APPENDICES

Contents

Appendix A Trouble-free Use of Inverters (Notes on Electrical Noise)

Excerpt from technical material of
the Japan Electrical Manufacturers' Association (JEMA) (December 2008)

A.1 Effect of inverters on other devices

Inverters have been and are rapidly expanding its application fields. This paper describes the effect that inverters have on electronic devices already installed or on devices installed in the same system as inverters, as well as introducing noise prevention measures. (Refer to "A.3 [3] Noise prevention examples" for details.)

[1] Effect on AM radios

Phenomenon: If an inverter operates, AM radios may pick up noise radiated from the inverter. (An inverter has almost no effect on FM radios or television sets.)

Probable cause: The noise radiated from the inverter may be received by a radio.

Measure: Inserting a noise filter on the power supply side of the inverter is effective.

[2] Effect on telephones

Phenomenon: If an inverter operates, nearby telephones may pick up noise radiated from the inverter in conversation so that it may be difficult to hear.

Probable cause: A high-frequency leakage current radiated from the inverter and motors enters shielded telephone cables, causing noise.

Measure: It is effective to commonly connect the grounding terminals of the motors and return the common grounding line to the grounding terminal of the inverter.

[3] Effect on pressure sensors

Phenomenon: If an inverter operates, pressure sensors may malfunction.

Probable cause: Noise may penetrate through a grounding wire into the signal line.

Measure: It is effective to install a noise filter on the power supply side of the inverter or to change the wiring.

[4] Effect on position detectors (pulse encoders)

Phenomenon: If an inverter operates, pulse encoders may produce erroneous pulses that shift the stop position of a machine.

Probable cause: Erroneous pulses are liable to occur when the signal lines of the PG and power lines are bundled together.

Measure: The influence of induction noise and radiated noise can be reduced by separating the PG signal lines and power lines. Providing noise filters at the input and output terminals is also an effective measure.

[5] Effect on proximity switches

Phenomenon: If an inverter operates, proximity switches (capacitance-type) may malfunction.

Probable cause: The capacitance-type proximity switches may provide inferior noise immunity.

Measure: It is effective to connect a filter to the input terminals of the inverter or change the power supply treatment of the proximity switches. The proximity switches can be replaced with superior noise immunity types such as magnetic types.

A.2 Noise

This section gives a summary of noises generated in inverters and their effects on devices subject to noise.

[1] Inverter Operating Principle and Noise

Fig. A.2-1 shows an Outline of inverter configuration. The inverter converts AC to DC (rectification) in a converter unit, and converts DC to AC (inversion) with 3-phase variable voltage and variable frequency. The conversion (inversion) is performed by PWM implemented by switching six transistors (IGBT: Insulated Gate Bipolar Transistor, etc.), and is used for variable speed motor control.

Switching noise is generated by high-speed on/off switching of the six transistors. Noise current (i) is emitted and at each high-speed on/off switching, the noise current flows through stray capacitance (C) of the inverter, cable and motor to the ground. The amount of the noise current is expressed as follows:

$$i = C \cdot dv/dt$$

It is related to the stray capacitance (C) and dv/dt (switching speed of the transistors). Further, this noise current is related to the carrier frequency since the noise current flows each time the transistors are switched on or off.

Noise is generated by the DC/DC power supply converter for the control circuit during transistor switching.

These noise frequency bands extend across several tens of MHz, and may interfere with communication devices such as AM radios, factory wireless networks, and telephones.

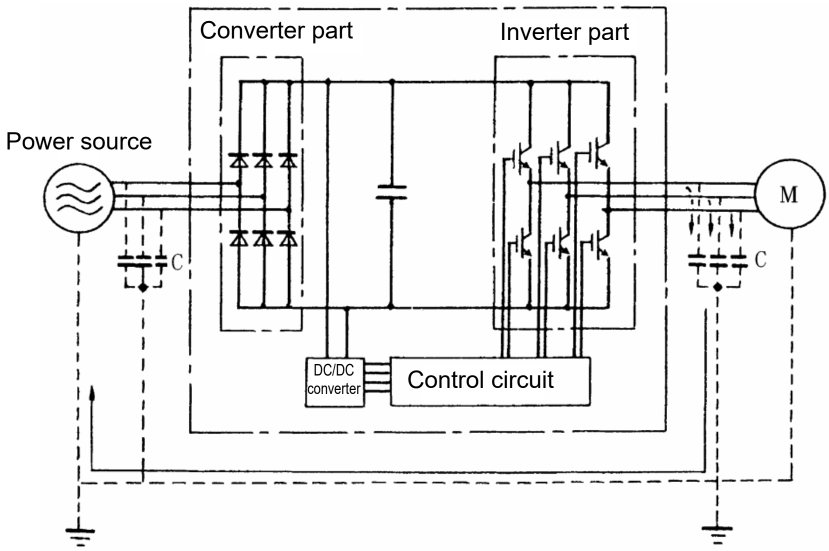


Fig. A.2-1 Outline of inverter configuration

[2] Types of noise

Noise generated in an inverter is propagated through the main circuit wiring to the power supply and the motor so as to affect a wide range of applications from the power supply transformer to the motor. The various propagation routes are shown in Fig. A.2-2. According to those routes, noises are roughly classified into three types:

(1) to (3) are conducted noise, (4) is induction noise, and (5) is radiated noise. Details are given below.

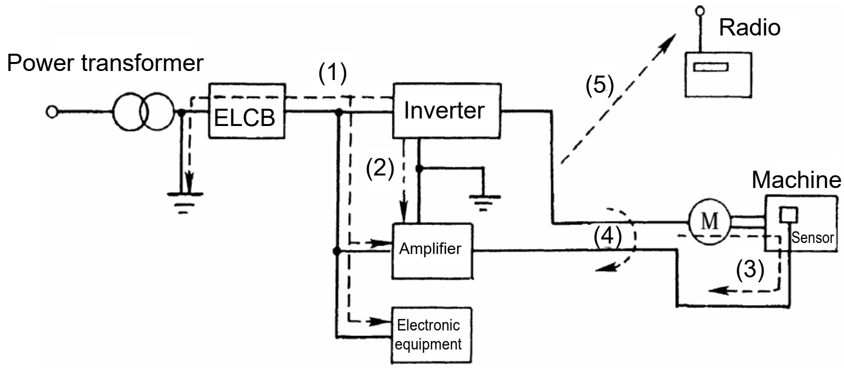


Fig. A.2-2 Noise propagation routes

(1) Conducted noise

The noise that has occurred in the inverter and propagates through a conductor to influence peripheral equipment is called conducted noise. Some conducted noise will propagate through the main circuit (1). If the ground wires are connected to a common ground, conducted noise will propagate through route (2). As shown in route (3), some conducted noise will propagate through signal lines or shielded wires.

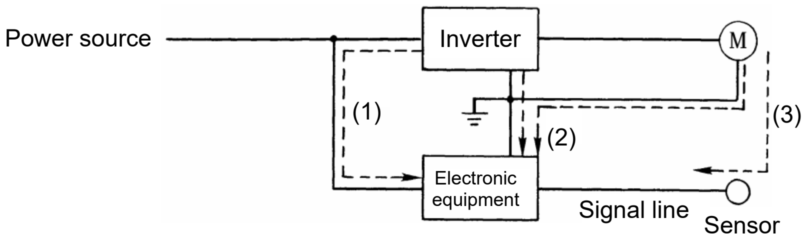


Fig. A.2-3 Conducted noise

(2) Induction noise

When wires or signal lines of peripheral devices are brought close to the wires on the input and output sides of the inverter through which noise current is flowing, noise will be induced into those wires and signal lines of the devices by electromagnetic induction (Fig. A.2-4) or electrostatic induction (Fig. A.2-5). This is called “induction noise” (4).

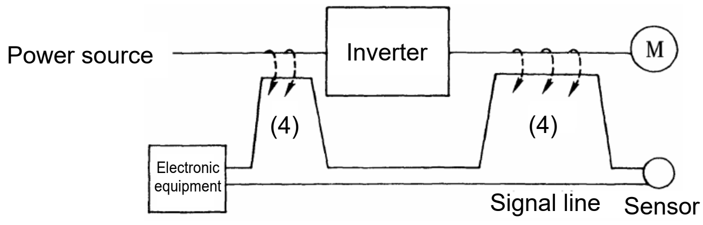


Fig. A.2-4 Electromagnetic induction noise

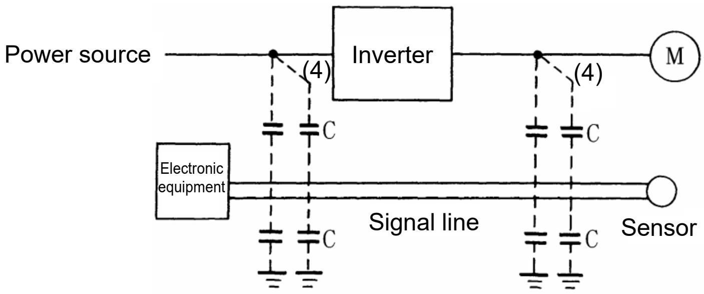


Fig. A.2-5 Electrostatic induction noise

(3) Radiated noise

Noise generated in an inverter radiates through the air with input side and output side main circuit wires, and ground wires acting as antennas, and this affects peripheral devices, as well as broadcast and wireless communication. This noise is called “radiated noise” as shown below as (5). Not only wires but motor frames or control system panels containing inverters may also act as antennas.

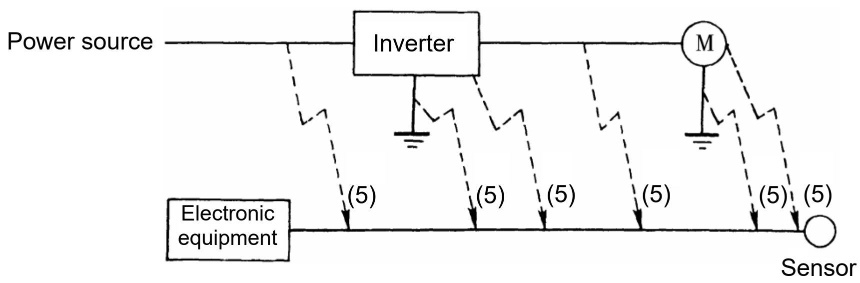


Fig. A.2-6 Radiated noise

A.3 Measure

As the noise prevention is strengthened, the more effective it is. However, with the use of appropriate measures, noise problems may be resolved easily. It is necessary to implement economical noise prevention according to the noise level and the equipment conditions.

[1] Noise prevention prior to installation

Before installing an inverter in your control panel or installing an inverter panel, you need to consider noise prevention. Once noise problems occur, it will cost additional materials and time for solving them.

Noise prevention prior to installation includes:

(1) Separate the main circuit from the control circuit.

(2) Accommodate the main circuit wiring in a metal pipe (conduit pipe).

(3) Use shielded wire or twisted shielded wire in the control circuit.

(4) Perform reliable grounding work and wiring.

These noise prevention measures can avoid most noise problems.

[2] Implementation of noise prevention measures

There are two types of noise prevention measures--one for noise propagation routes and the other for noise receiving sides (that are affected by noise).

The basic measures for reducing the effect of noise at the receiving side include:

(1) Separating the main circuit wiring from the control circuit wiring, avoiding noise effect.
Measures on the noise-affected side are:

(2) Lower the noise level for example by installing a noise filter.

(3) Suppress the noise level for example by using a metal wiring pipe or metal control panel.

(4) Block the noise propagation route for example by using an insulation transformer for power source.

Table A.3-1 lists the Noise prevention measures, their goals, and propagation routes.

