. Article 40 of interpretation for Guide Book of Electrical Equipment requires installation of ground fault circuit breakers on non-grounded circuits. In the past, appropriate devices for ground fault protection were not available, and the protection was provided by grounding capacitors and installing ELCB. However, to normally actuate ELCB, the capacitor capacity should be considerably increased. This can generate sparks upon occurrence of ground fault and is unfavorable for the purpose of non-grounded circuits.

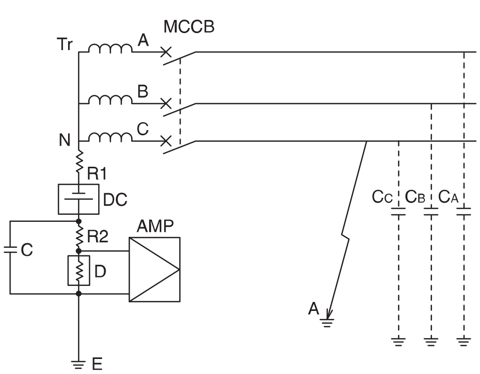


Fig. 9. 31 Explanation of operation

MEGMONITOR can detect insulation deterioration corresponding to ground fault current of several mA and is suitable for detection of ground faults on non-grounded circuits. A ground fault circuit breaker can be easily configured by combining it with breakers. The operation is explained based on Fig. 9. 31. As an AC content, charging current flows through the earth capacitances (C_A, C_B and C_C) on the circuit from the system power supply (commercial frequency) by the transformer (Tr). The signal detector (D) of the amplifier and the capacitor C are connected in series so that the signal by this current does not enter the amplifier (AMP). Therefore, the current flowing to the earth capacitances (C_A, C_B and C_C) is bypassed to the capacitor (C) to avoid giving input signals to the amplifier (AMP), and the AC signal is not amplified.

The DC content biases the lines of the phases (A, B and C) through the windings of the transformer (Tr) from the DC power supply (DC) installed in the device. If the insulation of the circuit is higher than a certain value (normal), the DC does not leak to the outside of the circuit, and DC current does not flow into the detector.

As stated above, since this device is biased by DC, charging current flows to the capacitances (C_A, C_B and C_C) only just after MCCB are closed even if the circuit is long and the earth capacitances (C_A, C_B and C_C) are large. After this, it will stabilize, and DC will not flow. Therefore, even on a long circuit, it will not be affected by the earth capacitances (C_A, C_B and C_C).

Against transient inrush current generated when MCCB is closed, a special circuit for prohibiting operation is provided to prevent malfunction. Then, if the insulation at the point A of T phase has deteriorated and the insulation to the earth is degraded, DC current from the DC power supply will flow to the resistor (R2), grounding point (E), fault point (A), transformer neutral point (N) and resistor (R1). After the completion of charging of the capacitor (C) connected in series with the detector (D), all DC current will flow to the detector (D), the signal of the detector (D) will be amplified by the amplifier (AMP), and insulation deterioration will be detected.

With this device, insignificant decrease of circuit insulation to 400kΩ or less can be detected. The sensitivity can be switched in 6 stages, 10 – 20 – 50 – 100 – 200 – 400k.

9. 7. 2 Method by combining grounded capacitors and ELCB

Capacitors are connected to the secondary side of non-grounded insulating transformer, the neutral point is grounded, and, when one-line ground occurs, ELCB detects the ground fault and protects the circuit.

(1) 3-phase 3-wire

Non-grounded insulating transformers are generally Δconnected. The relationship between grounded capacitor capacity and ground fault current in this case is shown below.

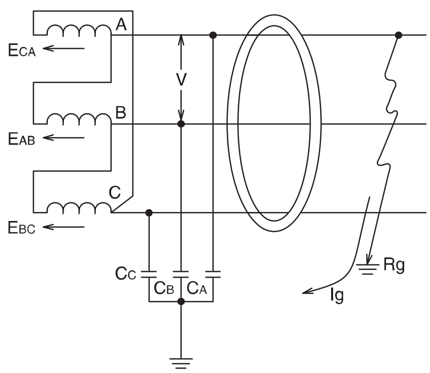


Fig. 9. 32

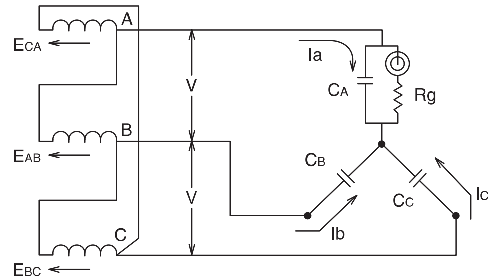


Fig. 9. 33

In Fig. 9. 32, the capacitors with capacitances C_A, C_B and C_C are star-connected, and the neutral point is grounded. This circuit is redrawn in Fig. 9. 33 to make it easier to understand the connection. In the normal state, the capacitors are a star-connected load consisting of capacitors when viewed from the power supply side, but, when a ground fault occurs, the resistance Rg (including the fault resistance of device, earth resistance of device and grounded resistance of capacitor) of the ground fault circuit is considered to be connected in series with the ground fault capacitor C_A of phase A, and the current flowing to Rg is detected by the ZCT. On condition that the capacitor capacities of the phases are identical and $C_A = C_B = C_C = C$, the relationship between capacitor capacity C and ground fault current Ig can be determined by the following formulas.

$$Ig = \frac{\sqrt{3}\,V}{\sqrt{(3Rg)^2 + \left(\frac{1}{\omega C}\right)^2}} \text{ (A)} \quad \cdots\cdots (1)$$

$$\therefore\ C = \frac{1}{\sqrt{3}\,\omega\sqrt{\left(\frac{V}{Ig}\right)^2 - 3Rg^2}} \text{ (F)} \quad \cdots\cdots (2)$$

Therefore, the required capacitor capacity C can be obtained from the formula (2) by determining the maximum detected ground fault current, the current sensitivity, and estimating the ground fault resistance Rg.

<Example>

Determine the capacitor capacity required to protect the circuit from ground fault with ELCB by grounding the capacitors as shown in Fig. 9. 34.

The line voltage is 440V, frequency is 60Hz, and the total resistance Rg of the ground fault circuit is 150Ω.

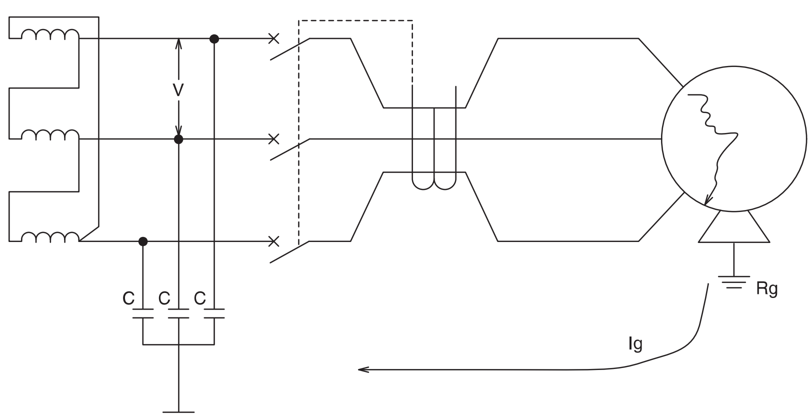


Fig. 9. 34

● Calculation method

At first, determine the maximum limit of ground fault current (related to the current sensitivity). The current should be about twice the rated current sensitivity of ELCB to be used.

In this example, assume that ELCB with sensitivity of 200mA is used, and the ground fault current is 0.5A.

From the formula (2),

$$C = \frac{1}{\sqrt{3}\,\omega\sqrt{\left(\frac{V}{Ig}\right)^2 - 3Rg^2}}$$

$$= \frac{1}{\sqrt{3}\times 2\pi\cdot 60\sqrt{\left(\frac{440}{0.5}\right)^2 - 3\times 150^2}} = 1.82\mu F \quad \cdots\cdots (3)$$

Therefore, if the capacitor capacity in Fig. 9. 34 is 1.8μF (actually, a capacitor with standard capacity of 2μF is used), current of 0.5A will flow when the grounded circuit resistance reduces to 150Ω, and the current sensitivity of 500mA is allowable. However, actually, the sensitivity is set to 200mA with a little margin for more reliable operation. If a high-sensitivity circuit breaker is used, ground fault current can be detected even when the grounded circuit resistance is high. For example, when ELCB with sensitivity of 30mA is used, Rg can be determined by the formula (2) as shown below.

$$Rg = \frac{1}{3}\sqrt{\left(\frac{\sqrt{3}\,V}{Ig}\right)^2 - \left(\frac{1}{\omega C}\right)^2}$$

$$= \frac{1}{3}\sqrt{\left(\frac{\sqrt{3}\times 440}{0.03}\right)^2 - \left(\frac{1}{2\pi\times 60\times 2\times 10^{-6}}\right)^2}$$

$$\fallingdotseq 8500W \quad \cdots\cdots (4)$$

That is, when the grounded circuit resistance reduces to 8500Ω, ELCB operates and protects the circuit. This offers the advantage of detection of ground fault at an early stage at which the degree of fault is minor. After the capacitor capacity is determined, it is necessary to select a capacitor having a withstand voltage (rated voltage) appropriate to the circuit voltage. Although the voltage applied to the capacitor is $V/\sqrt{3}$ in the normal state, use a capacitor having two times higher withstand voltage to allow a margin. Since $44/\sqrt{3}\times 2 \fallingdotseq 509$, use a 2-$\mu$F capacitor having the standard voltage of 600V.

(2) Single-phase 2-wire, neutral point grounding

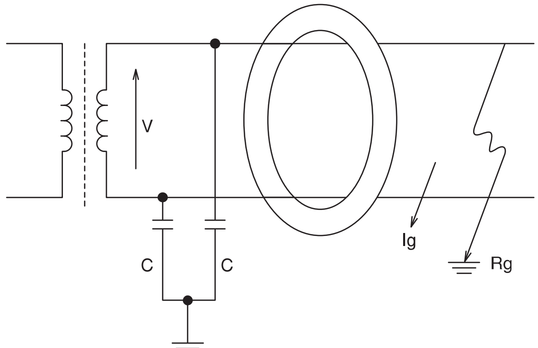


Fig. 9. 35

$$Ig = \frac{V}{\sqrt{\left(\frac{1}{\omega C}\right)^2 + (2Rg)^2}} \ (A) \quad \cdots\cdots (5)$$

$$\therefore \ C = \frac{1}{\omega\sqrt{\left(\frac{V}{Ig}\right)^2 - (2Rg)^2}} \ (F) \quad \cdots\cdots (6)$$

From the formula (6), the required capacitor capacity can be obtained.

(3) 3-phase 3-wire (star connection)

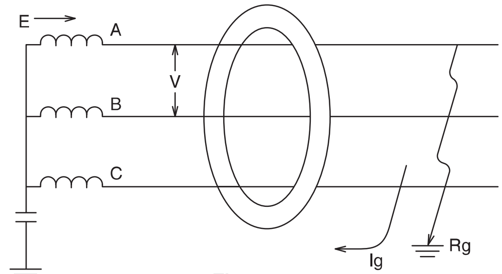


Fig. 9. 36

In the case of 3-phase, when the line voltage is V,

$$Ig = \frac{V/\sqrt{3}}{\sqrt{Rg^2 + \left(\frac{1}{\omega C}\right)^2}} \ (A) \quad \cdots\cdots (7)$$

$$C = \frac{1}{\omega\sqrt{\left(\frac{V}{\sqrt{3}\,Ig}\right)^2 - Rg^2}} \ (F) \quad \cdots\cdots (8)$$

From the formula (8), the required capacitor capacity can be obtained.

(4) Simplified calculation formula of capacitor capacitance

If the ground fault resistance Rg is negligible, the capacitor capacitance can be determined by the following simplified calculation formula.