Table A.3-1 Noise prevention measures

Noise prevention method		Goal of noise prevention measures				Propagation route		
		Make it more difficult to receive noise	Cutoff noise propagation	Contain noise	Reduce noise level	Conducted noise	Induction noise	Radiated noise
Wiring and installation	Separate main circuit from control circuit	Y					Y	
	Minimize wiring length	Y			Y		Y	Y
	Avoid parallel and bundled wiring	Y					Y	
	Use appropriate grounding	Y			Y		Y	Y
	Use shielded wire and twisted shielded wire	Y					Y	Y
	Use shielded cable in main circuit			Y				Y
	Use metal conduit pipe			Y			Y	Y
Control panel	Appropriate arrangement of devices in panel	Y					Y	Y
	Metal control panel			Y			Y	Y
Anti-noise devices	Line filter	Y			Y	Y		Y
	Insulation transformer		Y			Y		Y
Measures taken on noise-affected side	Use a decoupling capacitor for control circuit	Y					Y	Y
	Use ferrite core for control circuit	Y					Y	Y
	Line filter	Y				Y		
Other IMs	Separate power supply systems	Y	Y			Y		
	Lower the carrier frequency				Y	Y	Y	Y

In the table, a column marked with Y shows a measure expected to produce an effect depending on the conditions. An empty column shows an ineffective measure.

What follows is noise prevention measures for the inverter drive configuration.

(1) Wiring and grounding

As shown in Fig. A.3-1, separate the main circuit wiring from control circuit wiring as far as possible regardless of being located inside or outside the system control panel containing an inverter. Use shielded wires and twisted shielded wires that will block out extraneous noises, and minimize the wiring distance. Also avoid bundled wiring of the main circuit and control circuit or parallel wiring.

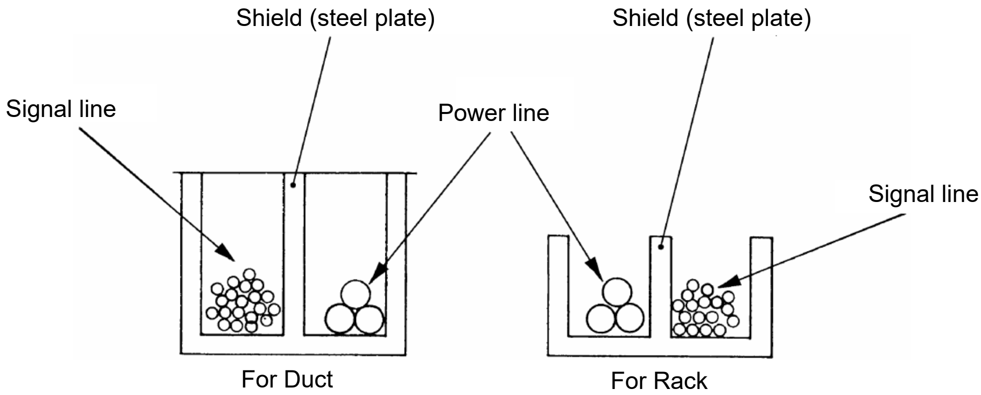


Fig. A.3-1 Separate wiring

For the main circuit wiring, use a metal conduit pipe and connect its wires to the ground to prevent noise propagation (see Fig. A.3-2).

The shield (braided wire) of a shielded wire should be securely connected to the base (common) side of the signal line at only one point to avoid the loop formation resulting from a multi-point connection (see Fig. A.3-3).

The grounding is effective not only to reduce the risk of electrical shocks due to leakage current, but also to block noise penetration and radiation. Corresponding to the main circuit voltage, the grounding work should be Class D (300 VAC or less) and Class C (300 to 600 VAC). Each ground wire is to be provided with its own ground or separately wired to a grounding point.

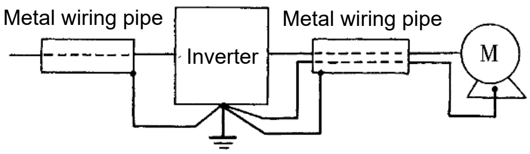


Fig. A.3-2 Grounding of metal conduit pipe

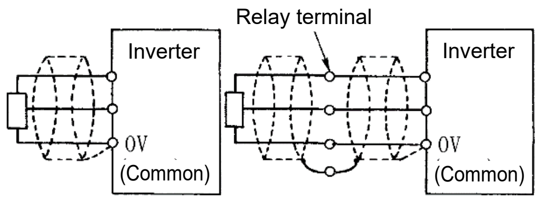


Fig. A.3-3 Treatment of braided wire of shielded wire

(2) Control panel

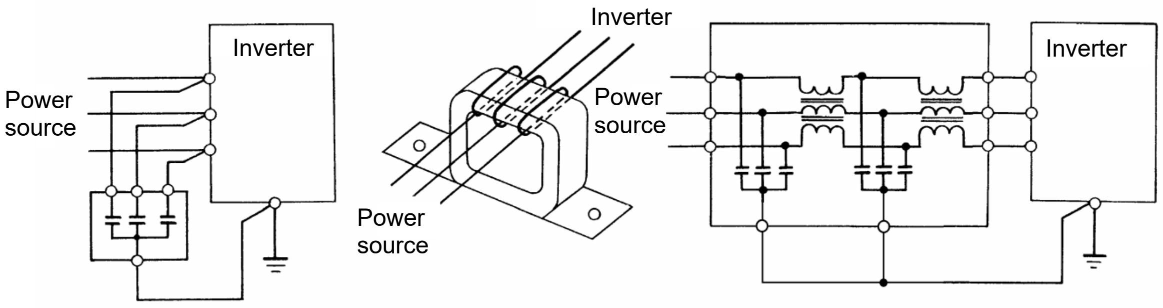
The system control panel containing an inverter is generally made of metal, which can shield noise radiated from the inverter itself.

When installing other electronic devices such as a programmable logic controller in the same control panel, be careful with the layout of each device. If necessary, arrange shield plates between the inverter and peripheral devices.

(3) Anti-noise devices

To reduce the noise propagated through the electrical circuits and the noise radiated from the main circuit wiring to the air, a line filter and power supply transformer should be used (see Fig. A.3-4).

Line filters are classified into simple-type filters including capacitive filters to be connected in parallel to a power line and inductive filters to be connected in series to a power line and authentic filters (LC filters) to address radio noise restrictions. They are used selectively used to meet the target noise reduction effect. Power transformers include generally used insulation transformers, shield transformers and noise-cut transformers, which have different effects to block propagation of noise.



(a) Capacitive filter (b) Inductive filter (zero-phase reactor) (c) LC filter

Fig. A.3-4 Various filters and their connection

(4) Noise prevention measures at the receiving side

It is important to strengthen the noise immunity of those electronic devices installed in the same control panel as the inverter or located near an inverter. Line filters and shielded or twisted shielded wires are used to block the penetration of noise in the signal lines of these devices. The following treatments are also implemented.

1) Lower the circuit impedance by connecting capacitors or resistors to the input and output terminals of the signal circuit in parallel.

2) Increase the circuit impedance for noise by inserting choke coils in series in the signal circuit or passing signal lines through ferrite core beads.

It is also effective to widen the signal base lines (0 V line) or grounding lines.

(5) Other IMs

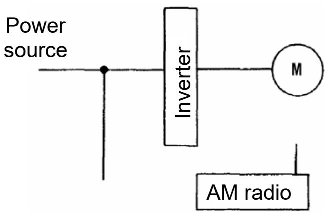
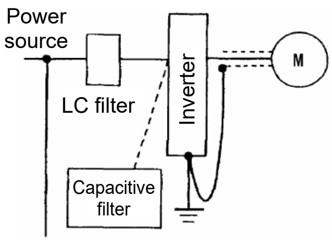
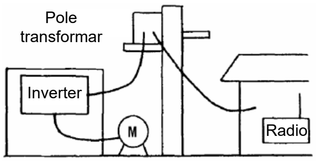
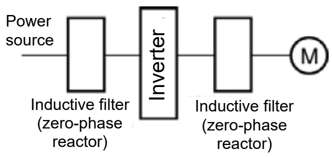
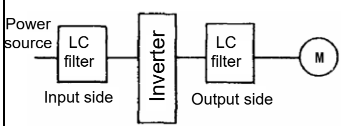
The level of generating/propagating noise will change with the carrier frequency of the inverter. The higher the carrier frequency, the higher the noise level.

In an inverter whose carrier frequency can be changed, lowering the carrier frequency can reduce the generation of electrical noise and result in a good balance with the audible noise of the motor under driving conditions.

[3] Noise prevention examples

Table A.3-2 lists examples of the measures to prevent noise generated by a running inverter.

Table A.3-2 Examples of noise prevention measures

No.	Target device	Phenomenon	Measure	Notes
1	AM radio	Noise enters the AM radio broadcast (500 to 1500 kHz) when the inverter is operated.  <Possible cause> Radiated noise from the power source and output wiring of inverted was received by the AM radio.	1) Install an LC filter at the power supply side of the inverter. (In some cases, a capacitive filter may be used as a simple method.) 2) Install a metal conduit wiring between the motor and inverter. Or use shielded wiring.  Note: Minimize the distance between the LC filter and the inverter (within 1 m).	1) The radiated noise of the wiring can be reduced. 2) Reduce the conducted noise to the power source or apply shielded wiring. Or use shielded wiring. Note: Sufficient improvement may not be expected in narrow regions such as between mountains.
2	AM radio	Noise enters the AM radio broadcast (500 to 1500 kHz) when the inverter is operated.  <Possible cause> Radiated noise from the power line of inverter's power source was received by the AM radio.	1) Install inductive filters at the input and output sides of the inverter.  The number of turns of the zero-phase reactor (or ferrite ring) should be as large as possible. Minimize the distance between the inverter and the inductive filter (within 1 m). 2) When further improvement is necessary, install LC filters.  	1) The radiated noise of the wiring can be reduced.

APPENDICES

Table A.3-2 Examples of noise prevention measures (cont.)

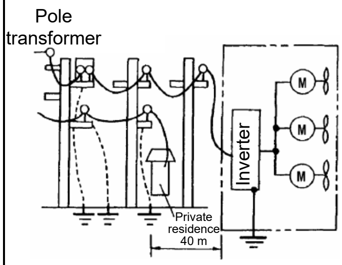
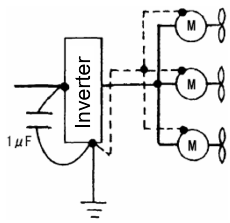
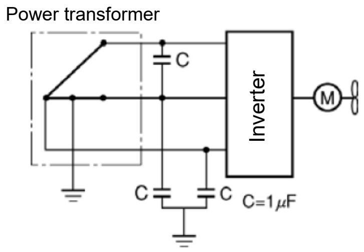
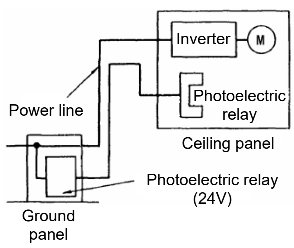
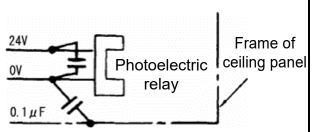
<table>
<tr><th>No.</th><th>Target device</th><th>Phenomenon</th><th>Measure</th><th>Notes</th></tr>
<tr><td>3</td><td>Telephone
(in a common private residence at a distance of 40 m)</td><td>When driving a ventilation fan with an inverter, noise enters a telephone in a private residence at a distance of 40 m.

<Possible cause>
High-frequency leak current of the inverter and motor flows into the shielded ground of the telephone cable on the way back via the ground of the pole transformer to cause noise by electrostatic induction.</td><td>1) Connect the ground terminals of the motors in a common connection. Return to the inverter panel, and insert a 1 μF capacitor between the input terminal of the inverter and ground.

</td><td>1) The effect of the inductive filter and LC filter may not be expected because of sound frequency component.
2) In the case of a V-connection power supply transformer in a 200 V system, it is necessary to connect capacitors as shown in the following figure, because of different potentials to ground.</td></tr>
<tr><td>4</td><td>Photoelectric relay</td><td>A photoelectric relay malfunctioned when the inverter runs the motor.
(The inverter and motor are installed in the same place (for overhead traveling)).

<Possible cause>
Input power line of the inverter and wiring of the photoelectric relay run parallel for 30 to 40 m with a spacing of about 25 mm, which invites induction noise. Due to conditions of the installation, these lines cannot be separated.</td><td>1) As a temporary measure, Insert a 0.1 μF capacitor between the 0 V terminal of the power supply circuit in the detection unit of the overhead photoelectric relay and a frame of the overhead panel.

2) As a permanent measure, move the 24 V power supply from the ground to the overhead unit so that signals are sent to the ground side with relay contacts in the ceiling part.</td><td>1) Separate the wiring (30 cm or more)
2) When separation is impossible, signals can be received and sent with dry contacts etc.
3) Do not wire low-current signal lines and power lines in parallel.</td></tr>
</table>

Table A.3-2 Examples of noise prevention measures (cont.)

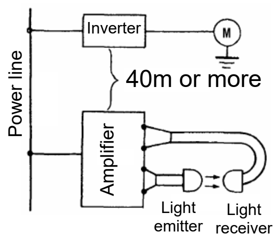
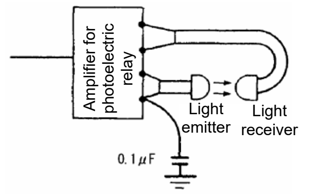
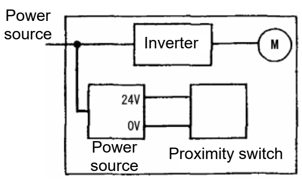
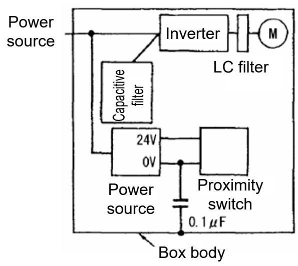
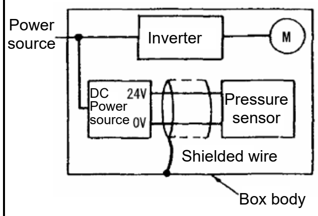
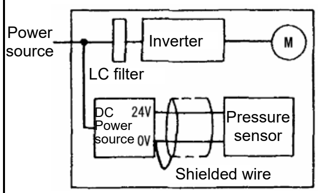
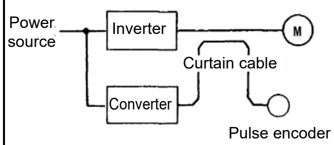
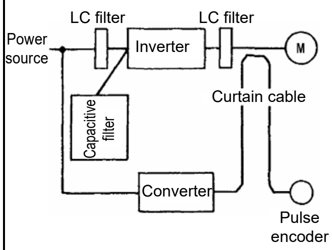
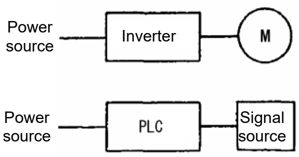
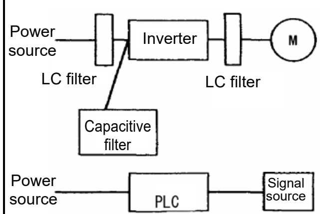
No.	Target device	Phenomenon	Measure	
				Notes
5	Photoelectric relay	A photoelectric relay malfunctioned when the inverter runs the motor.  <Possible cause> While the inverter is sufficiently away from the photoelectric relay, the power source is connected in common. Conducted noise has entered from the power source line.	1) Insert a 0.1 μF capacitor between the output common terminal of the amplifier of the photoelectric relay and the frame. 	1) If a low-current circuit at the malfunctioning side is observed, the measures may be simple and economical.
6	Proximity switch (capacitance type)	A proximity switch malfunctioned.  <Possible cause> The electrostatic capacitive proximity switch has a low noise immunity, and is vulnerable to circuit conducted noise and radiated noise.	1) Install an LC filter at the output side of the inverter. 2) Install a capacitive filter at the input side of the inverter. 3) Ground the 0 V (common) line of the DC power supply of the proximity switch through a capacitor to the box body of the machine. 	1) Noise generated in the inverter can be reduced. 2) The switch is superseded by a proximity switch of superior noise immunity (such as a magnetic type).

Table A.3-2 Examples of noise prevention measures (cont.)

No.	Target device	Phenomenon	Measure	Notes
7	Pressure sensor	A pressure sensor malfunctioned.  <Possible cause> Noise enters from the box body via the shielded wire to cause malfunctioning of the pressure sensor.	1) Install an LC filter on the input side of the inverter. 2) Connect the shield of the shielded wire of the pressure sensor to the 0 V line (common) of the pressure sensor, changing the original connection. 	1) The shielded parts of shield wires for sensor signals are connected to a common point in the system. 2) Conductive noise from the inverter can be reduced.
8	Position detector (pulse encoder)	Erroneous-pulse outputs from a pulse converter caused a shift in the stop position of a crane.  <Possible cause> The motor power line and the signal line for the encoder are wired together in a bundle. This produces induction noise to cause output of error pulses.	1) Install an LC filter and a capacitive filter at the input side of the inverter. 2) Install an LC filter at the output side of the inverter. 	1) This is an example of a measure where the power line and signal line cannot be separated. 2) Induction noise and radiated noise at the output side of the inverter can be reduced.
9	Programmable logic controller (PLC)	The PLC program sometimes malfunctions.  <Possible cause> Power sources of the inverter and PLC are in the same system so that noise enters PLC via the power source.	1) Install a capacitive filter and an LC filter on the input side of the inverter. 2) Install an LC filter on the output side of the inverter. 3) Lower the carrier frequency of the inverter. 	1) Total conducted noise and induction noise in the electric line can be reduced.

Appendix B Japanese Guideline for Suppressing Harmonics by Customers Receiving High Voltage or Special High Voltage (General-purpose Inverters)

Agency of Natural Resource and Energy of Japan published the following two guidelines for suppressing harmonic noise in September 30, 1994.

(1) "Guideline to Reduce Harmonic Emissions Caused by Electrical and Electronic Equipment for Household and General Use"

(2) "Guideline for Suppressing Harmonics by Customers Receiving High Voltage or Special High Voltage"

These guidelines were enacted based on the assumption that the use of electronic devices generating harmonic current would continue to rise in the future, and that they would lead to the prevention of harmonic interference at devices connected to systems by applying regulations beforehand. These guidelines apply to all electrical and electronic devices used with a commercial power supply and which generate harmonic current, however, the following explanation applies only to "general-purpose inverters".

Refer to “Japan Electrical Manufacturers’ Association JEM-TR201” for details on how to calculate harmonic current.

B.1 Application of general-purpose inverters

[1] Application for Other Than Special Customers

From January 2004, general-purpose inverters (input current of 20A or less) were excluded from the "Guideline to Reduce Harmonic Emissions Caused by Electrical and Electronic Equipment for Household and General Use" (established September, 1994) enacted by the Ministry of Economy, Trade and Industry. Customers for whom the "Guideline for Suppressing Harmonics by Customers Receiving High Voltage or Special High Voltage" does not apply are recommended to connect the "DC reactor" indicated in the catalog or this manual to the inverter as in the past.

[2] Application for "Guideline for Suppressing Harmonics by Customers Receiving High Voltage or Special High Voltage"

All customers receiving high voltage or special high voltage fall under the scope of the "Guideline for Suppressing Harmonics by Customers Receiving High Voltage or Special High Voltage". Devices generating harmonic current such as "general-purpose inverters" are not regulated directly, but for each customer using a power supply. It is necessary to calculate such values as the amount of harmonic current generated by individual devices.

(1) Regulation scope

Generally speaking, regulations apply if the following two conditions are satisfied.

- The device is receiving high or extra-high voltage.
- Converter load "equivalent capacity" exceeds the standard value (50kVA when receiving 6.6 kV) for the receiving voltage.

If calculating "equivalent capacity" in accordance with the guidelines, a supplementary description is provided in "B.2 [1] Calculation of equivalent capacity (Pi)".

(2) Regulation method

Regulate the size (calculated value) of the harmonic current flowing from the customer's power receipt point to the system. Regulation values are proportional to contracted demand. Guideline regulation values are shown in Table B.1-1.

If calculating "harmonic current" in accordance with the guidelines, a supplementary description is provided in "B.2 Complying with "Guideline for Suppressing Harmonics by Customers Receiving High Voltage or Special High Voltage"".

Table B.1-1 Harmonic outflow current upper limit per 1kW of contracted demand (mA/kW)

Receiving voltage	5th	7th	11th	13th	17th	19th	23rd	25th and above
6.6 kV	3.5	2.5	1.6	1.3	1.0	0.90	0.76	0.70
22 kV	1, 8	1.3	0.82	0.69	0.53	0.47	0.39	0.36

(3) Inspection interval

The guideline has been applied.

The estimation for “Voltage distortion factor” required as the indispensable conditions when entering into the consumer’s contract of electric power is already expired.

B.2 Complying with "Guideline for Suppressing Harmonics by Customers Receiving High Voltage or Special High Voltage"

If performing calculations for "general-purpose inverters" in accordance with the guidelines, do so as follows.
The following descriptions are based on “Application Guide for Evaluation of Harmonic Currents Emitted by Consumers of Middle or High Voltage Power Supply” (JEAG 9702-2013) published by the Japan Electrical Manufacturer’s Association (JEMA).

[1] Calculation of equivalent capacity (Pi)

Equivalent capacity is calculated by multiplying the (input rated capacity) by (conversion factor), however, the input rated capacity value is not indicated in previous general-purpose inverter catalogs, and is therefore described below.

(1) “Inverter rated capacity” corresponding to “Pi”

- In the guidelines, a 6-pulse converter is used as a reference for conversion factor 1, and therefore it is necessary to express the general-purpose inverter input rated capacity as a value including the harmonic current equivalent to conversion factor 1.
- In particular, calculate the input fundamental current I1 from the kW rating and efficiency of the motor and the efficiency of the inverter as loads and then calculate:
  Input rated capacity= √3 x (power voltage) x I1 x 1.0228/1000 (kVA). 1.0228 is the 6-pulse converter (effective value current)/(fundamental harmonic current) value.
- When a general-purpose motor or inverter motor is used, the appropriate value shown in Table B.2-1 can be used. Select a value based on the kW rating of the motor used, irrespective of the inverter type.

Note: The "input rated capacity" expressed here can be applied only if performing the calculation indicated in the harmonic guidelines, and cannot be used to select inverter power supply side devices and wiring size, etc., and therefore caution is required.

Refer to manufacturer catalogs or technical material for information on peripheral equipment capacity selection.

Table B.2-1 “Input Rated Capacities” of general-purpose inverters determined by the applicable motor ratings

Applicable motor (kW)		0.1	0.2	0.4	0.75	1.5	2.2	3.7	5.5	7.5	11	15	18.5
Pi (kVA)	200 V	0.22	0.35	0.57	0.97	1.95	2.81	4.61	6.77	9.07	13.1	17.6	21.8
	400 V	0.22	0.35	0.57	0.97	1.95	2.81	4.61	6.77	9.07	13.1	17.6	21.8

Applicable motor (kW)		22	30	37	45	55	75	90	110	132	160
Pi (kVA)	200 V	25.9	34.7	42.8	52.1	63.7	87.2	104	127		
	400 V	25.9	34.7	42.8	52.1	63.7	87.2	104	127	153	183

Applicable motor (kW)		200	220	250	280	315	355	400	450	500	630
Pi (kVA)	200 V										
	400 V	229	252	286	319	359	405	456	512	570	718

(2) “Ki (conversion factor)” size

Depending on whether an optional ACR (AC reactor) or DCR (DC reactor) is used, apply the appropriate conversion factor specified in the appendix to the guideline. The conversion factor sizes are listed in Table B.2-2.

Table B.2-2 “Conversion Factors Ki” for general-purpose inverters determined by reactors

Circuit class	Circuit type		Conversion factor Ki	Main applications
3	Three-phase bridge (capacitor smoothing)	No reactor used	K31 = 3.4	• General-purpose inverters
		Reactor used (AC side)	K32 = 1.8	• Elevators
		Reactor used (DC side)	K33 = 1.8	• Cold air refrigerating machines
		Reactor used (AC, DC side)	K34 = 1.4	• Other equipment in general

Note: Some models are equipped with a reactor as a standard accessory.