In the case of 3-phase 3-wire (Δ connection)

$$C \geq \frac{I_{\Delta N}(1+a)\,3\times 10^3}{\sqrt{3}\,\omega\times 2\pi fV} \quad \cdots\cdots (9)$$

In the case of single-phase 2-wire

$$C \geq \frac{I_{\Delta N}\,(1+a)\times 10^3}{2\pi fV} \quad \cdots\cdots (10)$$

C	: Capacitance of 1 phase of capacitor	(μF)
$I_{\Delta N}$	: Rated current sensitivity of ELCB	(mA)
V	: Line voltage	(V)
f	: Frequency	(Hz)
a	: Safety factor (1.0 to 1.5) … Normally, 1.0	

- Quick chart of capacitor grounded capacity on non-grounded electric circuit for the purpose of detection of earth leakage

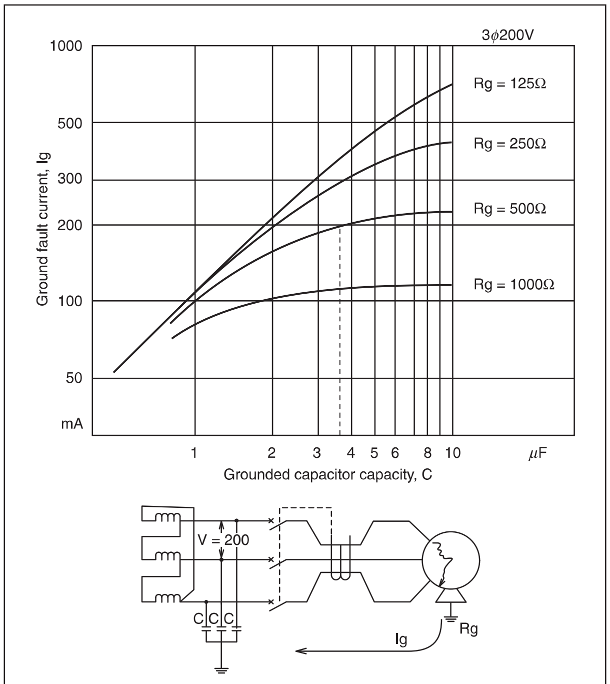


Fig. 9. 37-1

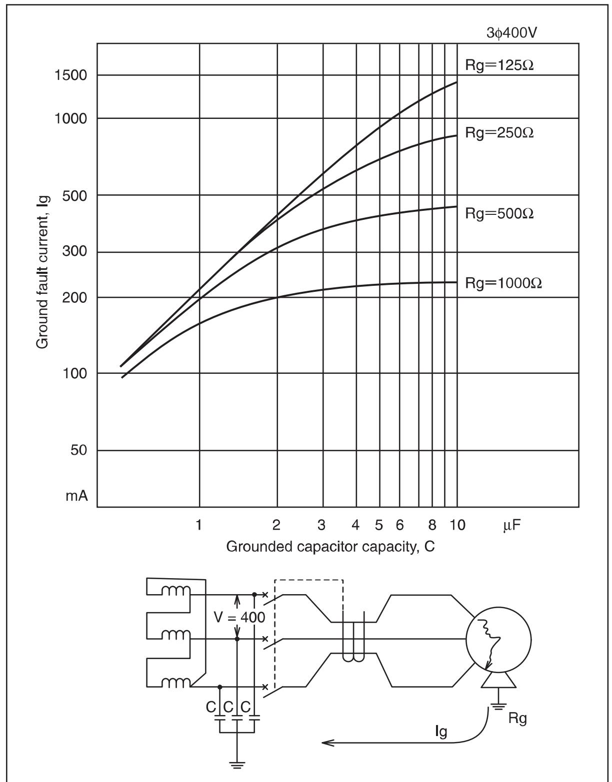


Fig. 9. 37-2

$$Ig = \frac{\sqrt{3}\,V}{\sqrt{(3Rg)^2 + \left(\frac{1}{\omega C}\right)^2}} \quad (A)$$

$$\therefore \quad C = \frac{1}{\sqrt{3}\,\omega\sqrt{\left(\frac{V}{Ig}\right)^2 - 3Rg^2}} \quad (F)$$

Example: To obtain a ground fault current of 200mA at ground fault resistance of 500Ω, the capacitor capacity shall be 3.5μF.
(The ground fault current shall be at least twice the rated current sensitivity.)

$$Ig = \frac{\sqrt{3}\,V}{\sqrt{(3Rg)^2 + \left(\frac{1}{\omega C}\right)^2}} \quad (A)$$

$$\therefore \quad C = \frac{1}{\sqrt{3}\,\omega\sqrt{\left(\frac{V}{Ig}\right)^2 - 3Rg^2}} \quad (F)$$

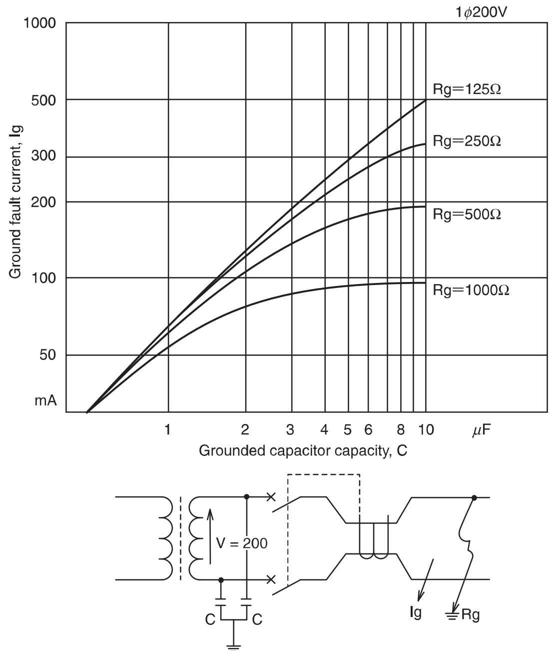


Fig. 9. 37-3

$$Ig = \frac{V}{\sqrt{\left(\frac{1}{\omega C}\right)^2 + (2Rg)^2}} \quad (A)$$

$$\therefore \quad C = \frac{1}{\omega\sqrt{\left(\frac{V}{Ig}\right)^2 - (2Rg)^2}} \quad (F)$$

9. 7. 3 Method by grounding transformer

This method is designed to detect zero-phase voltage and break the circuit owing to ground fault. When the devices are connected as shown in Fig. 9. 38, the voltage applied to the primary winding is $\overrightarrow{EA} + \overrightarrow{EB} + \overrightarrow{EC}$, and the corresponding voltage is induced to each phase of the secondary delta winding. The voltage applied to ⑭ is the vectorial sum of the voltages of the phases, $\overrightarrow{EA} + \overrightarrow{EB} + \overrightarrow{EC}$.

From Fig. 9. 39,

$$\overrightarrow{NA} = \overrightarrow{EA} + \overrightarrow{NE}$$
$$\overrightarrow{NB} = \overrightarrow{EB} + \overrightarrow{NE}$$
$$\overrightarrow{NC} = \overrightarrow{EC} + \overrightarrow{NE}$$

The both sides of these formulas are added to obtain the following formula.

$$\overrightarrow{NA} + \overrightarrow{NB} + \overrightarrow{NC} = \overrightarrow{EA} + \overrightarrow{EB} + \overrightarrow{EC} + 3\overrightarrow{EN}$$

As is evidenced from Fig. 9. 39, N is the center of the triangle, and the left side is 0. Therefore,

$$\overrightarrow{EA} + \overrightarrow{EB} + \overrightarrow{EC} = -3\overrightarrow{NE} = 3\overrightarrow{EN}$$

Since $\overrightarrow{EN}$ is zero-phase voltage, three times larger zero-phase voltage appears in ⑭. This voltage is detected, and the voltage relay is operated to trip the circuit breaker to protect the circuit from ground fault.

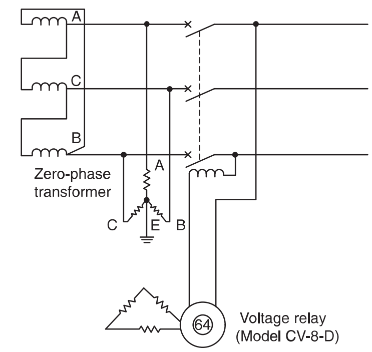


Fig. 9. 38

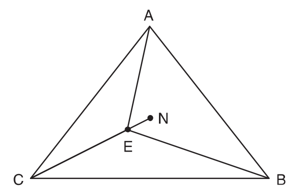


Fig. 9. 39

9. 7. 4 Method by grounding detector

This method is similar to the method stated in (2) "grounding transformer." The degree of ground fault and the grounding phase can be defined by the indicator.

Fig. 9. 40 shows the connection diagram of model LM-11NGD grounding detector.

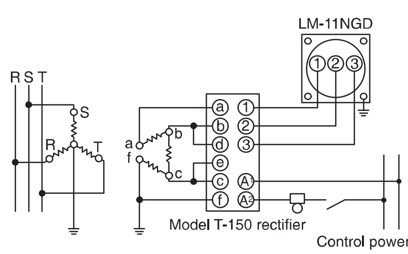


Fig. 9. 40

9. 8 Ground fault detection and protection at DC circuits

Usual MCCB are designed only for AC, and they can be used at DC circuits through DC ground fault detection relays.
Fig. 9. 41 shows the circuit diagram of a DC ground fault detection relay.
If a ground fault occurs at the ground fault resistance value Rg on the positive side, the potential at the point N will become higher than that at the point A, and current will flow to low-energy high-sensitivity DC moving coil element (D-5), thereby actuating the relay.
In the case of a ground fault on the negative side, current will flow from B to N.
In the case of a DC ground fault detection relay, the minimum working current of the element D-5 is ± 0.125mA.
The sensitivity can be adjusted with a variable resistor.

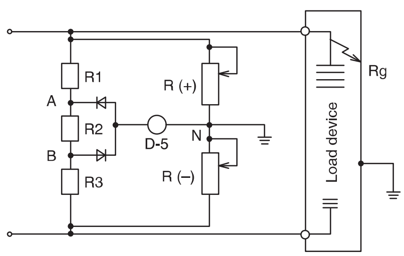
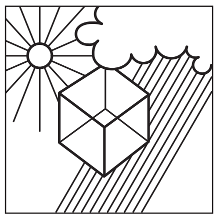


Fig. 9. 41



10. Environmental Characteristics

10. 1 Environmental characteristics

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10. 3. 2 The result of test 144

MCCB & ELCB

10 Environmental Characteristics

10. 1 Environmental characteristics

10. 1. 1 Atmospheric environment

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

(1) Ambient temperature range — –10°C~+40°C (Average temperature for 24 hours, however, shall not be higher than 35°C.)

(2) Relative humidity — 85% max. with no dewing

(3) Altitude — 2,000m max.

(4) Ambient — No excessive water or oil vapour, smoke, dust, salt content, corrosive substance, vibration, and impact

Expected service life (MTTF) under the above conditions is 15 years.

10. 1. 2 High temperature application

To comply with relevant standards, all circuit breakers are calibrated at 40°C. If the circuit breaker is to be used in an environment where the ambient temperature is likely to exceed 40°C please apply the de-rating factor shown in table 10. 2.

For example: To select a circuit breaker for use on a system where the full load current is 70A in an ambient temperature at 50°C then from table 10. 2

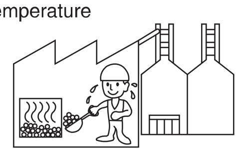
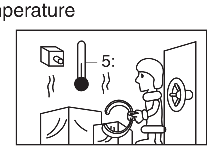
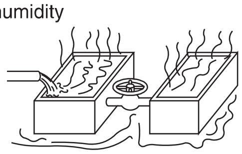
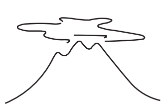
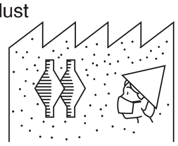
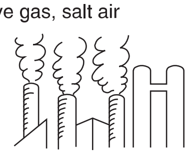
$$\frac{70A}{0.9} = 77.8A$$

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

Table 10. 2 MCCB Derating

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

Table 10. 1 Ambient environment for breaker

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

10. 1. 3 Low Temperature Application

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

For conditions where temperatures drop below –10°C special MCCB must be used.

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

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

Low Temperature MCCB

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

10. 1. 4 High humidity

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

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

There are two degrees of tropicalisation:

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

Treatment 2- painting of insulating material to avoid build up of mildew only.

10. 1. 5 Corrosive atmospheres

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

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

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

Allowable containment for corrosive gas.

H_2S 0.01ppm SO_2 0.05ppm

NH_2 0.25ppm

10. 1. 6 Affection of altitude

When MCCB are used at altitudes exceeding 2000m above sea level, the effects of a drop in pressure and drop in temperature will affect the operating performance of the MCCB. At an altitude of 2200m, the air pressure will drop to 80% and it drops to 50% at 5500m, however interrupting capacity is unaffected. The derating factors that are applicable for high altitude applications are shown in table 10. 3. (According to ANSI C 37.29-1970)

Table 10. 3 Derating Factors for High Altitude Applications

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

For example: NF800-SEW on 4000m

(1) Voltage

The rated operating voltage is AC690V. You should derate by 690 × 0.82 = 565.8V. It means that you can use this NF800-SEW up to AC565.8V rated voltage.