[2] Harmonic Current Calculation

(1) "Fundamental harmonic current" size

- When you calculate the amount of harmonics according to Table 2 in Appendix of the Guideline, you have to previously know the input fundamental harmonic current.
- Apply the appropriate value shown in Table B.2-3 based on the kW rating of the motor, irrespective of the inverter type or whether a reactor is used.

Note: If the input voltage is different, calculate the input fundamental current in inverse proportion to the voltage.

Table B.2-3 "Input fundamental harmonic current" of general-purpose inverters determined by applicable motor ratings

Applicable motor (kW)		0.4	0.75	1.5	2.2	3.7	5.5	7.5	11	15	18.5
Input fundamental harmonic current (A)	200 V	1.62	2.74	5.50	7.92	13.0	19.1	25.6	36.9	49.8	61.4
	400 V	0.81	1.37	2.75	3.96	6.50	9.55	12.8	18.5	24.9	30.7
6.6 kV conversion value (mA)		49	83	167	240	394	579	776	1121	1509	1860

Applicable motor (kW)		22	30	37	45	55	75	90	110	132	160
Input fundamental harmonic current (A)	200 V	73.1	98.0	121	147	180	245	293	357		
	400 V	36.6	49.0	60.4	73.5	89.9	123	147	179	216	258
6.6 kV conversion value (mA)		2220	2970	3660	4450	5450	7450	8910	10850	13090	15640

Applicable motor (kW)		200	220	250	280	315	355	400	450	500	630
Input fundamental harmonic curren (A)	200 V										
	400 V	323	355	403	450	506	571	643	723	804	1013
6.6 kV conversion value (mA)		19580	21500	24400	27300	30700	34600	39000	43800	48700	61400

(2) Harmonic current calculation

Generally speaking, harmonic current is calculated using "Table 3 Three-phase bridge (capacitor smoothing)" in "Guidelines - Appendix 2". Refer to Table B.2-4 for the guidelines appendices.

Table B.2-4 Amount of harmonic current generation (%), three-phase bridge (capacitor smoothing)

Degree	5th	7th	11th	13th	17th	19th	23rd	25th
No reactor used	65	41	8.5	7.7	4.3	3.1	2.6	1, 8
Reactor used (AC side)	38	14.5	7.4	3.4	3.2	1.9	1.7	1.3
Reactor used (DC side)	30	13	8.4	5.0	4.7	3.2	3.0	2.2
Reactor used (AC, DC side)	28	9.1	7.2	4.1	3.2	2.4	1.6	1.4

- AC side reactor: 3%
- DC side reactor: Stored energy is equivalent to 0.08 to 0.15 ms (100% load conversion)
- Smoothing capacitor: Stored energy is equivalent to 15 to 30 ms (100% load conversion)
- Load: 100%

n_{th} degree harmonic current (A)

$$= \text{Fundamental harmonic current (A)} \times \frac{\text{Amount of } n_{th} \text{ degree harmonic current generation (\%)}}{100}$$

The harmonic current for each degree is obtained as follows.

(3) Maximum availability factor

- For a load like elevators, which provides intermittent operation, or a load with a sufficient designed motor rating, reduce the current by multiplying the equation by the “maximum availability factor” of the load.
- According to the Appendix to Guideline, “Maximum availability factor of equipment refers to the ratio of the maximum capacity of the operating equipment to the total capacity of the harmonic generation equipment. Capacity of the operating equipment shall be an average value over 30 minutes.”
- In general, the maximum availability factor is calculated according to this definition, but the standard values shown in Table B.2-5 are recommended for inverters for building equipment, and therefore these values should also be referred to when handling similar equipment.

Table B.2-5 Availability factors of inverters, etc. for building equipment (standard values)

Equipment type	Inverter capacity category	Single inverter availability
Air conditioning systems	200 kW or less	0.55
	Over 200 kW	0.60
Sanitary pumps	-	0.30
Elevators	-	0.25
Refrigerators, freezers	50 kW or less	0.60
UPS (6-pulse)	200 kVA	0.60

Correction coefficient according to contract demand level

Since the total availability factor decreases if the scale of a building increases, the calculation of reduced harmonics with the correction coefficient β defined in Table B.2-6 is permitted.

Table B.2-6 Correction coefficient according to the building scale

Contract demand (kW)	Correction coefficient β
300	1.00
500	0.90
1,000	0.85
2,000	0.80

Note: If the contract demand is between two specified values listed in Table B.2-6, calculate the value by interpolation.

Note: The correction coefficient β is to be determined as a matter of consultation between the customer and electric power company for the customers receiving the electric power over 2000 kW or from the special high voltage lines.

(4) Degree of harmonics to be calculated

The higher the degree of harmonics, the lower the current flows. This is the property of harmonics generated by inverters so that the inverters are covered by “The case not causing a special hazard” of the term 3.(3) in the above Appendix for the 9th or higher degrees of the harmonics.

Therefore, “It is sufficient that the 5th and 7th harmonic currents should be calculated.”

[3] Examples of calculation

(1) Equivalent capacity

Example of loads	Input capacity and No. of inverters	Conversion factor	Equivalent capacity
[Example (1)] 400 V, 3.7 kW, 10 units with AC/DC reactor	4.61 kVA x 10 units	K32 = 1.4	4.61 x 10 x 1.4 = 64.54 kVA
[Example (2)] 400 V, 1.5 kW, 15 units with AC reactor	2.93 kVA x 15 units	K34 = 1.8	2.93 x 15 x 1.8 = 79.11 kVA
	See Table B.2-1	See Table B.2-2	

(2) Harmonic current for every harmonic order

Example 1: 400 V, 3.7 kW, 10 units (with AC reactor), maximum availability factor: 0.55

6.6 kV side fundamental current (mA)	Harmonic current onto 6.6 kV lines (mA)							
394 x 10 = 3940 3940 x 0.55 = 2167	5th (38%)	7th (14.5%)	11th (7.4%)	13th (3.4%)	17th (3.2%)	19th (1.9%)	23rd (1.7%)	25th (1.3%)
	823.5	314.2						
See Table B.2-3 and Table B.2-5	See Table B.2-4							

Example 2: 400 V, 3.7 kW, 15 units (with AC/DC reactor), maximum availability factor: 0.55

6.6 kV side fundamental current (mA)	Harmonic current onto 6.6 kV lines (mA)							
394 x 15 = 5910 5910 x 0.55 = 3250.5	5th (28%)	7th (9.1%)	11th (7.2%)	13th (4.1%)	17th (3.2%)	19th (2.4%)	23rd (1.6%)	25th (1.4%)
	910.1	295.8						
See Table B.2-3 and Table B.2-5	See Table B.2-4							

Appendix C Effect on Insulation of General-purpose Motors Driven with 400 V Class Inverters

Excerpt from technical material of
the Japan Electrical Manufacturers' Association (JEMA) (March 1995)

Preface

When an inverter drives a motor, surge voltages generated by switching the inverter elements are superimposed on the inverter output voltage and applied to the motor terminals. If the surge voltages are too high they may have an effect on the motor insulation and some cases have resulted in damage.

For preventing such cases this document describes the generating mechanism of the surge voltages and countermeasures against them.

Refer to "A.2 [1] Inverter Operating Principle and Noise" for details of the principle of inverter operation.

C.1 Generating mechanism of surge voltages

As the inverter rectifies a commercial power source voltage and smoothes into a DC voltage, the magnitude E of the DC voltage becomes about times that of the source voltage (about 620 V in case of an input voltage of 440 VAC). The peak value of the output voltage is usually close to this DC voltage value.

But, as there exists inductance (L) and stray capacitance (C) in wiring between the inverter and the motor, the voltage variation due to switching the inverter elements causes a surge voltage originating in LC resonance and results in the addition of high voltage to the motor terminals. (See Fig. C.1-1.)

This voltage sometimes reaches up to about twice that of the inverter DC voltage (620 V x 2 = approximately 1,200 V) depending on a switching speed of the inverter elements and wiring conditions.

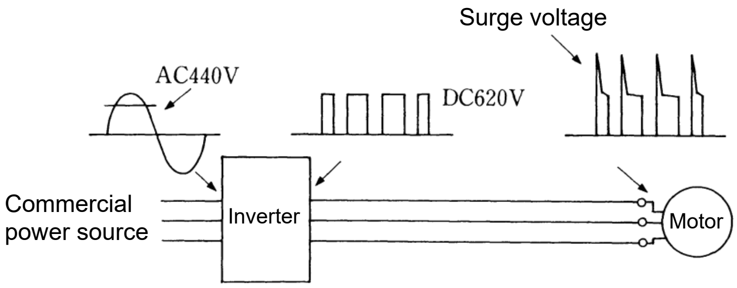


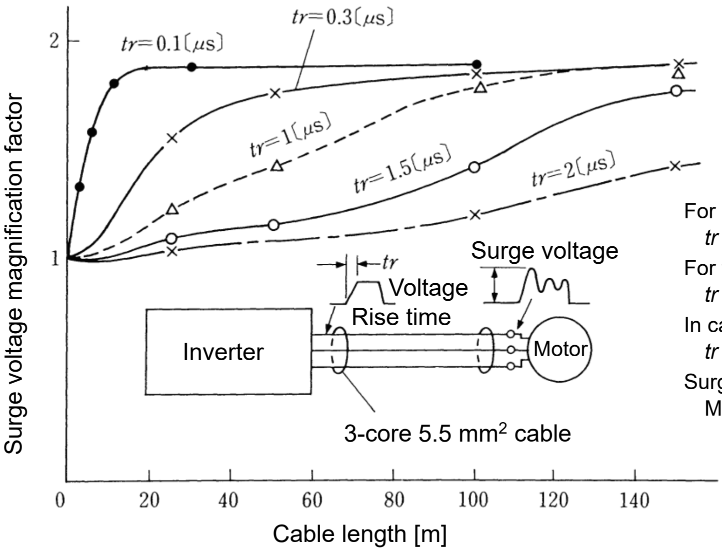
Fig. C.1-1 Voltage waveform of individual portions

APPENDICES

A measured example in Fig. C.1-2 illustrates the relation of a peak value of the motor terminal voltage with a wiring length between the inverter and the motor.

From this it can be confirmed that the peak value of the motor terminal voltage ascends as the wiring length increases and becomes saturated at about twice the inverter DC voltage.

The shorter a pulse rise time becomes, the higher the motor terminal voltage rises even in the case of a short wiring length.



For IGBT,
tr is equivalent to 0.1 to 0.3 μs.
For the bipolar transistor,
tr is equivalent to 0.3 to1 μs.
In case an output reactor or a filter is inserted,
tr is equivalent to 1 μs or more.
Surge voltage magnification factor:
Magnification factor for DC voltage (E)

Excerpt from Journal of IEEJ, No. 7, vol. 107, 1987

Fig. C.1-2 Measured example of wiring length and peak value of motor terminal voltage

C.2 Effect of surge voltages

The surge voltages originated in LC resonance of wiring may be applied to the motor terminals and depending on their magnitude sometimes cause damage to the motor insulation.

When the motor is driven with a 200 V class inverter, the dielectric strength of the insulation is no problem even the peak value at the motor terminal voltage increases twice due to the surge voltages (the DC voltage is only about 300 V).

But in case of a 400 V class inverter, the DC voltage is approximately 600 V and depending on the wiring length, the surge voltages may greatly increase and sometimes result in damage to the insulation.

C.3 Countermeasures against surge voltages

When driving a motor with a 400 V class inverter, the following are countermeasures against damage to the motor insulation by the surge voltages.

[1] Using a surge suppressor unit (SSU)

A surge suppressor unit (SSU) is a newly structured unit using circuits based on the impedance-matching theory of a transmission line. Just connecting the SSU to the surge suppressor cable of the existing equipment can greatly reduce the surge voltage that results in a motor dielectric breakdown.

For 50 m of wiring length: SSU 50TA-NS

For 100 m of wiring length: SSU 100TA-NS

[2] Suppressing surge voltages

To suppress surge voltage, a method is employed which involves suppressing voltage rise and peak value.