(2) Current

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

8.2Vibration-Withstand Characteristics

10. 2 The condition of test

1. Installation position and Direction of vibration
   - Every vertical and horizontal at vertical installed (as shown in Fig. 10. 1)
2. The position of MCCBs and vibration time
   Forty minutes in each position (ON, OFF and TRIP)
3. Vibration criteria
   - Frequency 10~100Hz
   - Vibration acceleration 22m/s^2
   - Period 10min./cycle

10. 2. 1 The result of test

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

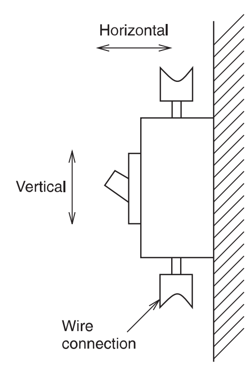


Fig. 10. 1 Applied Vibration

10. 3 Shock-withstand characteristics

10. 3. 1 The condition of test

(1) MCCB are drop-tested, as described in Fig. 10. 2.
The arrows show the drop direction.

(2) The samples are set to ON, with no current flowing.

10. 3. 2 The result of test

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

The judgment of failure:

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

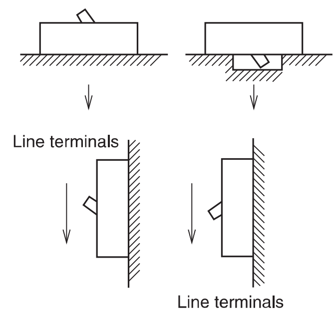


Fig. 10. 2 Drop-Test Attitudes

Table 10. 4 Shock-withstand characteristics of Mitsubishi MCCB

Series		Model						No tripped m/s^2	No damage m/s^2
BH		BH-DN	BH-S	BH-PS	BH-D6	BH-D10	BH	147	490
MB		MB30-CS						147	
		NF32-SV	NF63-CV	NF63-SV	NF63-SVF			196	
		NF125-SV	NF250-SV						
NF	S	NF32-SV	NF32-SVF	NF63-SV	NF63-HV	NF125-SV	NF125-HV	196	
		NF125-SEV	NF125-HEV	NF125-SGV	NF125-LGV	NF125-HGV	NF125-RGV		
		NF160-SGV	NF160-LGV	NF160-HGV	NF160-RGV	NF250-SV	NF250-HV		
		NF250-SEV	NF250-HEV	NF250-SGV	NF250-LGV	NF250-HGV	NF250-RGV		
		NF250-SEV with MDU	NF250-HEV with MDU	NF400-SW	NF400-SEW	NF400-HEW	NF400-REW		
		NF400-SEP with MDU	NF400-HEP with MDU	NF630-SW	NF630-SEW	NF630-HEW	NF630-REW		
		NF600-SEP with MDU	NF600-HEP with MDU	NF800-SDW	NF800-SEW	NF800-HEW	NF800-REW		
		NF800-SEP with MDU	NF800-HEP with MDU	NF1000-SEW	NF1250-SEW	NF1250-SDW	NF1600-SEW		
		NF1600-SDW							
	C	NF30-CS						147	
		NF63-CV						196	
		NF125-CV	NF250-CV	NF400-CW	NF630-CW	NF800-CEW			
	U	NF125-UV	NF250-UV	NF400-UEW	NF800-UEW			196	

Table 10. 5 Shock-withstand characteristics of Mitsubishi ELCB

Model							No tripped m/s^2	No damage m/s^2
BV-D	BV-DN						196	490
NV32-SV	NV63-CV	NV63-SV	NV63-HV				196	490
NV125-CV	NV125-SV	NV125-HV	NV125-SEV	NV125-HEV	NV250-CV	NV250-SV	147	294
NV250-HV	NV250-SEV	NV250-HEV						
NV400-CW	NV400-SW	NV400-SEW	NV400-HEW	NV400-REW	NV630-CW	NV630-SW	147	294
NV630-SEW	NV630-HEW	NV800-SEW	NV800-HEW					

11. Standards

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11 Standards

11. 1 International standards of circuit breakers

The main standards related to breakers and the usage methods are listed below.

11. 1. 1 Japanese standards

(1) Laws and regulations

- ◆ Ministerial ordinance setting technical standards concerning electrical facilities
- ◆ Interpretation of technical standards for electrical equipment
- ◆ Ministerial ordinance that establishes standards concerning technology for electrical appliances
- ◆ Labor Safety and Health Regulations

(2) JIS (Japan Industrial Standards)

- ◆ JIS C 8201-1 “Low-voltage switchgear and controlgear - Part 1: General rules”
- ◆ JIS C 8201-2-1 “Low-voltage switchgear and controlgear - Part 2-1: Circuit-breakers (wiring breaker and other breakers)”
- ◆ JIS C 8201-2-2 “Low-voltage switchgear and controlgear - Part 2-2: Circuit-breakers incorporating residual current protection
- ◆ JIS C 4610 “Circuit-breakers for equipment”
- ◆ JIS B 9960-1 “Safety of machinery - Electrical equipment of machines - Part 1: General requirements”

(3) Commercial standards

- ◆ JEAC 8001 “Indoor wiring regulations” (Japan Electrical Manufactures’ Association)
- ◆ Steel Boat Standards (Nippon Kaji Kyokai)

11. 1. 2 International standards - IEC standards

- ◆ IEC 60947-1 “Low-voltage switchgear and controlgear - Part 1: General rules”
- ◆ EC 60947-2 “Low-voltage switchgear and controlgear - Part 2: Circuit-breakers”
- ◆ IEC 60934 “Circuit-breakers for equipment (CBE)”
- ◆ IEC 60204-1 “Safety of machinery - Electrical equipment of machines - Part 1: General requirements”

11. 1. 3 European standards

(1) CE marking policy

These policies have been enforced to promote free distribution within the EEA district. Each product must comply with the corresponding EU Directive. The CE Mark indicates that the Directive is complied with. Product may not be sold in the European market without this Marking.

(2) EU directive

●LVD directive (Low voltage directive)

The low voltage directives are directives applied to devices designed to run at 50 to 1000VAC/75 to 1500VDC. There is no need to acquire a proof of model from a certifying agency (NB). Often, a self-declaration of compliance by the manufacturer is sufficient.

●EMC directive (Electro-magnetic compatibility)

This Directive stipulates that strong magnetic waves are not radiated outwards, and that the device is not affected by electromagnetic waves from an external source. Electronic breakers and leakage current breakers, etc., are subject to the evaluation test.

(3) EN standards - standardized as IEC standards

The optimum method to confirm that a product complies with the required safety requirements of the each EU Directive is to comply with the Standardized Standards. Most of the standardized standards are EN Standards.

- ◆ EN 60947-1 “Low-voltage switchgear and controlgear - Part 1: General rules” - EN 60947-2 “Low-voltage switchgear and controlgear - Part 2: Circuit-breakers” - EN 60934 “Circuit-breakers for equipment (CBE)”
- ◆ EN 60204-1 “Safety of machinery - Electrical equipment of machines - Part 1: General requirements”

(4) Third-party certification (TÜV Certification)

For many of Mitsubishi breakers, compliance with the EN Standards and safety are verified by the third-party certification agency TÜV Rheinland. (Refer to Section 11. 2 for the corresponding models.) When applying for TÜV verification as a machine system, inspection of the breaker will be excluded.

11. 1. 4 North American standards

(1) United States

- ◆ NFPA 70 “National Electrical Code”
- ◆ NFPA 79 “Electrical Standard for Industrial Machinery”
- ◆ UL 489 “Molded-Case Switches, and Circuit-Breaker Enclosures”
- ◆ UL 1053 “Standard for Ground-Fault Sensing and Relaying Equipment”
- ◆ UL 1077 “Standard for Supplementary Protectors for Use in Electrical Equipment”
- ◆ UL 508A “Standard for Industrial Control Panels”

(2) Canada

- ◆ CSA C22.2 No. 5 “Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures”
- ◆ CSA C22.2 No. 144 “Ground Fault Circuit Interrupters”
- ◆ CSA C22.2 No. 235 “Supplementary Protectors”

(3) Certification marks

Some of the Mitsubishi breaker models are certified with US UL Standards or Canadian CSA Standards by the certifying agency UL. (Refer to Section 11. 2 for the corresponding models.) The cULus or cURus marks indicate the certified model.

11. 1. 5 Chinese standards

(1) CCC policy

After China joined WTO in November 2001, the certification policy has been unified to CCC. There are 19 types and 132 products in the primary mandatory products subject to the CCC Certification policy. The Mitsubishi breaker has received CCC Certification as a low-voltage device. (Refer to Section 11.2 for the corresponding models.) The power distribution panel is subject to CCC, but the control panel (machine’s electric device) that complies with the GB 5226.1 compliance standards is not subject to CCC.

(2) GB standards

The GB standards (from Guojia BiaoZhun) are the basic standards applied in China.

The GB 14048 Series corresponds to the IEC 60947 Series.

- ◆ GB 14048.1 Low-voltage Switchgear and Controlgear General Rules
- ◆ GB 14048.2 Low-voltage Switchgear and Controlgear Low-voltage Circuit Breakers
- ◆ GB 17701 Circuit-breaker for equipment
- ◆ GB 5226.1 Electrical Safety of Machinery Electrical Equipment of Machines Part 1: General Requirements

11. 2 List of compatible standards

●Molded case circuit breakers and motor protection breakers

Specifications	Class	Applicable Models and Assignments	North American Safety Mark					Compulsory Mark		Third Party Mark	Classification Society (*1)
			UL Stgandards				CSA Standards	CCC	CE	TÜV Rheinland	NK
			USA				Canada	China	Europe	Germany	Japan
General	C	NF30-CS	–	–	–	–	–	●	●	●	●
		NF63-CV, NF125-CV	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF250-CV	–	–	–	–	–	●	●	●	●
		NF400-CW, NF630-CW, NF800-CEW	–	–	–	–	–	●	●(Self Declaration)	–	●
	S	NF32-SV, NF63-SV, NF125-SV	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF125-SEV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NF250-SV	–	–	–	–	–	●	●	● (Except for 4P)	●
		NF125-SGV, NF160-SGV, NF250-SGV, NF250-SEV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NF400-SW, NF630-SW NF400-SEW, NF630-SEW NF800-SEW, NF800-SDW	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF1000-SEW, NF1250-SEW	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF1600-SEW	–	–	–	–	–	●	●(Self Declaration)	–	–
		NF1250-SDW, NF1600-SDW	–	–	–	–	–	–	●(Self Declaration)	–	–
	L/H/R	NF63-HV	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF125-HV	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF125-HEV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NF250-HV	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF125-LGV, NF125-HGV, NF160-LGV, NF250-LGV, NF250-HGV, NF250-HEV, NF125-RGV, NF250-RGV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NF400-HEW, NF400-REW NF630-HEW, NF630-REW NF800-HEW, NF800-REW	–	–	–	–	–	●	●(Self Declaration)	–	●
	U	NF125-UV	–	–	–	–	–	–	●(Self Declaration)	–	●
		NF250-UV, NF400-UEW	–	–	–	–	–	–	●(Self Declaration)	–	●
		NF800-UEW	–	–	–	–	–	–	●(Self Declaration)	–	–
	Motor Protection	NF32-SV MB, NF63-CV MB, NF63-SV MB, NF125-SV MB	–	–	–	–	–	●	●(Self Declaration)	–	●
		NF250-SV MB	–	–	–	–	–	●	●	●	●
UL	UL 489 Listed	NF50-SVFU, NF100-CVFU	–	–	–	●	–	●	●	●	–
		NF125-SVU, NF125-HVU	–	–	–	●	–	●	●	●	–
		NF225-CWU	–	–	–	●	–	●(Except for 250A)	●	●(Except for 250A)	–
		NF250-SVU, NF250-HVU	–	–	–	●	–	●	●	●	–
		NF-SKW, NF-SLW	–	–	–	●	–	–	●	●	–

Note *1 Except for 4 poles breaker.
Remark: 1. KC (Korea Certification) Mark and GOST-R (Russian Standards) approval products are prepared. Please inquire details.

11 Standards

●Earth leakage circuit breakers

Specifications	Class	Applicable Models and Assignments	North American Safety Mark					Compulsory Mark		Third Party Mark	Classification Society
			UL Stgandards				CSA Standards	CCC	CE	TÜV Rheinland	NK
			USA				Canada	China	Europe	Germany	Japan
CE and CCC	C	NV63-CV, NV125-CV	–	–	–	–	–	● (Except for 2P)	●(Self Declaration)	–	–
		NV250-CV	–	–	–	–	–	●	●	●	–
		NV400-CW, NV630-CW	–	–	–	–	–	●	●(Self Declaration)	–	–
	S	NV32-SV, NV63-SV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NV125-SV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NV250-SV	–	–	–	–	–	●	●	●	–
		NV125-SEV, NV250-SEV, NV400-SW, NV400-SEW, NV630-SW, NV630-SEW, NV800-SEW	–	–	–	–	–	●	●(Self Declaration)	–	–
	H/R	NV63-HV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NV125-HV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NV125-HEV, NV250-HV, NV250-HEV	–	–	–	–	–	●	●(Self Declaration)	–	–
		NV400-HEW, NV400-REW, NV630-HEW, NV800-HEW	–	–	–	–	–	–	–	–	–
UL	UL 489 Listed	NV50-SVFU, NV100-CVFU	–	–	–	●	–	●	●	●	–
		NV125-SVU, NV125-HVU	–	–	–	●	–	●	●	●	–
		NV250-SVU, NV250-HVU	–	–	–	●	–	●	●	●	–

Remark: 1. KC (Korea Certification) Mark and GOST-R (Russian Standards) approval products are prepared. Please inquire details.

●Miniature circuit breakers

Specifications	Class	Applicable Models	Compulsory Mark	
			CCC	CE
			China	Europe
IEC	BH	BH	–	–
		BH-P	–	–
		BH-S	–	–
		BH-PS	–	–
General	DIN	BH-D6	●	●(Self Declaration)
		BH-D10	●	●(Self Declaration)
		BH-DN	●	●(Self Declaration)
		BV-D	●	●(Self Declaration)
		BV-DN	●	●(Self Declaration)
		KB-D	●	●(Self Declaration)

●Circuit protectors

Specifications	Class	Applicable Models and Assignments	North American Safety Mark					Compulsory Mark		Third Party Mark	Classification Society
			UL Stgandards				CSA Standards	CCC	CE	TÜV Rheinland	NK
			USA				Canada	China	Europe	Germany	Japan
General	CP	CP30-BA	–	–	●	–	–	●	●(EN 60934) ●(EN 60947-2) (Self-Declaration)	●(EN 60934) –	–

Remark: 1. KC (Korea Certification) Mark and GOST-R (Russian Standards) approval products are prepared. Please inquire details.

●Air circuit breakers

Specifications	Class	Applicable Models	Assignments	North American Safety Mark					Compulsory Mark		Third Party Mark
				UL Stgandards				CSA Standards	CCC	CE	TÜV Rheinland
				USA				Canada	China	Europe	Germany
IEC	SW	AE630-SW, AE1000-SW AE1250-SW, AE1600-SW AE2000-SWA, AE2000-SW AE2500-SW, AE3200-SW AE4000-SWA, AE4000-SW AE5000-SW, AE6300-SW	IEC 60947-2 or JIS C 8201-2-1	–	–	–	–	–	–	●(Self Declaration)	–
	SH	AE630-SH, AE1000-SH AE1250-SH, AE1600-SH AE2000-SH, AE2500-SH AE3200-SH	IEC 60947-2	–	–	–	–	–	–	●(Self Declaration)	–
JEC	SW	AE630-SW, AE1000-SW AE1250-SW, AE1600-SW AE2000-SWA, AE2000-SW AE2500-SW, AE3200-SW AE4000-SWA, AE4000-SW AE5000-SW, AE6300-SW	JEC 160	–	–	–	–	–	–	–	–
	SH	AE630-SH, AE1000-SH AE1250-SH, AE1600-SH AE2000-SH, AE2500-SH AE3200-SH		–	–	–	–	–	–	–	–
CCC	SW	AE630-SW, AE1000-SW AE1250-SW, AE1600-SW AE2000-SWA, AE2000-SW AE2500-SW, AE3200-SW AE4000-SWA, AE4000-SW AE5000-SW, AE6300-SW	CCC	–	–	–	–	–	●	●(Self Declaration)	–

Note *1 Except for four poles breaker.
Remark: 1. GOST-R (Russian Standards) approval products are prepared. Please inquire details.

●Molded case circuit breakers, motor protection breakers, air circuit breakers, circuit protectors and miniature circuit breakers (classification society)

Specifications	Class	Applicable Models	Classification societies (Note)						
			NK	LR	ABS	GL	BV	CCS	DNV
			Japan	United Kingdam	USA	Germany	France	China	Norway
General	C	NF30-CS	●	●	●	–	–	–	–
		NF63-CV, NF125-CV	●	●	●	●	●	Scheduled to be certified	●
		NF250-CV	●	●	●	●	●	Scheduled to be certified	●
		NF400-CW, NF630-CW	●	●	●	●	●	–	–
		NF800-CEW	●	●	●	●	●	–	●
	S	NF32-SV, NF63-SV, NF125-SV	●	●	●	●	●	Scheduled to be certified	●
		NF250-SV	●	●	●	●	●	Scheduled to be certified	●
		NF400-SW, NF630-SW NF400-SEW, NF630-SEW NF800-SEW	●	●	●	●	●	●	– ●
		NF1000-SEW, NF1250-SEW	●	●	●	–	–	–	–
	H/R	NF63-HV, NF125-HV	●	●	●	●	●	Scheduled to be certified	●
		NF250-HV	●	●	●	●	●	Scheduled to be certified	●
		NF400-HEW, NF400-REW NF630-HEW, NF630-REW						● (HEW)	–
		NF800-HEW, NF800-REW						–	
	U	NF125-UV, NF250-UV	●	●	●	●	●	Scheduled to be certified	●
		NF400-UEW, NF800-UEW						–	–
	Motor Protection	NF32-SV MB, NF63-CV MB NF63-SV MB, NF125-SV MB NF250-SV MB	●	●	●	●	●	Scheduled to be certified	●
	AE	AE630-SW, AE1000-SW AE1250-SW, AE1600-SW AE2000-SWA, AE2000-SW AE2500-SW, AE3200-SW AE4000-SWA	●	●	●	●	●	●	●
		AE4000-SW, AE5000-SW, AE6300-SW	●	●	●	●	●	–	–
	CP	CP30-BA	●	–	–	–	–	–	–
	BH	BH-P	●	●	●	●	●	–	–

Remark: 1. Four poles breakers does not acquire Classification Society approval.

11. 3 Comparison of international standards

11. 3. 1 MCCB

Standard	IEC 60947-2 EN 60947-2	JIS C 8201-2-1 Appendix 1	JIS C 8201-2-1 Appendix 2
Name	Low-voltage switchgear and controlgear –Part 2: Circuit-breakers	Molded case circuit breakers	Molded case circuit breakers
Scope	Rated voltage 1000VAC or less 1500VDC or less	Rated voltage 1000VAC or less 1500VDC or less Applies to electric installations constructed according to JIS C 0364 Series. Based on JIS C 3662-3 tolerable temperature 70°C insulation wire (PCV70°C reference insulation wire).	Rated voltage 1000VAC or less 1500VDC or less Applies to electric installations constructed according to conventional electrical installation regulations. Based on JIS C 3307 tolerable temperature 60°C insulation wire (PCV 60°C reference insulation wire).
Rated current (In)	No stipulations The rated current (In) is the rated continuous current (Iu) (Refer to section 4. 3. 2. 4 of Part 1). It is equal to the thermal current (Ith).		
Rated insulation voltage (Ui)	No stipulations Unless specified, the maximum value of the rated working voltage (Ue) is Ui.	No stipulations Unless specified, the maximum value of the rated working voltage (Ue) is Ui.	No stipulations Unless specified, the maximum value of the rated working voltage (Ue) is Ui.
Rated working voltage (Ue)	No stipulations Where, IEC 60038 stipulates the standard voltage for the AC system. 3ϕ3W or 3ϕ4W: 230/400, 400/690, 1000V 1ϕ3W: 120/240V	No stipulations	No stipulations
Rated impulse withstand voltage (Uimp)	Peak value (kV) of 1.2/50μs waveform 0.33 0.5 0.8 1.5 2.5 4 6 8 12		
Rated control circuit voltage (Us)	Rated control circuit voltage (When different from main circuit voltage): AC 24-48-110-127-220-230 DC 24-48-110-125-220-250 Operating voltage range %: 85 to 110 For AC: rated frequency	Rated control circuit voltage (When different from main circuit voltage): AC 24-48-100-110-127-200-220-230-240-415 DC 24-48-100-110-125-200-220-250	Operating voltage range % 85 to 110 For AC: rated frequency

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers
	Rated voltage 100V or more 300V or less Rated current 100A or less
	(1) Capacity of 15A or less (2) Capacity of 15A or more, 30A or less (3) Capacity of 30A or more, 50A or less (4) Capacity of more than 50A Note) The frame size is not stipulated.
	No stipulations
	(1) Capacity of 125V or less (2) Capacity of more than 125V
	No stipulations
	No stipulations

11 Standards

<table>
<tr><td>Standard</td><td>IEC 60947-2
EN 60947-2</td><td>JIS C 8201-2-1
Appendix 1</td><td colspan="2">JIS C 8201-2-1
Appendix 2</td><td></td></tr>
<tr><td>Name</td><td>Low-voltage switchgear and controlgear
–Part 2: Circuit-breakers</td><td>Molded case circuit breakers</td><td colspan="2">Molded case circuit breakers</td><td></td></tr>
<tr><td rowspan="2">Tripping voltage</td><td>Voltage tripping</td><td>Undervoltage tripping</td><td>Voltage tripping</td><td>Undervoltage tripping</td><td rowspan="2"></td></tr>
<tr><td>Must trip at 70 to 110% of rated voltage.</td><td>Must trip at 70 to 35% of rated voltage; prevent closed circuit at 35% or less and create closed circuit at 85% or more.
Voltage upper limit at 110%.</td><td>Must trip at 85 to 110% (AC) or 75 to 110% (DC) of rated working voltage.</td><td>Must trip at 70 to 20% of rated voltage; prevent closed circuit at 35% or less and create closed circuit at 85% or more. Voltage upper limit at 110%.</td></tr>
<tr><td>Rated frequency</td><td>No stipulation</td><td>No stipulation</td><td colspan="2">No stipulation</td><td></td></tr>
<tr><td>No. of poles</td><td colspan="4">1 2 3 4 (with N pole)</td><td></td></tr>
<tr><td>Reference ambient temperature</td><td>30°C ± 2°C</td><td>30°C</td><td colspan="2">40°C</td><td></td></tr>
<tr><td>Rated tripping current (Icn)</td><td colspan="4">Icu (rated maximum short-circuit breaking capacity) is not stipulated.
Ics (rated service short-circuit breaking capacity) is expressed as a percentage of the %, and is 25, 50, 75 to 100%.
Indicated as a % display or a rounded up decimal value.
Lcw (rated short-time current) at a rated current of 2500A or less must be 12-times or 5kA the rated current, and at more than 2500A must be larger than 30kA.</td><td></td></tr>
<tr><td>Structure</td><td colspan="4">(1) Using the Glow Wire Testing method, the insulation material shall be verified to have a performance of 960°C (when holding the main circuit's energized section) or 650°C (when used in other sections).
(2) The energized section shall have the required strength and energizing capacity. The connector shall not be tightened via an insulator.
(3) The surface distance shall be stipulated by the rated insulation voltage (Ui), Pollution Degree and insulation material. The clearance distance shall be stipulated by the rated impulse voltage (Uimp).
(4) The operation panel's operation direction shall follow the IEC60447 stipulations.
(5) The ON/OFF position shall be clearly indicated. ON/OFF may be indicated with the IEC60417 symbols. (I, O)
(6) Required functions are added to products complying with Isolation stipulations. (Details omitted)
(7) Terminal screws shall not be used to fix other parts.
(8) Terminal symbols must be clear, not disappear easily, and must comply with IEC60447.
(9) Products with an N pole shall be indicated with an N. This pole shall not open faster or close slower than other poles.
The energizing capacity of the N pole shall be the same as other poles if the breaker capacity is 63A or lower. If the capacity is 63A or more, the energizing capacity shall be 50% or more of other poles and larger than 63A.
(10) Terminal strength
①Connection and removal shall be performed five times. The screw type terminal shall be tightened with the tightening torque given in IEC 60947-1 Table IV, or 110% of the manufacturer's specified torque, whichever is larger.
The strength shall be tightened with two terminals. A new conductor shall be used each time. The terminal shall not be damaged.
②A wire with the specified length (IEC 60947-1 Table V + 75mm) shall be tightened with the specified torque (IEC 60947-1 Table IV or manufacturer's designated value). A specified weight shall be attached to the wire at diameter 37.5mm, 10 ± 2rpm, swung 135 times. The wire must not dislocate or break. The pulling test shall be performed immediately with the specified load (IEC 60947-1 Table VI). The conductor shall not dislocate and the terminal shall not break.
(11) Draw type terminal structure (Details omitted)
(12) Stored energy type operation method (Details omitted)
(13) Mechanism
①The breaker must trip even if the closing device activates.
②There must be no damage even if the closing device activates when the breaker is ON.
③The trip-free breaker must not maintain a closed contact when the tripping device activates.</td><td></td></tr>
</table>

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers
	No stipulation
	50/60Hz
	1 2 3
	40°C ± 2°C(25°C ± 2°C)
	Symmetrical value Capacity of 1000A or less Capacity of 1000A or more 1500A or less Capacity of 1500A or more 2500A or less Capacity of 2500A or more 5000A or less Capacity of 5000A or more 7500A or less Capacity of 7500A or more 10000A or less Capacity of 10000A or more 15000A or less Capacity of 15000A or more 20000A or less Capacity of 20000A or more 25000A or less Capacity of 25000A or more 30000A or less Capacity exceeding 30000A
	(1) If the rated current exceeds 20A, it must be possible to connect the wire without bending it into a ring. (2) When using a large round head flat screw, the area of the terminal fitting covered by the terminal screws head shall be larger than the area of the large head round flat screw's head. (3) If the product has two or more poles, it must be possible to switch each pole simultaneously (when there are three or more poles, the poles other than the grounding side poles). (4) Insulation distance If the rated current is 15A or more, the space distance shall be 4mm or more at the switch side. The surface distance must be 6mm or more (4mm at sections other than terminal section in breaker with a structure which the user cannot open the cover or outer housing). (5) The ventilation hole size shall not permit a 5mm diameter sphere to pass through it. (6) The breaker shall be a free tripping type. (7) The effective thread length of the terminal shall be 2 pitches or more if the nominal diameter is 8mm or less, and 50% of more of the nominal diameter if the nominal diameter is 8mm or more. Note that this shall not apply to a terminal with a nominal diameter of 8mm or more with a threaded section inside the terminal frame, and to which the following points do not apply. (a) The effective length of the total thread section is 25% or more of the nominal diameter, and the sum of the total thread section and partial thread section is 55% or more of the nominal diameter. (b) The terminal section's strength test is passed when repeated five times.