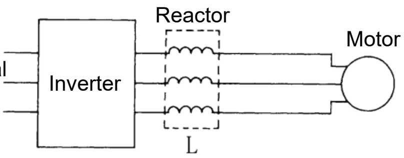
(1) Output reactor

If wiring length is relatively short, the surge voltages can be suppressed by reducing the voltage rise time (dv/dt) with the installation of an AC reactor on the output side of the inverter. (See Fig. C.3-1(1) .)

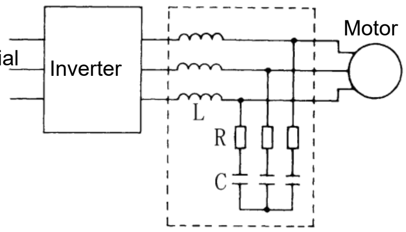
However, if the wiring length becomes long, suppressing the peak voltage due to surge voltage may be difficult.

(2) Output filter

Installing a filter on the output side of the inverter allows the peak value of the motor terminal voltage to be reduced. (See Fig. C.3-1(2) .)



(1) Output reactor



(2) Output filter

Fig. C.3-1 Method to suppress surge voltage

Tip If the wiring length between the inverter and the motor is comparatively long, the crest value of the surge voltage can be suppressed by connecting a surge suppressor unit (SSU) to the motor terminal.
For details, refer to Chapter 11 “11.13 Surge Suppression Unit (SSU)”.

[3] Using motors with enhanced insulation

Enhanced insulation of a motor winding allows its surge withstanding to be improved.

C.4 Regarding existing equipment

[1] In case of a motor being driven with 400 V class inverter

A survey over the last five years on motor insulation damage due to the surge voltages originating from switching of inverter elements shows that the damage incidence is 0.013% under the surge voltage condition of over 1,100 V and most of the damage occurs several months after commissioning the inverter. Therefore there seems to be little probability of occurrence of motor insulation damage after a lapse of several months of commissioning.

[2] In case of an existing motor driven using a newly installed 400 V class inverter

We recommend suppressing the surge voltages with the methods shown in "C.3 ".

Appendix D Inverter Generating Loss

The table below lists the inverter generating loss.

Table C.4-1

Power system	Inverter type	Inverter generated loss (W)			
		HHD specification		HND specification	
		Low carrier	High carrier	Low carrier	High carrier
Three-phase 200 V	FRN0003G2S-2G	35	45	-	-
	FRN0005G2S-2G	50	60	-	-
	FRN0008G2S-2G	80	110	-	-
	FRN0011G2S-2G	110	140	-	-
	FRN0018G2S-2G	170	210	-	-
	FRN0032G2S-2G	240	310	290	370
	FRN0046G2S-2G	300	415	410	550
	FRN0059G2S-2G	450	620	500	670
	FRN0075G2S-2G	540	700	630	840
	FRN0088G2S-2G	660	860	770	970
	FRN0115G2S -2G	790	1040	1120	1250*1
	FRN0146G2S-2G	1300	1450	1650	1750*1
	FRN0180G2S-2G	1300	1550	1650	1850*1
	FRN0215G2S-2G	1450	1600	1850	1950*1
	FRN0288G2S-2G	1750	1900	2250	2400*1
	FRN0346G2S-2G	2300	2550*1	2700	2800*2
	FRN0432G2S-2G	2750	3050*1	3250	3350*2
Three-phase 400 V	FRN0002G2☐-4G	35	60	-	-
	FRN0003G2☐-4G	45	80	-	-
	FRN0004G2☐-4G	60	110	-	-
	FRN0006G2☐-4G	80	140	-	-
	FRN0009G2☐-4G	130	230	-	-
	FRN0018G2☐-4G	170	300	210	370
	FRN0023G2☐-4G	230	400	300	520
	FRN0031G2☐-4G	300	520	360	610
	FRN0038G2☐-4G	360	610	460	770
	FRN0045G2☐-4G	440	770	510	870
	FRN0060G2☐-4G	510	900	710	1310*1
	FRN0075G2☐-4G	800	1150	1000	1250*1
	FRN0091G2☐-4G	1000	1450	1250	1550*1
	FRN0112G2☐-4G	1100	1600	1350	1700*1
	FRN0150G2☐-4G	1350	1950	1950	2400*1
	FRN0180G2☐-4G	1600	2150*1	2000	2250*2
	FRN0216G2☐-4G	1900	2600*1	2250	2550*2
	FRN0260G2☐-4G	2300	3050*1	2700	3050*2
	FRN0325G2☐-4G	2500	3300*1	3050	3400*2
	FRN0377G2☐-4G	3100	4000*1	3900	4350*2
	FRN0432G2☐-4G	3850	5000*1	4250	4750*2
	FRN0520G2☐-4G	4350	5600*1	5600	6200*2
	FRN0650G2☐-4G	5300	6900*1	6500	7300*2
	FRN0740G2☐-4G	6000	7800*1	7500	8350*2
	FRN0960G2☐-4G	6450	8450*1	8100	9100*2
	FRN1040G2☐-4G	7350	9650*1	9200	10350*2
	FRN1170G2☐-4G	9600	10700*1	11550	12950*2
	FRN1386G2☐-4G	11900	13300*1	13500	13800*2

(Note) ☐ in the inverter type is replaced by a letter of the alphabet.

S (basic type), E (type with built-in EMC filter)

Low carrier：2 kHz

High carrier：FRN0115G2S-2G/FRN0060G2☐-4G or less：16 kHz [*1：10 kHz]

FRN0146G2S-2G/FRN0075G2☐-4G or higher：15 kHz [*1：10 kHz, *2：6 kHz]

Appendix E Conversion to other than SI Units

All expressions given in Chapter 10 "SELECTING OPTIMAL MOTOR AND INVERTER CAPACITIES" are based on SI units (The International System of Units). This section explains how to convert expressions to other units.

E.1 Conversion of units

(1) Force

- 1 [kgf] ≈ 9.8 [N]
- 1 [N] ≈ 0.102 [kgf]

(2) Torque

- 1 [kgf·m] ≈ 9.8 [N•m]
- 1 [N•m] ≈ 0.102 [kgf•m]

(3) Power (energy)

- 1 [kgf•m] ≈ 9.8 [N•m] = 9.8 [J] = 9.8 [W•s]

(4) Power

- 1 [kgf•m/s] ≈ 9.8 [N•m/s] = 9.8 [J/s] = 9.8 [W]
- 1 [N•m/s] ≈ 1 [J/s] = 1 [W] ≈ 0.102 [kgf•m/s]

(5) Rotation speed

- 1 [min^{-1}] = $\frac{2\pi}{60}$ [rad/s] ≈ 0.1047 [rad/s]
- 1 [rad/s] = $\frac{60}{2\pi}$ [min^{-1}] ≈ 9.549 [min^{-1}]

(6) Inertia constant

J [kg•m^2]: moment of inertia

GD^2 [kg·m^2]: flywheel effect

- $GD^2 = 4J$
- $J = \frac{GD^2}{4}$

(7) Pressure, stress

- 1 [mmAq] ≈ 9.8 [Pa] ≈ 9.8 [N/m^2]
- 1 [Pa] ≈ 1 [N/m^2] ≈ 0.102 [mmAq]
- 1 [bar] ≈ 100000 [Pa] ≈ 1.02 [kg•cm^2]
- 1 [kg•cm^2] ≈ 98000 [Pa] ≈ 980 [mbar]
- 1 barometric pressure
  = 1013 [mbar] = 760 [mmHg]
  = 101300 [Pa] ≈ 1.033 [kg/cm^2]

E.2 Calculation formulas

(1) Torque, power, rotation speed

- $P[W] \approx \frac{2\pi}{60} \cdot N[min^{-1}] \cdot \tau\,[N \cdot m]$

- $P\,[W] \approx 1.026 \cdot N\,[min^{-1}] \cdot T\,[kgf \cdot m]$

- $\tau\,[N \cdot m] \approx 9.55 \cdot \frac{P\,[W]}{N\,[min^{-1}]}$

- $T\,[kgf \cdot m] \approx 0.974 \cdot \frac{P\,[W]}{N\,[min^{-1}]}$

(2) Kinetic energy

- $E\,[J] \approx \frac{1}{182.4} \cdot J\,[kg \cdot m^2] \cdot N^2\,[(min^{-1})^2]$

- $E\,[J] \approx \frac{1}{730} \cdot GD^2\,[kg \cdot m^2] \cdot N^2\,[(min^{-1})^2]$

(3) Linear motion load torque

[Driving mode]

- $\tau\,[N \cdot m] \approx 0.159 \frac{V\,[m/min]}{N_M\,[min^{-1}] \cdot \eta_G} \cdot F\,[N]$

- $T\,[kgf \cdot m] \approx 0.159 \frac{V\,[m/min]}{N_M\,[min^{-1}] \cdot \eta_G} \cdot F\,[kgf]$

[Braking mode]

- $\tau\,[N \cdot m] \approx 0.159 \frac{V\,[m/min]}{N_M\,[min^{-1}] / \eta_G} \cdot F\,[N]$

- $T\,[kgf \cdot m] \approx 0.159 \frac{V\,[m/min]}{N_M\,[min^{-1}] / \eta_G} \cdot F\,[kgf]$

(4) Acceleration torque

[Driving mode]

- $\tau\,[N \cdot m] \approx \frac{J\,[kg \cdot m^2]}{9.55} \cdot \frac{\Delta N\,[min^{-1}]}{\Delta t\,[s] \cdot \eta_G}$

- $T\,[kgf \cdot m] \approx \frac{GD^2\,[kg \cdot m^2]}{375} \cdot \frac{\Delta N\,[min^{-1}]}{\Delta t\,[s] \cdot \eta_G}$

[Braking mode]

- $\tau\,[N \cdot m] \approx \frac{J\,[kg \cdot m^2]}{9.55} \cdot \frac{\Delta N\,[min^{-1}] \cdot \eta_G}{\Delta t\,[s]}$

- $T\,[kgf \cdot m] \approx \frac{GD^2\,[kg \cdot m^2]}{375} \cdot \frac{\Delta N\,[min^{-1}] \cdot \eta_G}{\Delta t\,[s]}$

(5) Acceleration time

- $t_{ACC}\,[s] \approx \frac{J_1 + J_2/\eta_G\,[kg \cdot m^2]}{\tau_M - \tau_L/\eta_G\,[N \cdot m]} \cdot \frac{\Delta N\,[min^{-1}]}{9.55}$

- $t_{ACC}\,[s] \approx \frac{GD_1^2 + GD_2^2/\eta_G\,[kg \cdot m^2]}{T_M - T_L/\eta_G\,[kgf \cdot m]} \cdot \frac{\Delta N\,[min^{-1}]}{375}$

(6) Deceleration time

- $t_{DEC}\,[s] \approx \frac{J_1 + J_2 \cdot \eta_G\,[kg \cdot m^2]}{\tau_M - \tau_L \cdot \eta_G\,[N \cdot m]} \cdot \frac{\Delta N\,[min^{-1}]}{9.55}$

- $t_{DEC}\,[s] \approx \frac{GD_1^2 + GD_2^2 \cdot \eta_G\,[kg \cdot m^2]}{T_M - T_L \cdot \eta_G\,[kgf \cdot m]} \cdot \frac{\Delta N\,[min^{-1}]}{375}$

Appendix F Permissible Current of Insulated Wires

The tables below list the permissible current of IV wires, HIV wires, and 600 V cross-linked polyethylene insulated wires.