Standard	IEC 60947-2 EN 60947-2	JIS C 8201-2-1 Appendix 1	JIS C 8201-2-1 Appendix 2	
Name	Low-voltage switchgear and controlgear –Part 2: Circuit-breakers	Molded case circuit breakers	Molded case circuit breakers	
Size of terminal for wire connection	The maximum connectable wire shall be larger than the values given below. It shall be possible to tighten a terminal two sizes smaller than the sizes given in IEC 60947-1 Table I Wire sizes.			
Test wire	(see tables below)		(see tables below)	

Test wire — IEC 60947-2 / EN 60947-2, JIS C 8201-2-1 Appendix 1

Test current		Conductor size mm^2
More than 0A	8A or less	1.0
8	12	1.5
12	15	2.5
15	20	2.5
20	25	4.0
25	32	6.0
32	50	10
50	65	16
65	85	25
85	100	35
100	115	35
115	130	50
130	150	50
150	175	70
175	200	95
200	225	95
225	250	120
250	275	150
275	300	185
300	350	185
350	400	240

Test wire — JIS C 8201-2-1 Appendix 2

Rated current A	Wire	
	Single wire (diameter) mm	Strand wire (cross sectional area) mm^2
In ≦ 15	1.6	–
15 < In ≦ 20	2.0	–
20 < In ≦ 30	–	5.5
30 < In ≦ 40	–	8
40 < In ≦ 50(60)	–	14
50 < In ≦ 75	–	22
75 < In ≦ 113	–	38
113 < In ≦ 152	–	60
152 < In ≦ 208	–	100
208 < In ≦ 276	–	150
276 < In ≦ 328	–	200
328 < In ≦ 389	–	250
389 < In ≦ 455	–	2 X 100 or 325
455 < In ≦ 520	–	2 X 150 or 400
520 < In ≦ 600	–	2 X 200 or 500

Range of test current A		Conductor			
		Meter		MCM	
		No. of wires	Size mm^2	No. of wires	Size MCM
400	500	2	150	2	250
500	630	2	185	2	350
630	800	2	240	3	300

Electric Appliance Safety Law

Standards concerning technology for electrical appliances

Molded case circuit breakers

Rated current A	Wire	
	Single wire (diameter mm)	Strand wire (nominal cross sectional area mm^2)
15 or less	1.6(2.0)	–
More than 15, less than 20	1.6 and 2.0 (2.0, 2.6 and 3.2)	2.0 and 5.5
More than 20, less than 30	20 and 2.6 (2.6 and 3.2)	3.5 and 8 (14.0)
More than 30, less than 50	–	8.0 and 14.0 (14.0 and 22.0)
More than 50, less than 60	–	8.0, 14.0 and 22.0 (14.0, 22.0 and 38.0)
More than 60, less than 75	–	14.0, 22.0 and 30.0 (14.0, 22.0 and 38.0)
More than 75	–	2.20, 30.0 and 38.0 (38.0, 50.0 and 60.0)

Values given in parentheses apply to wires with Aℓ or Aℓ-Cu markings.

Rated current A	Wire	
	Single wire (diameter mm)	Strand wire (nominal cross sectional area mm^2)
15 or less	1.6 (2.0)	–
More than 15, less than 20	2.0 (2.6)	–
More than 20, less than 30	(3.2)	5.5
More than 30, less than 40	–	8 (14.0)
More than 40, less than 60	–	14.0 (22.0)
More than 60, less than 75	–	22.0 (38.0)
More than 75	–	38.0 (60.0)

11 Standards

Standard	IEC 60947-2 EN 60947-2	JIS C 8201-2-1 Appendix 1	JIS C 8201-2-1 Appendix 2
Name	Low-voltage switchgear and controlgear –Part 2: Circuit-breakers	Molded case circuit breakers	Molded case circuit breakers
Overcurrent tripping test	(1) Long-time delay tripping At the reference ambient temperature, the breaker must not function when a current 1.05 times the rated current (non-operating current if it can be set) is passed for 2h (1h if rated current is 63A or less). When the current is immediately increased to 1.30 times, the breaker must trip within 2h (within 1h if rated current is 63A or less). If the breaker is not affected by the ambient temperature, the similar test shall be carried out at 30°C ± 2°C, 20°C ± 2°C or 40°C ± 2°C. Energize the three poles simultaneously, and perform a cold start. (2) Short-circuit protection tripping (a) Instantaneous tripping The breaker must not function for 0.2s at 80% of set current value. The breaker must function within 0.2s at 120% of set current value. (b) The short-time delay tripping must not function for a time 2-times the short-time delay tripping time set by the manufacturer at 80% of the rated current. At 120% of the set current value, the breaker must function within 2-fold the short-time delay tripping time set by the manufacturer. Two poles must be connected in series and tested. All possible combinations must be tested for the two poles. The test per pole must also be carried out thereafter. The tripping current shall be the value set by the manufacturer. (3) Additional test of short-time delay tripping (a) With a current that is 1.5 times the tripping current setting value, the tripping time for a 2-pole series must be measured and be within the range set by the manufacturer. All possible two-pole combinations must be tested. (b) Under the same conditions as (a), after passing a current 1.5 times the set value for the non-operating time set by the manufacturer, pass the rated current for 2-times the short-time delay tripping time. The breaker must not trip. (4) Instantaneous tripping for overload protection, short-time delay tripping (Details omitted) (5) The connected wire must have the size indicated in the Wire connection terminal column, and the length must be the length given in the Temperature rise test column. If the overcurrent tripping can be adjusted with the breaker, test with the maximum and minimum settings. Select the connected current from the setting In. The test voltage shall be an arbitrary value. (6) Sequence I, II Overcurrent tripping after temperature rise test Immediately after the temperature test, increase the rated current to 1.45 times. The breaker must function within 2 hours (within 1 hour for 63A or less). Connect all poles in series. A 3-phase current may be used. The voltage may be an arbitrary value. (7) Sequence III (a) The breaker must function within the time set by the manufacturer when a current double the rated current is passed to each pole. The voltage may be an arbitrary value. (b) Overcurrent tripping must occur after the Icu and withstand voltage test. The breaker must function within the time of the current 2 times set by the manufacturer when a current 2.5 times the rated current is passed to each pole.	Matters other than the following are the same as IEC. (2) Short-circuit protection tripping (a) Instantaneous tripping The breaker must not function for 0.2 at 80% of set current value. The breaker must function within 0.2s at 120% of set current value.	Matters other than the following are the same as Appendix 1. (1) Long-time delay tripping At the reference ambient temperature, the breaker must not function when a current 1.0 times the rated current (non-operating current if it can be set) is passed for 2h (1h if rated current is 50A or less). When the current is immediately increased to 1.25 times, the breaker must trip within 2h (within 1h if rated current is 50A or less). When a current 2.0 times the rated current is passed to each pole, the breaker must function within the specified operating time. If the breaker is not affected by the ambient temperature, the similar test shall be carried out at 30°C ± 2°C, 20°C ± 2°C or 40°C ± 2°C. Energize the three poles simultaneously, and perform a cold start. 200% Operating time (minutes) Within 2 (In ≦ 30A) Within 4 (30A < In ≦ 50A) Within 6 (50A < In ≦ 100A) Within 8 (100A < In ≦ 225A) Within 10 (225A < In ≦ 400A) Within 12 (400A < In ≦ 600A) Within 14 (600A < In ≦ 800A) Within 16 (800A < In ≦ 1000A) Within 18 (1000A < In ≦ 1200A) Within 20 (1200A < In ≦ 1600A) Within 22 (1600A < In ≦ 2000A) Within 24 (2000A < In)
100% current test	No stipulation	No stipulation	Follows stipulations above

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers

Rated current A	Operating time (min)	
	Current 200% of rated current	Current 125% of rated current
30 or less	Within 2	Within 60
More than 30, less than 50	Within 4	Within 60
More than 50	Within 6	Within 120

(1) Pass the 200% current to each pole.
(2) Pass the 125% current simultaneously to each pole.

The overcurrent tripping device must not function when a current equal to the rated current is passed until the temperature at each section stabilizes.

Standards MCCB & ELCB

<table>
<tr><td>Standard</td><td>IEC 60947-2
EN 60947-2</td><td>JIS C 8201-2-1
Appendix 1</td><td>JIS C 8201-2-1
Appendix 2</td><td></td></tr>
<tr><td>Name</td><td>Low-voltage switchgear and controlgear
–Part 2: Circuit-breakers</td><td>Molded case circuit breakers</td><td>Molded case circuit breakers</td><td></td></tr>
<tr><td>Overload test</td><td>This test applies to a breaker with rated current of 630A or less.
The test circuit shall follow IEC 947-1 Figures 3 to 6.
The power capacity and copper fuse standards are the same as the conductivity durability test.
The test voltage shall be the maximum Ue.
The adjustable tripping setting shall be set to the maximum.
The test shall be performed 12 times in total. Nine times shall be manual switching, and three times shall be automatic breaking using the overcurrent tripping function.
The energizing time shall be the time that the current can sufficiently reach the specified value, but shall be within 2s.
The switching frequency shall be the same as the value given in the Durability column. The frequency can be lowered if the breaker cannot be reset.
The frequency shall be in the range of 45 to 62Hz.
<table>
<tr><td></td><td>AC</td><td>DC</td></tr>
<tr><td>Current</td><td>6In</td><td>2.5In</td></tr>
<tr><td>Voltage</td><td>1.05Ue max</td><td>1.05Ue</td></tr>
<tr><td>Power factor cosϕ</td><td>0.5</td><td>max</td></tr>
<tr><td>Time constant L/R (ms)</td><td>–</td><td>2.5</td></tr>
</table></td><td colspan="2">Matters other than those below shall be the same as IEC.
<table>
<tr><td></td><td>AC</td><td>DC</td></tr>
<tr><td>Current</td><td>6In</td><td>2.5In</td></tr>
<tr><td>Voltage</td><td>1.1Ue max</td><td>1.1Ue</td></tr>
<tr><td>Power factor cosϕ</td><td>0.5</td><td>max</td></tr>
<tr><td>Time constant L/R (ms)</td><td>–</td><td>2.5</td></tr>
</table></td><td></td></tr>
<tr><td>Overflow current test</td><td>No stipulation</td><td>When indicating the overflow performance with a rated working voltage of 100VAC or 110/220VAC and rated current of 50A or less, perform the following test. The breaker must not open automatically, and must not weld.
(1) Using a 100V, 200W incandescent light bulb as a reference, the number of lit bulbs to which the breaker's rated current flows.
(2) Test voltage is 100 to 105V. The voltage drop when the bulb turns ON must be within 5%.
(3) The test shall be carried out for 2s. After the closing, the circuit shall be opened and cooled for 2 minutes. This process shall be repeated three times in succession.</td><td>When the rated working voltage is 100VAC or 110/220VAC and the rated current is 50A or less, perform the following test. The breaker must not function or weld when the incandescent light bulb turns ON at room temperature.
(1) Using a 100V, 200W incandescent light bulb as a reference, the number of lit bulbs to which the breaker's rated current flows.
(2) Test voltage is 100 to 105V. The voltage drop when the bulb turns ON must be within 5%.
(3) The test shall be carried out for 2s. After the closing, the circuit shall be opened and cooled for 2 minutes. This process shall be repeated three times in succession.</td><td></td></tr>
</table>

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers
	When a current 6 times the rated current (150A if the rated current is 25A or less) is passed for 1 minute, the breaker must switch 35 times manually, and 15 times with the manual setting automatic tripping operation. The switching ratio is 4 times per minute. (1) The voltage drop shall be 15% or less when a current 6 times the rated current is passed. (2) Connect an insulated wire having the specified size to the test product and mount in the normal working state. Apply a voltage equivalent to the rated voltage. (3) The test circuit's power factor is 0.45 or more, 0.5 or less. (Note) If the breaker has individual tripping wires, automatic breaking must be tested for each pole.
	If the rated current is 50A or less, the breaker must not automatically break and the contact must not weld when the following test is performed. (1) Connect tungsten bulb having a rated voltage of 100V and rated power consumption of 200W to the load side of the test part (when using single-phase 3-wire type, connect to neutral wire on load side and voltage side wire of 1) so that the current in the ON state is approximately equal to the rated current. In this case, a bulb having a rated power consumption of 200W or less can be used within the required limit to adjust the current. (2) The no-load voltage of the power side terminal of the test part shall be 100V or more 105V or less. The voltage drop when the bulb turns ON shall be within 5%. (3) Turn the tungsten bulbs connected ON simultaneously, open the circuit after 2 second and allow the circuit to cool naturally for two minutes. Repeat this process three times in succession.

Standard	IEC 60947-2 EN 60947-2	JIS C 8201-2-1 Appendix 1	JIS C 8201-2-1 Appendix 2	
Name	Low-voltage switchgear and controlgear –Part 2: Circuit-breakers	Molded case circuit breakers	Molded case circuit breakers	

Temperature rise test (IEC 60947-2 / EN 60947-2; JIS C 8201-2-1 Appendix 1)

Place		Temperature rise limit (K)
External insulated conductor connection terminal		80
Operation section	Metal	25
	Non-metal	35
Section accessible by worker	Metal	40
	Non-metal	50
Section normally inaccessible by worker	Metal	50
	Non-metal	60

Even insulators and parts that are not listed must not be damaged by a rise in temperature.

(1) Testing method

(a) The ambient temperature must be measured by at least two sensors.
Mount the sensors at a position at approx. 1m from the breaker and a height approx. half of the breaker mounting height. Protect the sensor from drafts and radiated heat.

(b) The ambient temperature must be within the range of +10 to +40°C, and must not fluctuate by 10K or more. If the temperature fluctuates by 3K or more, compensate the temperature rise value taking the thermal time constants into consideration.

(c) The electromagnetic coil's temperature shall follow the resistance method. $T2 = R2/R1\ (T1 + 234.5) - 234.5$
The temperature rise shall follow the IEC 60216 or IEC 60085 stipulations.
T1: Temperature at start (°C) R1: Resistance at start (Ω)
T2: Temperature at saturation (°C) R2: Resistance at saturation temperature (Ω)

(d) A temperature rise fluctuation of within 1°C/hour shall be viewed as saturation. It shall not take more than 8h to achieve a saturated state.

(e) The breaker shall be mounted properly.

(f) The breaker's rated thermal current (Ith) shall be passed. Ith shall be the same as the breaker's rated current (In).
The voltage may be an arbitrary voltage.

(d) The DC breaker may be tested with an AC. the multi-pole breaker may be tested by passing a single-phase current to the series of all poles.

(h) With the 4-pole breaker having an N-pole:
① Test with the three voltage poles,
② Set the N pole in series with the adjacent pole, and use a single-phase current to test the N pole's Ith.

(i) When Ith = In is 400A or less
The connected wire shall follow the wire indicated in the Wire connection terminal column.
The minimum wiring length between terminals or to other terminals shall be 1m if the wire diameter is $35mm^2$ or less, and 2m if the diameter is $35mm^2$ or more.

(j) When Ith = In is more than 400A, 800A or less
The connected wire shall be a PVC wire or copper bar indicated in the Wire connection terminal column. A different copper bar with similar cross section area may also be used. The copper bar shall be painted black. When connecting several copper bars to one terminal, provide a space equivalent to the bar's thickness. When connecting multiple wires to one terminal, bundle the wires while providing a 10mm gap. The minimum conductor length between terminals and to other terminals shall be 2m. The length to the star point may be 1.2m.

(k) When Ith = In is more than 800A, 3150A or less
The connected copper bar is indicated in the Wire connection terminal column. A different copper bar with similar cross section area may also be used. When connecting a wire, the manufacturer's designations must be followed. The copper bar shall be painted black. When connecting several copper bars to one terminal, provide a space equivalent to the bar's thickness. The minimum length of the copper bar between the terminals and to other terminals shall be 3m. If the power terminal's temperature rise is not 5K lower than the copper bar length's interim value, the length may be 2m. The minimum length to the star point is 2m.

(l) When Ith = In exceeds 3150A, the test shall be decided by the manufacturer and user.

(m) The control circuit's temperature rise shall be tested by applying the rated voltage and rated current.
When testing an auxiliary or alarm switch, the voltage may be an arbitrary value.

(n) When using a 4-pole breaker, first the 3 voltage poles shall be tested. After that, the N pole and adjacent pole shall be tested with In if In is 63A or less, and with a current value decided by the manufacturer and user if In exceeds 63A.

(2) Temperature rise test after sequence II Ics
Only the terminal's temperature rise shall be measured. The result shall be 80K or less.
There is no need to test at the minimum In.

Temperature rise test (JIS C 8201-2-1 Appendix 2)

Matters other than those below shall be the same as Appendix 1.

Place		Temperature rise limit (K)
External insulated conductor connection terminal		60
Operation section	Metal	25
	Non-metal	35
Section accessible by worker	Metal	40
	Non-metal	50
Section normally inaccessible by worker	Metal	50
	Non-metal	60

	Electric Appliance Safety Law Standards concerning technology for electrical appliances		
	Molded case circuit breakers		
	Measurement position	**Temperature rise**	
		Thermoelectric pyrometer method	**Resistance method**
	Switch contact section of a breaker with copper or copper alloy contact material, lump-type or a flat plate shape, and a butt contact mechanism	40	–
	Switch contact section of a breaker with copper or copper alloy contact material, lump-type or a flat plate shape, and a sliding contact mechanism	45	–
	Switch contact section of a breaker with silver or silver alloy contact material, lump-type or a flat plate shape, and a sliding contact mechanism	100	–
	Terminal fitting	60	–
	Class Y insulation coil	50	70
	Class A insulation coil	65	85
	Class E insulation coil	80	100
	Class B insulation coil	90	110
	Class F insulation coil	115	135
	Class H insulation coil	140	160
	Coil with bare wires wound in single layer	90	–
	Coil with enameled wire wound in single layer	90	–
	Coil with enabled wire wound in double layer	80	–
	Selenium coil	45	–
	Germanium coil	30	–
	Silicon coil	105	–
	Reference ambient temperature shall be 30°C.		

<table>
<tr><th>Standard</th><th>IEC 60947-2
EN 60947-2</th><th>JIS C 8201-2-1
Appendix 1</th><th>JIS C 8201-2-1
Appendix 2</th><th></th></tr>
<tr><td>Name</td><td>Low-voltage switchgear and controlgear
–Part 2: Circuit-breakers</td><td>Molded case circuit breakers</td><td>Molded case circuit breakers</td><td></td></tr>
<tr><td>Durability test</td><td colspan="3">
<table>
<tr><th rowspan="2">Rated current A</th><th rowspan="2">Switching frequency Times/hour</th><th colspan="3">Number of switching times</th></tr>
<tr><th>Non-energized</th><th>Energized</th><th>Total</th></tr>
<tr><td>100 or less</td><td>120</td><td>8500</td><td>1500</td><td>10000</td></tr>
<tr><td>More than 100, 315 or less</td><td>120</td><td>7000</td><td>1000</td><td>8000</td></tr>
<tr><td>More than 315, 630 or less</td><td>60</td><td>4000</td><td>1000</td><td>5000</td></tr>
<tr><td>More than 630, 2500 or less</td><td>20</td><td>2500</td><td>500</td><td>3000</td></tr>
<tr><td>More than 2500</td><td>10</td><td>1500</td><td>500</td><td>2000</td></tr>
</table>
The switching frequency is the minimum value
The breaker must be energized with a closed circuit for a maximum of two seconds.

(1) The test shall be performed at room temperature.
The voltage applied on the control circuit shall be measured at the terminal of the enclosed device.
The order for testing the overload, energizing durability and non-energizing durability is arbitrary.
(2) 10% of the total number of times in the non-energizing test shall be tripped with UVT or SHT. The applied voltage shall be the maximum operating voltage.
Half of the operation shall be performed at the start of the durability test, and the remaining half shall be performed when the test is finished.
When switching with an electric operation switch, apply the rated control voltage and test.
(3) Energizing durability test.
The test circuit shall follow IEC 60947-1 Figures 3 to 6.
The power capacity shall be more than 10 times the test current or 50kA, whichever is smaller.
A ϕ0.8mm, minimum 50mm long copper fuse shall be connected between the mounting plate and neutral point to detect accidents.
The accident current shall be 1500A ± 10%. A copper wire thinner than ϕ0.8 may be used. (Conditions omitted)
The rated current and rated working voltage (Ue) shall be switched.
The power factor shall be 0.8, the time constant shall be 2ms. The frequency shall be within the range of 45 to 62Hz.
When using adjustable tripping, the overcurrent setting shall be the maximum. The short-circuit setting shall be the minimum.
When switching with an electric operation switch, the rated control voltage shall be applied.
</td><td></td></tr>
<tr><td>Insulation resistance test</td><td>No stipulation</td><td>No stipulation</td><td>No stipulation</td><td></td></tr>
</table>

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers
	Apply a voltage equal to the rated voltage, and pass a current equal to the rated current. Switch 5000 times at a switching rate of 10 times per minute. The test circuit's power factor is 0.75 or more, 0.8 or less The test circuit's voltage drop is 2.5% of less

Measurement place	Insulation resistance (MΩ)
Between live section with different polarity (Excluding motor's live section and operating circuit with rated voltage of less than 100V. This also applies hereinafter in this table.). Between live sections with same polarity in open circuit state. Between live section and non-live metal section that could be grounded, or nonmetal section that could be touched by worker. Between live section and test metal plate. Between main circuit and operation circuit.	5
Between motor's live section, non-live section and metal. Between operating circuit with rated voltage less than 100V and nonmetal section that could be grounded, or nonmetal section that could be touched by worker. Between operation circuit with rated voltage less than 100V and test metal plate.	1

<table>
<tr><td>Standard</td><td>IEC 60947-2
EN 60947-2</td><td>JIS C 8201-2-1
Appendix 1</td><td>JIS C 8201-2-1
Appendix 2</td></tr>
<tr><td>Name</td><td>Low-voltage switchgear and controlgear
–Part 2: Circuit-breakers</td><td>Molded case circuit breakers</td><td>Molded case circuit breakers</td></tr>
<tr><td>Withstand voltage test</td><td colspan="2">(1) Impulse withstand voltage
The test voltage shall follow IEC 60947-1 Table 12.
If the breaker is equipped with an isolation function, the contact will be opened, and the voltage indicated in IEC 60947-1 Table 14 shall be applied.
If the spatial distance is larger than case A in IEC 60947-1 Table 13, the Uimp test may be omitted.
The surface distance must be larger than IEC 60947-1 Table 15. The material's CTI value is stipulated by the working environment's pollution degree.
If the breaker is equipped with an isolation function, the 1.1Ue test voltage shall be applied. The leakage current between the power and load shall be 0.5mA or less.
Cover the insulator's operation handle with metal foil, and connect to a metal mounting plate.
A 1.2/50μs impulse waveform voltage shall be applied as a positive and negative voltage five times each at a minimum 1 second interval.
Voltage application position.
① Between main circuit and control circuit's level section batch and mounting plate. Contact is ON, OFF, trip.
② Connect one pole of the main circuit, and the other poles in a batch to the mounting plate. Contact is ON, OFF, trip.
③ Between a control circuit that is not connected to the main circuit, and the main circuit, other control circuit and mounting plate.
④ Between the power terminal batch and load side terminal batch. Contact open.
(2) Voltage withstand test (high frequency voltage withstand test)
The withstand voltage test in the test sequence shall follow the sine wave voltage.
Mount on a metal plate. Cover the insulator's operation handle with metal foil, and connect to a metal mounting plate.
If the breaker is equipped with a motor, instrument, snap switch or semiconductor device, etc., disconnect the connection during the test.
Voltage application position.
(a) Main circuit (Control circuit not connected to main circuit and auxiliary circuit are all connected to mounting plate)
① Breaker ON: Between batch of all live sections and mounting plate
Between each pole and batch of all other poles connected to mounting plate
② Breaker OFF, trip: Between batch of all live sections and mounting plate
Between power side terminal batch and load side terminal batch
(b) Control/auxiliary circuit (All live sections of main circuit connected to mounting plate)
① Between control/auxiliary circuit batch not connected to main circuit and mounting plate
② Between one enclosed device and other enclosed device
The voltage is applied for five sections. The test voltage shall be a sine wave with frequency between 45 and 62Hz. The current at the short-circuit shall be smaller than 0.2A.
Withstand voltage
Rated insulation voltage Ui (V) — Withstand voltage AC rms (V)
60 or less — 1000
More than 60, less than 300 — 1500
More than 300, less than 690 — 1890
More than 690, less than 800 — 2000
More than 800, less than 1000 — 2200
The test voltage of the control/auxiliary circuit not connected to main circuit shall be 1000V for Ui 60V, and 2Ui + 1000V at Ui 60V. The minimum value shall be 1500V.
(3) Sequence I Withstand voltage test after overload and energizing durability. Apply 2Ue. Note that minimum value is 1000V.
(4) Sequence II Withstand voltage test after Ics. Apply 2Ue. Note that the minimum value is 1000V.
(5) Sequence III Withstand voltage test after Ics. Apply 2Ue. Note that the minimum value is 1000V.</td><td>Matters other than the following shall be the same as Appendix 1.
(1) Impulse withstand voltage test

• When declaring Uimp.
Same as Appendix 1.