■ IV wire (maximum permissible temperature: 60 °C (140 °F))

Table F-1 (a) Permissible current of insulated wires

Wire size (mm^2)	Permissible current	Aerial wiring					Wire duct wiring (3 wires or less in same duct)			
	Threshold value (30 °C or less) Io (A)	35 °C (Io x 0.91) (A)	40 °C (Io x 0.82) (A)	45 °C (Io x 0.71) (A)	50 °C (Io x 0.58) (A)	55 °C (Io x 0.41) (A)	35 °C (Io x 0.64) (A)	40 °C (Io x 0.57) (A)	45 °C (Io x 0.49) (A)	50 °C (Io x 0.40) (A)
2.0	27	24	22	19	15	11	17	15	13	10
3.5	37	33	30	26	21	15	23	21	18	14
5.5	49	44	40	34	28	20	31	28	24	19
8.0	61	55	49	43	35	24	38	34	30	24
14	88	80	71	62	50	35	56	50	43	35
22	115	104	93	81	66	46	73	65	56	46
38	162	147	132	114	93	66	103	92	80	65
60	217	198	177	153	125	88	138	124	107	87
100	298	272	243	210	172	121	190	170	147	120
150	395	360	322	279	228	161	252	225	195	159
200	469	428	382	331	270	191	299	268	232	189
250	556	507	453	393	321	226	355	317	275	224
325	650	593	530	459	375	265	415	371	321	262
400	745	680	608	526	430	304	476	425	368	301
500	842	768	687	595	486	343	538	481	416	340
2 x 100	497	453	405	351	286	202	317	284	246	200
2 x 150	658	600	537	465	379	268	420	376	325	265
2 x 200	782	713	638	552	451	319	499	446	387	316
2 x 250	927	846	756	655	535	378	592	529	458	374
2 x 325	1083	988	884	765	625	442	692	618	536	437
2 x 400	1242	1133	1014	878	717	507	793	709	614	501
2 x 500	1403	1280	1145	992	810	572	896	801	694	567

■ **HIV wire (maximum permissible temperature: 75 °C (167 °F))**

Table F-1 (b) Permissible current of insulated wires

Wire size (mm^2)	Permissible current	Aerial wiring					Wire duct wiring (3 wires or less in same duct)			
	Threshold value (30 °C or less) Io (A)	35 °C (Io x0.94) (A)	40 °C (Io x 0.88) (A)	45 °C (Io x 0.81) (A)	50 °C (Io x0.74) (A)	55 °C (Io x 0.66) (A)	35 °C (Io x0.65) (A)	40 °C (Io x0.61) (A)	45 °C (Io x 0.57) (A)	50 °C (Io x0.52) (A)
2.0	33	31	29	26	24	21	21	20	18	17
3.5	45	42	39	36	33	29	29	27	25	23
5.5	60	56	52	48	44	39	39	36	34	31
8.0	74	69	65	59	54	48	48	45	42	38
14	107	100	94	86	79	70	69	65	60	55
22	140	131	123	113	103	92	91	85	79	72
38	198	186	174	160	146	130	128	120	112	102
60	265	249	233	214	196	174	172	161	151	137
100	364	342	320	294	269	240	236	222	207	189
150	483	454	425	391	357	318	313	294	275	251
200	574	539	505	464	424	378	373	350	327	298
250	680	639	598	550	503	448	442	414	387	353
325	796	748	700	644	589	525	517	485	453	413
400	912	857	802	738	674	601	592	556	519	474
500	1,031	969	907	835	762	680	670	628	587	536
2 x 100	608	571	535	492	449	401	395	370	346	316
2 x 150	805	756	708	652	595	531	523	491	458	418
2 x 200	957	899	842	775	708	631	622	583	545	497
2 x 250	1,135	1066	998	919	839	749	737	692	646	590
2 x 325	1,326	1246	1,166	1,074	981	875	861	808	755	689
2 x 400	1,521	1429	1,338	1,232	1,125	1,003	988	927	866	790
2 x 500	1,718	1614	1,511	1,391	1,271	1,133	1,116	1,047	979	893

■ 600 V crosslinked polyethylene insulated wire (maximum permissible temperature: 90 °C (194 °F))

Table F-3 (c) Permissible current of insulated wires

Wire size (mm^2)	Permissible current	Aerial wiring					Wire duct wiring (3 wires or less in same duct)			
	Threshold value (30 °C or less) Io (A)	35 °C (Io x 0.95) (A)	40 °C (Io x 0.91) (A)	45 °C (Io x 0.86) (A)	50 °C (Io x 0.81) (A)	55 °C (Io x 0.76) (A)	35 °C (Io x0.67) (A)	40 °C (Io x0.63) (A)	45 °C (Io x 0.60) (A)	50 °C (Io x0.57) (A)
2.0	38	36	34	32	30	28	25	23	22	21
3.5	52	49	47	44	42	39	34	32	31	29
5.5	69	65	62	59	55	52	46	43	41	39
8.0	86	81	78	73	69	65	57	54	51	49
14	124	117	112	106	100	94	83	78	74	70
22	162	153	147	139	131	123	108	102	97	92
38	229	217	208	196	185	174	153	144	137	130
60	306	290	278	263	247	232	205	192	183	174
100	421	399	383	362	341	319	282	265	252	239
150	558	530	507	479	451	424	373	351	334	318
200	663	629	603	570	537	503	444	417	397	377
250	786	746	715	675	636	597	526	495	471	448
325	919	873	836	790	744	698	615	578	551	523
400	1,053	1,000	958	905	852	800	705	663	631	600
500	1,190	1,130	1,082	1,023	963	904	797	749	714	678
2 x 100	702	666	638	603	568	533	470	442	421	400
2 x 150	930	883	846	799	753	706	623	585	558	530
2 x 200	1,105	1,049	1,005	950	895	839	740	696	663	629
2 x 250	1,310	1,244	1,192	1,126	1,061	995	877	825	786	746
2 x 325	1,531	1,454	1,393	1,316	1,240	1,163	1,025	964	918	872
2 x 400	1,756	1,668	1,597	1,510	1,422	1,334	1,176	1,106	1,053	1,000
2 x 500	1,984	1,884	1,805	1,706	1,607	1,507	1,329	1,249	1,190	1,130

Appendix G Conformity with Standards

G.1 Compliance with European Standards (CE)

The CE marking on Fuji products indicates that they comply with the essential requirements of the Electromagnetic Compatibility (EMC) Directive, Low Voltage Directive, and Machinery Directive issued by the Council of the European Communities.

Note Keep the ambient temperature to 50°C or less to comply with European standards.
Products with no standards indicated do not comply with European Standards.

Table G.1-1 Compliance standards

	Standards
EMC Directive	EN 61800-3 Immunity: Second environment (Industrial) Emission: Category C2 or C3 (Refer to Table G.1-2. Applicable only when an optional EMC-compliant filter is attached.) : Category C3 (Applicable only to the EMC filter built-in type of inverters)
Low Voltage Directive	Adjustable speed electrical power drive systems. Part 5-1: Safety requirements. Electrical, thermal and energy EN61800-5-1:2007
Machine Directives	EN ISO 13849-1 : Cat.3 PL:e EN 60204-1 : Stop Category 0 EN 61800-5-2 : SIL3 (Functional Safety : STO) EN 62061 : SIL3

* A basic type inverter that does not have a built-in EMC filter complies with the EMC Directive by combining it with an external filter dedicated to Fuji.

Warning

Category C2 : In a domestic environment this product may cause radio interference in which case supplementary mitigation measures may be required.

Category C3: This type of PDS is not intended to be used on a low-voltage public network which supplies domestic premises ; radio frequency interference is expected if used on such a network.

Category C2 and C3 : It has a risk about other equipment malfunction or breakdown by radiated electric field strength out of frequency range that is defined EN 61800-3: 2004 + A1: 2012 2nd Environment and EN/IEC 61800-3: 2018 2nd Environment.

[1] Compliance with EMC standards

The CE marking on inverters does not ensure that the entire equipment including our CE-marked products is compliant with the EMC Directive. Therefore, CE marking for the equipment shall be the responsibility of the equipment manufacturer. For this reason, Fuji's CE mark is indicated under the condition that the product shall be used within equipment meeting all requirements for the relevant Directives. Instrumentation of such equipment shall be the responsibility of the equipment manufacturer.

Generally, machinery or equipment includes not only our products but other devices as well. Manufacturers, therefore, shall design the whole system to be compliant with the relevant Directives.

■ List of EMC-compliant filters

To comply with standards, either use an inverter with built-in EMC filter, or use an inverter with no built-in EMC filter in combination with a dedicated Fuji external filter (option). No matter what the application, please install noise filters using the following recommended installation method. It is recommended that noise filters be installed inside metal cabinets to ensure more reliable compliance with standards.

Tip Our EMC compliance test is performed under the following conditions.
Wiring length (of the shielded cable) between the inverter (EMC filter built-in type) and motor: 5 m

Note To use Fuji inverters in combination with a PWM converter, the basic type of inverters having no built-in EMC filter should be used. Use of an EMC filter built-in type may increase heat of capacitors in the inverter, resulting in damage. In addition, the effect of the EMC filter can no longer be expected.

Table G.1-2 EMC-compliant filters

<table>
<tr><th rowspan="2">Power system</th><th rowspan="2">Inverter type</th><th colspan="2">Filter type</th></tr>
<tr><th>HHD specification</th><th>HND specification</th></tr>
<tr><td rowspan="17">Three-phase 200 V</td><td>FRN0003G2S-2G</td><td rowspan="2">EFL-0.75SP-2 (*1)</td><td rowspan="5">-</td></tr>
<tr><td>FRN0005G2S-2G</td></tr>
<tr><td>FRN0008G2S-2G</td><td rowspan="3">EFL-3.7SP-2 (*1)</td></tr>
<tr><td>FRN0011G2S-2G</td></tr>
<tr><td>FRN0018G2S-2G</td></tr>
<tr><td>FRN0032G2S-2G</td><td rowspan="2">EFL-7.5SP-2 (*1)</td><td>EFL-7.5SP-2 (*1)</td></tr>
<tr><td>FRN0046G2S-2G</td><td rowspan="3">EFL-15SP-2 (*1)</td></tr>
<tr><td>FRN0059G2S-2G</td><td rowspan="2">EFL-15SP-2 (*1)</td></tr>
<tr><td>FRN0075G2S-2G</td></tr>
<tr><td>FRN0088G2S-2G</td><td rowspan="2">EFL-22SP-2 (*1)</td><td>EFL-22SP-2 (*1)</td></tr>
<tr><td>FRN0115G2S -2G</td><td>SF5536-180-40</td></tr>
<tr><td>FRN0146G2S-2G</td><td>FS5536-180-40</td><td rowspan="2">SF5536-250-99-1</td></tr>
<tr><td>FRN0180G2S-2G</td><td rowspan="2">FS5536-250-99-1</td></tr>
<tr><td>FRN0215G2S-2G</td><td rowspan="3">SF5536-400-99-1</td></tr>
<tr><td>FRN0288G2S-2G</td><td rowspan="3">FS5536-400-99-1</td></tr>
<tr><td>FRN0346G2S-2G</td></tr>
<tr><td>FRN0432G2S-2G</td><td>FN3359-600-99</td></tr>
<tr><td rowspan="28">Three-phase 400 V</td><td>FRN0002G2☐-4G</td><td rowspan="2">FS5536-5-07
(EFL-0.75G11-4)</td><td rowspan="5">-</td></tr>
<tr><td>FRN0003G2☐-4G</td></tr>
<tr><td>FRN0004G2☐-4G</td><td rowspan="2">FS5536-12-07
(EFL-4.0G11-4)</td></tr>
<tr><td>FRN0006G2☐-4G</td></tr>
<tr><td>FRN0009G2☐-4G</td><td>FS21312-18-07</td></tr>
<tr><td>FRN0018G2☐-4G</td><td rowspan="3">FS5536-35-07
(EFL-7.5G11-4)</td><td rowspan="2">FS5536-35-07
(EFL-7.5G11-4)</td></tr>
<tr><td>FRN0023G2☐-4G</td></tr>
<tr><td>FRN0031G2☐-4G</td><td>FS5536-50-07</td></tr>
<tr><td>FRN0038G2☐-4G</td><td>FS5536-50-07
(EFL-15G11-4)</td><td rowspan="2">FS5536-72-07
(EFL-22G11-4)</td></tr>
<tr><td>FRN0045G2☐-4G</td><td rowspan="2">FS5536-72-07
(EFL-22G11-4)</td></tr>
<tr><td>FRN0060G2☐-4G</td><td>FS21312-78-07</td></tr>
<tr><td>FRN0075G2☐-4G</td><td rowspan="2">FS5536-100-35</td><td>FS5536-100-35</td></tr>
<tr><td>FRN0091G2☐-4G</td><td rowspan="4">FS5536-180-40</td></tr>
<tr><td>FRN0112G2☐-4G</td><td rowspan="4">FS5536-180-40</td></tr>
<tr><td>FRN0150G2☐-4G</td></tr>
<tr><td>FRN0180G2☐-4G</td></tr>
<tr><td>FRN0216G2☐-4G</td><td rowspan="2">FS5536-250-99-1</td></tr>
<tr><td>FRN0260G2☐-4G</td><td rowspan="2">FS5536-250-99-1</td></tr>
<tr><td>FRN0325G2☐-4G</td><td rowspan="3">FS5536-400-99-1</td></tr>
<tr><td>FRN0377G2☐-4G</td><td rowspan="3">FS5536-400-99-1</td></tr>
<tr><td>FRN0432G2☐-4G</td></tr>
<tr><td>FRN0520G2☐-4G</td><td>FN3359-600-99(*2)</td></tr>
<tr><td>FRN0650G2☐-4G</td><td rowspan="2">FN3359-600-99 (*2)</td><td rowspan="2">FN3359-800-99 (*2)</td></tr>
<tr><td>FRN0740G2☐-4G</td></tr>
<tr><td>FRN0960G2☐-4G</td><td rowspan="2">FN3359-800-99 (*2)</td><td rowspan="2">FN3359-1000-99 (*2)</td></tr>
<tr><td>FRN1040G2☐-4G</td></tr>
<tr><td>FRN1170G2☐-4G</td><td>FN3359-1000-99 (*2)</td><td rowspan="2">FN3359-1600-99 (*2)</td></tr>
<tr><td>FRN1386G2☐-4G</td><td>FN3359-1600-99 (*2)</td></tr>
</table>