• When not declaring Uimp.
① Commercial frequency withstand voltage test.
Same as Appendix 1.
② Lightning impulse withstand voltage test
Apply a 1.2/50μs impulse waveform voltage 5kV three times each in positive and negative state, between the live section and non-live metal section.</td></tr>
</table>

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers

Rated voltage (V)	Test voltage (V)
30 or less	500
More than 60, 150 or less	1000
More than 150, 300 or less	1500
More than 300, 600 or less	2000
More than 600, 1000 or less	3000

(Remarks) If a double rating is provided, the higher rated voltage shall be used.

The breaker must withstand when the voltage listed above is continuously applied for one minute to the measurement position indicated for the insulation resistance test.

Standard	IEC 60947-2 EN 60947-2	JIS C 8201-2-1 Appendix 1	JIS C 8201-2-1 Appendix 2	
Name	Low-voltage switchgear and controlgear −Part 2: Circuit-breakers	Molded case circuit breakers	Molded case circuit breakers	
Short-circuit test	(1) Test conditions (a) Tolerable difference of each element Current +5 to 0% Voltage +5 to 0% Power factor 0 to −0.05 Time constant +25 to 0% Frequency ±5% (b) The recovery voltage must be 105% of rated working voltage (Ue). (c) If an electric operation device is provided, test by applying an 85% voltage. (d) If power side and load side terminal indications are provided, follow the indications. If there are no indications, follow the Standards. (e) The test circuit follows IEC 60947-1 Figure 9 to Figure 12. The section grounded during use, the wire mesh covering the breaker, and the box shall be connected to power's neutral point via a ϕ0.8mm min. 50mm long copper fuse for accident current detection. A resistor may be inserted so that the accident current is 1500A ± 10%. If a neutral point is created, regardless of the wiring method, the accident setting current and copper fuse may be smaller. (f) The connected wire size shall be the value given in the Wire connection terminal column. The wire length shall be 50cm on the power side and 25cm on the load side for a capacity breaker if In is 630A or smaller. (g) With a 4-pole breaker, the short-circuit breaking test for the N pole and adjacent pole shall be tested with the additional new part specimen. The applied voltage shall be Ue/. The test current shall be decided by the manufacturer in user, but shall not be smaller than 60% of Icu and Icw. (h) During the short-circuit breaking test, the copper fuse for detecting a short-circuit, ground fault or accident between the poles must not weld. (i) The tripping current is indicated as the average value for the 3-phase rms. The current for each phase must not fluctuate more than 10% from the average value. (j) The closing current is expressed as the maximum value for three phases. (k) The time during the breaking test is either 3 minutes or the reset time, whichever is longer. (2) Rated working short-circuit breaking test (Ics) The test specimen's rated working voltage (Ue), rated current (In), Ics, and number of test units shall follow IEC 60947-2 Table X. The test liability is O-t-CO-t-CO. If the breaker is equipped with a fuse, the fuse must be replaced each time it blows. (3) Rated maximum short-circuit breaking test (Icu) The test specimen's rated working voltage (Ue), rated current (In), Ics, and number of test units shall follow IEC 60947-2 Table X. The test liability is O-t-CO. (4) Details on the rated short-time withstand current (Icw), fuse built-in breaker short-circuit breaking test, and combination test (Icw = Ics, Icw = Ics = Icu) have been omitted.	Matters other than the following conditions are the same as IEC. (1) Test conditions (b) The recovery voltage shall be 110% of the rated working voltage (Ue). (2) Rated working short-circuit breaking test (ICs) This test sequence does not need to be applied for the time being.		

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers

(1) Short-circuit current AC element active value at 0.5 cycle after a voltage equal to the rated voltage is applied and a short-circuit is caused

(2) Circuit constant

Rated tripping current or rated cord protection current (A)	Short-circuit power factor
1500 or less	0.7 or more, 0.8 or less
1500 or more, 5000 or less	0.5 or more, 0.6 or less
More than 5000	0.3 or more, 0.4 or less

(3) Recovery voltage Must be equal to rated voltage. Test voltage must be applied for 0.2s or more after test unit opens.

(4) Short-circuit test The following test order shall apply.

(a) Connect a closed test unit serially to the open switch unit. The test unit must automatically trip the test circuit when the switch unit is closed.

(b) When 2min have passed from the automatic tripping (if more than two minutes is required for resetting, the minimum time required for resetting), close the test unit. The test circuit must automatically trip again.

(c) If there is only a single pole, perform test specified in (a) and (b) once on the single-phase test circuit. In this case, if the rated tripping current exceeds 10000A, perform the test with the test current set to 10000A. Then, switch the test unit, and perform with a test current equal to the rated tripping current.

(d) For a single-phase 2-wire 2-pole unit, use the following test.

a. If the rated tripping current is 10000A or less, perform the test specified in (a) and (b) once each on each pole (excluding pole with no overcurrent tripping element). Next, connect two poles in series, and perform the test specified in (a) and (b) once. If the rated tripping current exceeds 5000A at this time, the test current for each pole can be 5000A.

b. If the rated tripping current exceeds 10000A, perform the test specified in (a) and (b) once with a test current of 5000A for each pole (excluding pole that does not have overcurrent tripping element). Next, connect two poles in series, and perform the test specified in (a) and (b) with a test current of 10000A. Replace the test unit, and perform the test specified in (a) and (b) with a current equal to the rated tripping current.

(e) For the single-phase 3-wire type breaker, connect serially to the pole connected to the test unit's voltage side wire and pole connected to the neutral wire (neutral wire for wiring breaker with two poles and with individual tripping mechanism), and perform the test specified in (a) and (b) one time each. Next, in the single-phase 3-wire test circuit, connect serially to the pole connected to each voltage side wire of the test unit and perform the test specified in (a) and (b) once.

(f) The following test shall be performed for the 3-phase unit.

a. If the rated tripping current is 10000A or less, perform the test specified in (a) and (b) once each on each pole (excluding pole with no overcurrent tripping element). Next, with the 3-phase test circuit perform the test specified in (a) and (b) once. If the rated tripping current exceeds 5000A at this time, the test current for each pole can be 5000A.

b. If the rated tripping current is more than 10000A, perform the test specified in (a) and (b) once with a test current of 5000A on each pole (excluding pole with no overcurrent tripping element). Next, with the 3-phase test circuit perform the test specified in (a) and (b) once with a test current of 10000A. Replace the test unit, and perform the test specified in (a) and (b) on the 3-phase test circuit with a current equal to the rated tripping current.

11 Standards

Standard	IEC 60947-2 EN 60947-2	JIS C 8201-2-1 Appendix 1	JIS C 8201-2-1 Appendix 2	
Name	Low-voltage switchgear and controlgear –Part 2: Circuit-breakers	Molded case circuit breakers	Molded case circuit breakers	
Cord protection test	No stipulation	No stipulation	No stipulation	
Test order (model test) Whether to carry out each test item with the same test unit or a different test unit shall follow the Standards.	Sequence I (1) Overcurrent tripping (2) Withstand voltage (Uimp) (3) Mechanical switching durability Energizing switching durability (4) Overload (5) Withstand voltage (commercial frequency) (6) Temperature rise (7) Overcurrent tripping Sequence II (1) Rated working short-circuit breaking (o-co-co) (2) Withstand voltage (commercial frequency) (3) Temperature rise (4) Overcurrent tripping Sequence III (1) Overcurrent tripping (2) Rated maximum short-circuit breaking (o-co) (3) Withstand voltage (commercial frequency) (4) Overcurrent tripping		Sequence I (1) Overcurrent tripping (2) Withstand voltage (Uimp, commercial frequency, lightning impulse) (3) Overload (4) Withstand voltage (commercial frequency) (5) Overflow current (6) Temperature rise (7) Switching durability Sequence II Same as Appendix 1. Sequence III Same as Appendix 1.	

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Molded case circuit breakers
	When the rated cord protection current is indicated, the breaker must automatically tripped at the (a) stipulation after two minutes have passed after the short-circuit test (if more than two minutes is required for resetting, the minimum time required for resetting). Reference If the rated cord protection circuit is indicated, the vinyl cord insulator must not fuse, and the vinyl cord's conductor must not melt.
	(1) Structure inspection (2) Overflow current (3) Overcurrent tripping (4) Overload (5) Switching performance (6) Overcurrent tripping (7) Temperature rise (8) Insulation performance (9) Short-circuit breaking (10) Cord protection

11. 3. 2 ELCB

<table>
<tr><td>Standard</td><td>IEC 60947-2 Annex B
EN 60947-2 Annex B</td><td>JIS C 8201-2-2
Appendix 1</td><td>JIS C 8201-2-2
Appendix 2</td><td></td></tr>
<tr><td>Name</td><td>Low-voltage switchgear and controlgear
–Part 2: Circuit-breakers</td><td>Earth leakage circuit breakers</td><td>Earth leakage circuit breakers</td><td></td></tr>
<tr><td>Scope</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated current (In)</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated insulation voltage (Ui)</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated working voltage (Ue)</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated impulse withstand voltage (Uimp)</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated control circuit voltage (Us)</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated sensitivity current (IΔn)</td><td>Recommended value 0.006, 0.01, 0.03, 0.1, 0.3, 0.5, 1, 3, 10, 30A</td><td colspan="2">Recommended value 0.005, 0.006, 0.01, 0.015, 0.03, 0.05, 0.1, 0.2, 0.3, 0.5, 1, 3, 5, 10, 20 or 30A</td><td></td></tr>
<tr><td>Rated non-operating current</td><td>Minimum value 0.5IΔn</td><td colspan="2">Minimum value 0.5IΔn</td><td></td></tr>
<tr><td>Operating characteristics</td><td>
<table>
<tr><td colspan="2">Leakage current</td><td>IΔn</td><td>2IΔn</td><td>5IΔn
10IΔn</td></tr>
<tr><td>Maximum operating time (Second)</td><td>Inverse time delay type</td><td>0.3</td><td>0.15</td><td>0.04</td></tr>
</table>
Time-delay type
The time-delay type's inertia dead time is stipulated with 2IΔn, and must be designated by the manufacturer.
The recommended inertia dead time at 2IΔn is 0.06sec., 0.1sec., 0.2sec., 0.3sec., 0.4sec., 0.5sec. and 1sec. The minimum inertia dead time is 0.06sec.
If the leakage breaker has an inertia dead time longer than 0.06 seconds, the manufacturer must indicate the maximum operating time at IΔn, 2IΔn, 4IΔn and 10IΔn.
Operating characteristics when inertial dead time is 0.06sec.
<table>
<tr><td>Leakage current</td><td>IΔn</td><td>2IΔn</td><td>5IΔn
10IΔn</td></tr>
<tr><td>Maximum operating time (Second)</td><td>0.5</td><td>0.2</td><td>0.15</td></tr>
</table>
</td><td colspan="2">
<table>
<tr><td colspan="2">Leakage current</td><td>IΔn</td><td>2IΔn</td><td>5IΔn
10IΔn</td></tr>
<tr><td rowspan="2">Maximum operating time (Second)</td><td>Inverse time delay type</td><td>0.3</td><td>0.15</td><td>0.04</td></tr>
<tr><td>High-speed type</td><td>0.1</td><td>-</td><td>-</td></tr>
</table>
Time delay type
Same as IEC
</td><td></td></tr>
<tr><td>Tripping voltage</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated frequency</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Number of poles</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Reference ambient temperature</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Rated tripping current (Icn)</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Structure</td><td colspan="3">MCCB details are added below.
(1) the testing device must not be the only way to open the circuit. This function must not be used to open the circuit.
(2) The color of the test unit's operation means must not be red or green. It should be a bright color.</td><td></td></tr>
<tr><td>Size of wire connection terminal</td><td colspan="4">Same as MCCB</td></tr>
<tr><td>Test wire</td><td colspan="4">Same as MCCB</td></tr>
</table>

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Earth leakage circuit breakers
	(1) Capacity of 15mA or less (2) Capacity of more than 15mA, 30mA or less (3) Capacity of more than 30mA, 100mA or less (4) Capacity exceeding 100mA
	50% of rated sensitivity current
	1. After a voltage equal to the rated voltage is applied and a current equal to the rated current is passed, when a leakage current equal to 50% of the rated sensitivity current is superimposed on one pole of the test unit, the circuit must not open. In addition, the breaker must comply with the following matters. (a) The high-speed type breaker must open within 0.1 seconds when a leakage current equal to the rated sensitivity current is superimposed. (b) With the time-delay type, when a leakage current equal to the rated sensitivity current is imposed, it must open within the range of 50% (0.1sec. if less than 0.1sec.) and 150% (2sec. when more than 2sec.) of the rated operating time. (c) With the inverse time-delay type, the circuit must open within the range of more than 0.2sec. to 1sec. when a current equal to the rated sensitivity current is superimposed, within the range of more than 0.1sec. to 0.5sec. when a current equal to 140% of the rated sensitivity current is superimposed, and within 0.05sec. when a leakage current equal to 440% of the rated sensitivity current is superimposed. 2. After a voltage equal to the rated voltage is applied and the test unit is closed without connecting a load, when a leakage current is continuously applied on one pole of the test unit and increased from current equal to 50% of the rated sensitivity current in 30 seconds, the breaker must open before the current reaches a level equal to the rated sensitivity current. 3. After a voltage equal to the rated voltage is applied and the test unit is closed without connecting a load, when a 20A current is passed to one pole of the test unit, the high-speed type must open within 0.1sec., the time-delay type must open within the range of range of 50% (0.1sec. if less than 0.1sec.) and 150% (2sec. when more than 2sec.) of the rated operating time. The inverse time-delay type must open within 0.05sec.
	Same as MCCB

11 Standards

Standard	IEC 60947-2 Annex B EN 60947-2 Annex B	JIS C 8201-2-2 Appendix 1	JIS C 8201-2-2 Appendix 2	
Name	Circuit breaker incorporating residual current protection (CBR)	Earth leakage circuit breakers	Earth leakage circuit breakers	
Leakage current tripping test	85% of rated voltage 25°C, –5°C, no load The following test shall be performed on one pole. Each test shall be measured three times. ① The leakage current shall be started from 0.2IΔn or less, and gradually increased so that it reaches IΔn in approx. 30sec. The operating current shall be measured each time. ② The test circuit shall be set to the rated sensitivity current value IΔn, and shall be closed with the earth leakage breaker. The operating time shall be measured three times. ③ Set the test circuit's leakage current value IΔ for each, close switch S_2 and the leakage current shall be passed suddenly.		85% of rated voltage 25°C, –5°C, no load The following test shall be performed on one pole. Each test shall be measured three times. ① The leakage current shall be started from 0.2IΔn or less, and gradually increased so that it reaches IΔn in approx. 30sec. The operating current shall be measured each time. ② Set the test circuit's leakage current value IΔ for each, close switch S_2 and the leakage current shall be passed suddenly.	
Equilibrium characteristics test (non-operating overcurrent test at single-phase load)	The test shall be performed with a single-phase load. 6In or 80% of the instantaneous tripping current setting maximum value, whichever is smaller. The sensitivity current adjustable type is set to the minimum setting. Power factor 0.5. The multi-phase equilibrium load test is not required.			
Testing of test device	① Apply a voltage 1.1 times the maximum rated voltage. Operate the test device 25 times at a 5 second interval. ② Operate the test device three times at a 5 second interval with a voltage 0.85 fold of the minimum rated voltage. ③ Apply a voltage 1.1 times the maximum rated voltage, and press the test device for five seconds.			
Overcurrent tripping test	Same as MCCB			
100% current test	Same as MCCB			
Overload test	Same as MCCB			
Overflow current test	Same as MCCB			
Temperature rise test	Same as MCCB			
Durability test	Same as MCCB			
Insulation resistance test	Same as MCCB			
Withstand voltage test	Same as MCCB			
Short-circuit test	Same as MCCB			
Cord protection test	Same as MCCB			
Environment test	Temperature and humidity cycle test Perform following IEC 60068-2-30. The number of cycles at the upper limit temperature 55 ± 2°C is as follows: 6 cycles when – IΔn > 1A 28 cycles when – IΔn ≤ 1A Set the test circuit leakage current to 1.25IΔn, open switch S_2, and the leakage current shall be passed suddenly.	Temperature and humidity cycle test Perform following IEC 60068-2-30. The number of cycles at the upper limit temperature 55 ± 2°C is as follows: 6 cycles when – IΔn > 1A 28 cycles when – IΔn ≤ 1A Set the test circuit leakage current to 1.25IΔn, open switch S_2, and the leakage current shall be passed suddenly.		
Heavy ground fault breaking test	No stipulation	No stipulation	No stipulation	
Short-time current performance	No stipulation	No stipulation	No stipulation	

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Earth leakage circuit breakers
	No stipulation
	No stipulation
	① Apply a voltage equal to 80% of rated voltage and equal to 110%. Operate the test device ten times at a 10 second interval at each voltage level. ② Apply a voltage equal to the rated voltage, and operate the test device 1000 times at an interval of less than 10 seconds.
	No stipulation
	No stipulation
	No stipulation

Standard	IEC 60947-2 Annex B EN 60947-2 Annex B	JIS C 8201-2-2 Appendix 1	JIS C 8201-2-2 Appendix 2	
Name	Circuit breaker incorporating residual current protection (CBR)	Earth leakage circuit breakers	Earth leakage circuit breakers	
Lightning impulse withstand voltage test	Refer to impulse withstand voltage test given in the withstand voltage test section (same as MCCB).			
Lightning impulse non-operating test	No stipulation	No stipulation	Same as JIS C8371.	
Aging test of electronic parts	No stipulation	No stipulation	No stipulation	
Heat cycle test of wire connection terminal for main circuit	No stipulation	No stipulation	No stipulation	
Radiated electromagnetic wave non-operating test	No stipulation	No stipulation	Follows immunity test.	
High frequency current superimposed trip test	No stipulation	No stipulation	Follows immunity test.	
High frequency current superimposed trip test	No stipulation	No stipulation	Follows immunity test.	

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Earth leakage circuit breakers
	No stipulation
	No stipulation
	No stipulation
	No stipulation
	No stipulation
	No stipulation
	No stipulation

<table>
<tr><td>Standard</td><td>IEC 60947-2 Annex B
EN 60947-2 Annex B</td><td>JIS C 8201-2-2
Appendix 1</td><td>JIS C 8201-2-2
Appendix 2</td><td></td></tr>
<tr><td>Name</td><td>Circuit breaker incorporating residual current protection (CBR)</td><td>Earth leakage circuit breakers</td><td>Earth leakage circuit breakers</td><td></td></tr>
<tr><td>Immunity test</td><td colspan="2">The test follows Appendix J.
Electrostatic discharge
Radiated radio-frequency electromagnetic field
Electrical fast transient/burst
Surge
Conductive disturbance caused by radio-frequency</td><td>(1) Radiated electromagnetic wave non-operating test
In the circuit shown in Appendix 2 Fig. X.2, apply the rated voltage on the leakage breaker, and in the closed circuit state, apply the radiated electromagnetic waves for two seconds under the conditions given in the Table.
<table>
<tr><td>Frequency (MHz)</td><td>Strength of electric field around test unit</td></tr>
<tr><td>27</td><td>130dB (3.16V/m)</td></tr>
<tr><td>144</td><td>130dB (3.16V/m)</td></tr>
<tr><td>430</td><td>140dB (10V/m)</td></tr>
<tr><td>900</td><td>146dB (20V/m)</td></tr>
<tr><td colspan="2">Remarks 1μ mV/m shall equal 0dB.</td></tr>
</table>
(2) High frequency current superimposition tripping test
In the circuit shown in Appendix 2 Fig. X.3, apply the rated voltage with 50Hz or 60Hz frequency, and in the state with no load current passing, pass the commercial frequency current to one pole in the closed circuit state. Pass the high frequency current shown in the table to the other pole, and gradually increase the commercial frequency current. Measure the sensitivity current value when the leakage breaker functions.
<table>
<tr><td>I_{RF} frequency kHz</td><td>I_{RF} value</td></tr>
<tr><td>1</td><td>0.1 times the rated sensitivity current</td></tr>
<tr><td>3</td><td>0.26 times the rated sensitivity current</td></tr>
<tr><td>30</td><td>2.0 times the rated sensitivity current</td></tr>
<tr><td colspan="2">Remarks The maximum I_{RF} value shall be 2A.</td></tr>
</table>
(3) Higher harmonic current superimposition tripping test
In the circuit shown in Appendix 2 Fig. X.4, apply the rated voltage with 50Hz or 60Hz frequency, and in the state with no load current passing and circuit closed, superimpose the higher harmonic current to the forward phase and reverse phase so that the distortion rate is 10%. Gradually increase this current, and measure the sensitivity current where the leakage breaker functions. The higher harmonic current in this case shall be both the third-order and fifth-order higher harmonics.</td><td></td></tr>
<tr><td>Emission test</td><td colspan="2">The test follows Appendix J.
Conductive radio-frequency disturbance
Radiated radio-frequency disturbance</td><td>No stipulation</td><td></td></tr>
<tr><td>Test order
(model test)

Whether to carry out each test item with the same test unit or a different test unit shall follow the Standards.</td><td>Sequence I
(1) Overcurrent tripping
(2) Withstand voltage (Uimp)
(3) Mechanical switching durability
Energized switching durability
(4) Overload
(5) Withstand voltage (commercial frequency)
(6) Temperature rise
(7) Overcurrent tripping

Sequence II
(1) Rated working short-circuit breaking (o-co-co)
(2) Withstand voltage (commercial frequency)
(3) Temperature rise
(4) Overcurrent tripping

Sequence III
(1) Overcurrent tripping
(2) Rated maximum short-circuit breaking (o-co)
(3) Withstand voltage (commercial frequency)
(4) Overcurrent tripping</td><td>Additional sequence
(1) Operating characteristics
(2) Withstand voltage
(3) Test device
(4) Equilibrium characteristics
(5) Impulse wave non-operation
(6) DC superimposition
(7) Power voltage loss
(8) Open phase
(9) Heavy ground fault
(10) Environment
(11) Immunity
(12) Emission</td><td>Sequence I
(1) Overcurrent tripping
(2) Withstand voltage (Uimp, commercial frequency, lightning impulse)
(3) Overload
(4) Withstand voltage (commercial frequency)
(5) Overflow current
(6) Temperature rise
(7) Switching durability

Sequence II
Same as Appendix 1.

Sequence III
Same as Appendix 1.

Additional sequence
Same as Appendix 1.</td><td></td></tr>
</table>

	Electric Appliance Safety Law Standards concerning technology for electrical appliances
	Earth leakage circuit breakers
	No stipulation
	No stipulation
	(1) Structure inspection (2) Overflow current (3) Overcurrent tripping (4) Overload (5) Switching performance (6) Overcurrent tripping (7) Temperature rise (8) Insulation performance (9) Short-circuit breaking (10) Cord protection

11 Standards

MOULDED CASE CIRCUIT BREAKERS
EARTH LEAKAGE CIRCUIT BREAKERS

eco Changes

for a greener tomorrow

Eco Changes is the Mitsubishi Electric Group's environmental statement, and expresses the Group's stance on environmental management. Through a wide range of businesses, we are helping contribute to the realization of a sustainable society.

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FACTORY AUTOMATION SYSTEMS: TOKYO BUILDING, 2-7-3 MARUNOUCHI, CHIYODA-KU, TOKYO 100-8310, JAPAN

Revised publication, effective Jul. 2013.
Specifications subject to change without notice.
This pamphlet is made from **recycled paper.**

Y-0729 1307 printed in Japan(MDOC)