(*1) Filter type EFL-☐SP-☐ : Pass the EMC filter input cables (power cables and grounding cable in a bundle) through the attached ferrite ring reactor for reducing radio noise.

(*2) Emission Category C3

■ **Recommended installation method**

To make the machinery or equipment fully compliant with the EMC Directive, certified technicians should wire the motor and inverter in strict accordance with the procedure described below.

EMC-compliant filter (option) installation method

(1) Mount the inverter and the filter on a grounded panel or metal plate. Use shielded wires for the motor cable and route the cable as short as possible. Firmly clamp the shields to the metal plate to ground them. Furthermore, connect shields and motor grounding terminals electrically. Use wiring guides to keep the input line away from the output line as far as possible.

For inverters with a capacity of FRN0032G2S-2G/FRN0018G2□-4G to FRN0059G2S-2G/FRN0031G2□-4G, connect the input grounding wire to the grounding terminal at the front, left-hand side, and the output grounding wire to that on the main circuit terminal block.
(Refer to Fig. G.1-1)

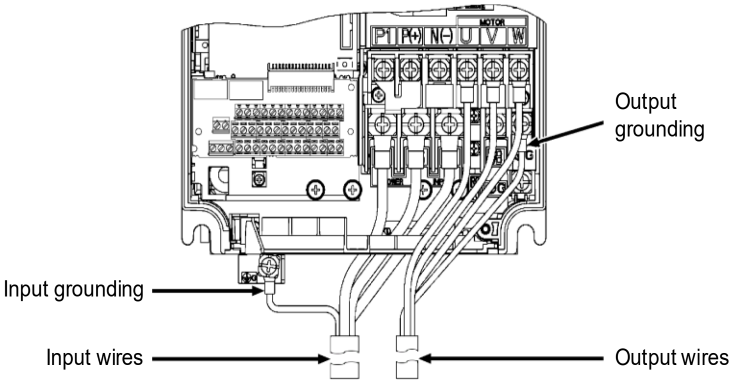


Fig. G.1-1 Wiring for the EMC Filter Built-in Type with a Capacity of FRN0032G2S-2G/ FRN0018G2□-4G to FRN0059G2S-2G/FRN0031G2□-4G

(2) For connection to inverter’s control terminals and for connection of the RS-485 communication signal cable, use shielded wires. As with the motor connections, clamp the shields firmly to a grounded panel.

(3) If noise from the inverter exceeds the permissible level, enclose the inverter and its peripherals within a metal panel as shown in Fig. G.1-2.

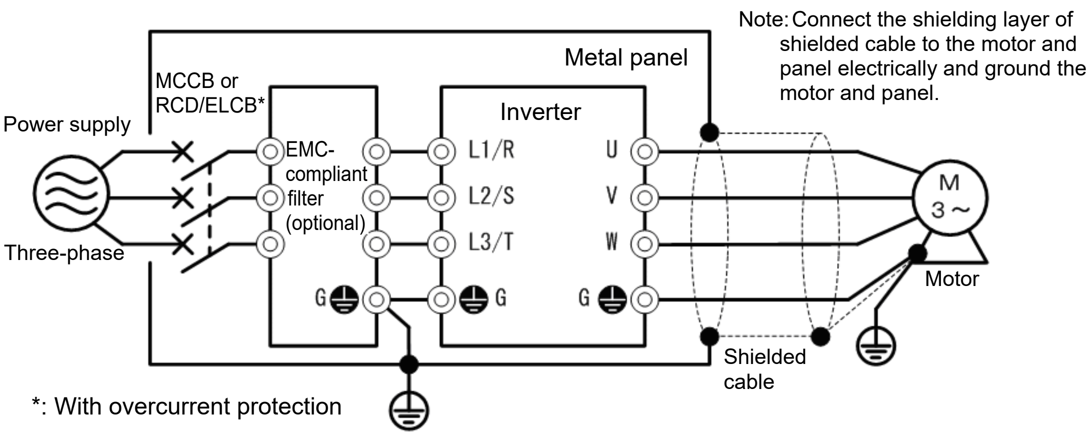


Fig. G.1-2 EMC-compliant filter (option) installation method

APPENDICES

In case of EMC filter built-in type inverter

(1) Mount the inverter on a grounded panel or metal plate. Use shielded wires for the motor cable and route the cable as short as possible. Firmly clamp the shields to the metal plate to ground them. Further, connect the shielding layers electrically to the grounding terminal of the motor. Use a wiring guide, etc., and try as best as possible to keep input wires and output wires separate from one another.

(2) For connection to inverter's control terminals and for connection of the RS-485 communication signal cable, use shielded wires. As with the motor connections, clamp the shields firmly to a grounded panel.

(3) If noise from the inverter exceeds the permissible level, enclose the inverter and its peripherals within a metal panel as shown in Fig. G.1-3.

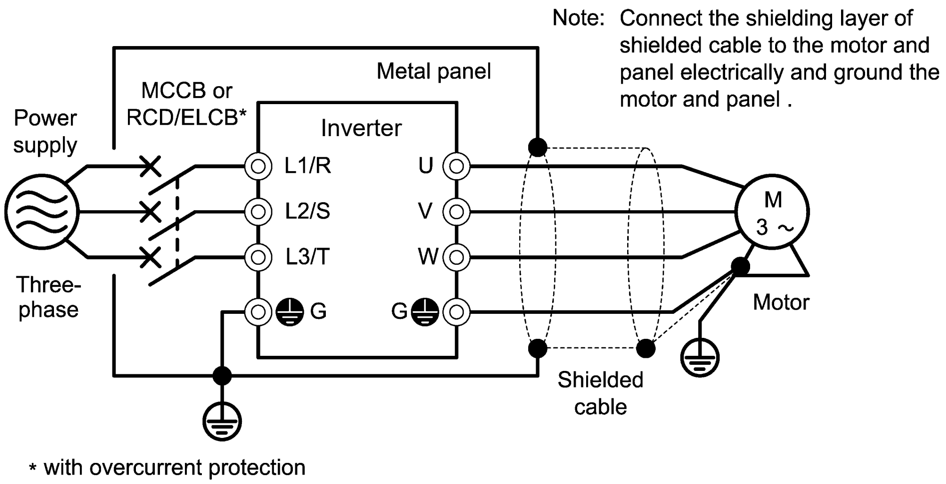


Fig. G.1-3 Installation method for built-in type EMC-compliant filter

■ Leakage current of EMC-filter built-in type of inverters

An EMC filter uses grounding capacitors for noise suppression which increase leakage current. The use of grounding capacitors leads to an increase in leakage current, and therefore a check should be carried out to ensure that the power supply system has not been affected.

⚠CAUTION⚠

As the touch current (leakage current) of inverters with EMC-filter is relatively high, it is of essential importance to always assure a reliable connection to Protective Earth (PE). (Current values are shown in Table G.1-3.)
In Table G.1-3, for the inverter types whose leakage currents are equal to or exceed the critical value of 3.5 mA AC or 10 mA DC (IEC 61800-5-1), the minimum cross sectional area of the PE-conductor should be:

- 10 mm^2 (Cu-conductors)
- 16 mm^2 (Al-conductors)

Failure to observe this could result in electric shock.

Table G.1-3 Leakage current of EMC filter built-in type of inverters

Power system	Inverter type	Leakage current (mA)
Three-phase 400 V *1)	FRN0002G2E-4G	3
	FRN0003G2E-4G	
	FRN0004G2E-4G	
	FRN0006G2E-4G	
	FRN0009G2E-4G	
	FRN0018G2E-4G	7
	FRN0023G2E-4G	
	FRN0031G2E-4G	
	FRN0038G2E-4G	5
	FRN0045G2E-4G	
	FRN0060G2E-4G	
	FRN0075G2E-4G	11
	FRN0091G2E-4G	
	FRN0112G2E-4G	
	FRN0150G2E-4G	5
	FRN0180G2E-4G	
	FRN0216G2E-4G	
	FRN0260G2E-4G	
	FRN0325G2E-4G	
	FRN0377G2E-4G	
	FRN0432G2E-4G	
	FRN0520G2E-4G	
	FRN0650G2E-4G	
	FRN0740G2E-4G	
	FRN0960G2E-4G	
	FRN1040G2E-4G	
	FRN1170G2E-4G	
	FRN1386G2E-4G	

*1) Calculated based on these measuring conditions: 480 V/60 Hz, neutral grounding, interphase voltage unbalance ratio of 2%.

[2] Compliance with European Low Voltage Directive

General-purpose inverters are subject to compliance with the European Low Voltage Directive. The CE marking on inverters represents a self-declaration that the product complies with the Low Voltage Directive.

■ Note

If using as a European Low Voltage Directive compatible product, compatibility with Low Voltage Directive 2014/35/EU is achieved by installing the product as follows.

Compliance with European standards

Adjustable speed electrical power drive systems.

Part 5-1: Safety requirements. Electrical, thermal and energy EN61800-5-1

Compliance with European Low Voltage Directive

⚠WARNING⚠

1. Always ground the grounding terminal ⏚G, and do not attempt to provide electric shock protection simply with an earth leakage circuit breaker* (RCD (Residual-current-operated protective) or ELCB (Earth Leakage Circuit Breaker). Be sure to use ground wires whose size is greater than power lines.
   * With overcurrent protection function
2. This offers protection against the risk of high voltage or accidents that may result in inverter damage, and therefore a fuse of specification indicated in the following table must be installed at the power supply side.
   • Breaking capacity of 10 kA or higher, rated voltage of 500 V or lower

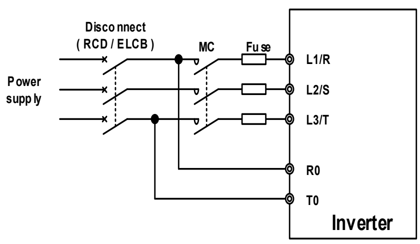
<table>
<tr><th>Power supply system</th><th>Standard applicable motor (kW)</th><th>Inverter type</th><th>Specification</th><th>Fuse rating (A)</th></tr>
<tr><td rowspan="29">Three-phase 200 V</td><td>0.4</td><td>FRN0003G2S-2G</td><td rowspan="5">HHD</td><td rowspan="2">50(IEC 60269-4)</td></tr>
<tr><td>0.75</td><td>FRN0005G2S-2G</td></tr>
<tr><td>1.5</td><td>FRN0008G2S-2G</td><td>80(IEC 60269-4)</td></tr>
<tr><td>2.2</td><td>FRN0011G2S-2G</td><td rowspan="2">125(IEC 60269-4)</td></tr>
<tr><td>3.7</td><td>FRN0018G2S-2G</td></tr>
<tr><td>5.5</td><td rowspan="2">FRN0032G2S-2G</td><td>HHD</td><td rowspan="2">160 (IEC60269-4)</td></tr>
<tr><td rowspan="2">7.5</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0046G2S-2G</td><td>HHD</td><td rowspan="4">200(IEC 60269-4)</td></tr>
<tr><td rowspan="2">11</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0059G2S-2G</td><td>HHD</td></tr>
<tr><td rowspan="2">15</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0075G2S-2G</td><td>HHD</td><td rowspan="4">250(IEC 60269-4)</td></tr>
<tr><td rowspan="2">18.5</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0088G2S-2G</td><td>HHD</td></tr>
<tr><td rowspan="2">22</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0115G2S -2G</td><td>HHD</td><td rowspan="2">315(IEC 60269-4)</td></tr>
<tr><td rowspan="2">30</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0146G2S-2G</td><td>HHD</td><td rowspan="2">450(IEC 60269-4)</td></tr>
<tr><td rowspan="2">37</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0180G2S-2G</td><td>HHD</td><td rowspan="2">500(IEC 60269-4)</td></tr>
<tr><td rowspan="2">45</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0215G2S-2G</td><td>HHD</td><td rowspan="6">550(IEC 60269-4)</td></tr>
<tr><td rowspan="2">55</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0288G2S-2G</td><td>HHD</td></tr>
<tr><td rowspan="2">75</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0346G2S-2G</td><td>HHD</td></tr>
<tr><td rowspan="2">90</td><td>HND</td></tr>
<tr><td rowspan="2">FRN0432G2S-2G</td><td>HHD</td><td rowspan="2">700(IEC 60269-4)</td></tr>
<tr><td>110</td><td>HND</td></tr>
</table>

(cont.)

Compliance with European Low Voltage Directive(cont.)

Power supply system	Standard applicable motor (kW)	Inverter type	Specification	Fuse rating (A)
Three-phase 400 V	0.4	FRN0002G2☐-4G	HHD	50(IEC 60269-4)
	0.75	FRN0003G2☐-4G		
	1.5	FRN0004G2☐-4G		
	2.2	FRN0006G2☐-4G		63(IEC 60269-4)
	3.7	FRN0009G2☐-4G		
	5.5	FRN0018G2☐-4G	HHD	100(IEC 60269-4)
	7.5		HND	
		FRN0023G2☐-4G	HHD	
	11		HND	
		FRN0031G2☐-4G	HHD	125 (IEC60269-4)
	15		HND	
		FRN0038G2☐-4G	HHD	160(IEC 60269-4)
	18.5		HND	
		FRN0045G2☐-4G	HHD	
	22		HND	
		FRN0060G2☐-4G	HHD	200(IEC 60269-4)
	30		HND	
		FRN0075G2☐-4G	HHD	315(IEC 60269-4)
	37		HND	
		FRN0091G2☐-4G	HHD	
	45		HND	
		FRN0112G2☐-4G	HHD	350(IEC 60269-4)
	55		HND	
		FRN0150G2☐-4G	HHD	400(IEC 60269-4)
	75		HND	
		FRN0180G2☐-4G	HHD	350(IEC 60269-4)
	90		HND	
		FRN0216G2☐-4G	HHD	
	110		HND	
		FRN0260G2☐-4G	HHD	400(IEC 60269-4)
	132		HND	
		FRN0325G2☐-4G	HHD	500(IEC 60269-4)
	160		HND	
		FRN0377G2☐-4G	HHD	550(IEC 60269-4)
	200		HND	
		FRN0432G2☐-4G	HHD	700(IEC 60269-4)
	220		HND	
		FRN0520G2☐-4G	HHD	800(IEC 60269-4)
	280		HND	
		FRN0650G2☐-4G	HHD	1000(IEC 60269-4)
	355		HND	
	315	FRN0740G2☐-4G	HHD	1100(IEC 60269-4)
	400		HND	
	355	FRN0960G2☐-4G	HHD	1250(IEC 60269-4)
	400		HND	
	500		HND	
	400	FRN1040G2☐-4G	HHD	1500(IEC 60269-4)
	500		HND	
	560			
	500	FRN1170G2☐-4G	HHD	2000(IEC60269-4)
	630		HND	
		FRN1386G2☐-4G	HHD	
	710		HND	

Note) The ☐ in the inverter type is replaced by a letter of the alphabet indicating the type.



(cont.)

APPENDICES

Compliance with European Low Voltage Directive(cont.)

⚠WARNING⚠

3. When used with the inverter, a molded case circuit breaker (MCCB), residual-current-operated protective device (RCD)/earth leakage circuit breaker (ELCB) or magnetic contactor (MC) should conform to the EN or IEC standards.

4. When you use a residual-current-operated protective device (RCD)/earth leakage circuit breaker (ELCB) for protection from electric shock in direct or indirect contact power lines or nodes, be sure to install type B of RCD/ELCB on the input (primary) of the inverter.

<table>
<tr><th rowspan="3">Power supply voltage</th><th rowspan="3">Nominal applied motor (kW)</th><th rowspan="3">Inverter type</th><th rowspan="3">HHD / HND</th><th colspan="2">MCCB *1</th><th colspan="4">RCD / ELCB *1</th></tr>
<tr><th colspan="2">Rated current</th><th colspan="2">Rated current</th><th rowspan="2">Sensitivity current *2</th><th rowspan="2">Maximum Fault Loop Impedance</th></tr>
<tr><th>w/ DCR</th><th>w/o DCR</th><th>w/ DCR</th><th>w/o DCR</th></tr>
<tr><td rowspan="29">Three-phase 200V</td><td>0.4</td><td>FRN0003G2S-2G</td><td>HHD</td><td rowspan="3">5</td><td>5</td><td rowspan="3">5</td><td>5</td><td>30mA</td><td>200Ω</td></tr>
<tr><td>0.75</td><td>FRN0005G2S-2G</td><td>HHD</td><td>10</td><td>10</td><td>30mA</td><td>200Ω</td></tr>
<tr><td>1.5</td><td>FRN0008G2S-2G</td><td>HHD</td><td>15</td><td>15</td><td>30mA</td><td>200Ω</td></tr>
<tr><td>2.2</td><td>FRN0011G2S-2G</td><td>HHD</td><td>10</td><td>20</td><td>10</td><td>20</td><td>30mA</td><td>200Ω</td></tr>
<tr><td>3.7</td><td>FRN0018G2S-2G</td><td>HHD</td><td>20</td><td>30</td><td>20</td><td>30</td><td>30mA</td><td>200Ω</td></tr>
<tr><td>5.5</td><td rowspan="2">FRN0032G2S-2G</td><td>HHD</td><td>30</td><td>50</td><td>30</td><td>50</td><td rowspan="2">30mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">7.5</td><td>HND</td><td rowspan="2">40</td><td rowspan="2">75</td><td rowspan="2">40</td><td rowspan="2">75</td></tr>
<tr><td rowspan="2">FRN0046G2S-2G</td><td>HHD</td><td rowspan="2">30mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">11</td><td>HND</td><td rowspan="2">50</td><td rowspan="2">100</td><td rowspan="2">50</td><td rowspan="2">100</td></tr>
<tr><td rowspan="2">FRN0059G2S-2G</td><td>HHD</td><td rowspan="2">30mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">15</td><td>HND</td><td rowspan="2">75</td><td rowspan="2">125</td><td rowspan="2">75</td><td rowspan="2">125</td></tr>
<tr><td rowspan="2">FRN0075G2S-2G</td><td>HHD</td><td rowspan="2">30mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">18.5</td><td>HND</td><td rowspan="4">100</td><td rowspan="2">150</td><td rowspan="4">100</td><td rowspan="2">150</td></tr>
<tr><td rowspan="2">FRN0088G2S-2G</td><td>HHD</td><td rowspan="2">30mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">22</td><td>HND</td><td rowspan="2">175</td><td rowspan="2">175</td></tr>
<tr><td rowspan="2">FRN0115G2S-2G</td><td>HHD</td><td rowspan="2">30mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">30</td><td>HND</td><td rowspan="2">150</td><td rowspan="2">200</td><td rowspan="2">150</td><td rowspan="2">200</td></tr>
<tr><td rowspan="2">FRN0146G2S-2G</td><td>HHD</td><td rowspan="2">100mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">37</td><td>HND</td><td rowspan="2">175</td><td rowspan="2">250</td><td rowspan="2">175</td><td rowspan="2">250</td></tr>
<tr><td rowspan="2">FRN0180G2S-2G</td><td>HHD</td><td rowspan="2">100mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">45</td><td>HND</td><td rowspan="2">200</td><td rowspan="2">300</td><td rowspan="2">200</td><td rowspan="2">300</td></tr>
<tr><td rowspan="2">FRN0215G2S-2G</td><td>HHD</td><td rowspan="2">100mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">55</td><td>HND</td><td rowspan="2">250</td><td rowspan="2">350</td><td rowspan="2">250</td><td rowspan="2">350</td></tr>
<tr><td rowspan="2">FRN0288G2S-2G</td><td>HHD</td><td rowspan="2">100mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">75</td><td>HND</td><td rowspan="2">350</td><td rowspan="5">–</td><td rowspan="2">350</td><td rowspan="5">–</td></tr>
<tr><td rowspan="2">FRN0346G2S-2G</td><td>HHD</td><td rowspan="2">100mA</td><td rowspan="2">200Ω</td></tr>
<tr><td rowspan="2">90</td><td>HND</td><td rowspan="2">400</td><td rowspan="2">400</td></tr>
<tr><td rowspan="2">FRN0432G2S-2G</td><td>HHD</td><td rowspan="2">100mA</td><td rowspan="2">200Ω</td></tr>
<tr><td>110</td><td>HND</td><td>500</td><td>500</td></tr>
</table>

Note:

*1 The frame size and model of the MCCB or RCD/ELCB (with overcurrent protection) will vary, depending on the power transformer capacity. Refer to the related technical documentation for details.

*2 Sensitivity current settings in the TT-system vary each country, so follow the instructions of the authorities.

(cont.)

Compliance with European Low Voltage Directive(cont.)

⚠WARNING⚠

Power supply voltage	Nominal applied motor (kW)	Inverter type	HHD / HND	MCCB*1 Rated current w/ DCR	MCCB*1 Rated current w/o DCR	RCD / ELCB*1 Rated current w/ DCR	RCD / ELCB*1 Rated current w/o DCR	RCD / ELCB*1 Sensitivity current *2	RCD / ELCB*1 Maximum Fault Loop Impedance
Three-phase 400V	0.4	FRN0002G2□-4G	HHD	5	5	5	5	30mA	20Ω
	0.75	FRN0003G2□-4G	HHD					30mA	20Ω
	1.5	FRN0004G2□-4G	HHD		10		10	30mA	20Ω
	2.2	FRN0006G2□-4G	HHD		15		15	30mA	20Ω
	3.7	FRN0009G2□-4G	HHD	10	20	10	20	30mA	20Ω
	5.5	FRN0018G2□-4G	HHD	15	30	15	30	30mA	20Ω
	7.5		HND	20	40	20	40		
		FRN0023G2□-4G	HHD					100mA	20Ω
	11		HND	30	50	30	50		
		FRN0031G2□-4G	HHD					100mA	20Ω
	15		HND	40	60	40	60		
		FRN0038G2□-4G	HHD					100mA	20Ω
	18.5		HND		75		75		
		FRN0045G2□-4G	HHD					100mA	20Ω
	22		HND	50	100	50	100		
		FRN0060G2□-4G	HHD					100mA	20Ω
	30		HND	75	125	75	125		
		FRN0075G2□-4G	HHD					100mA	20Ω
	37		HND	100		100			
		FRN0091G2□-4G	HHD					100mA	20Ω
	45		HND		150		150		
		FRN0112G2□-4G	HHD					100mA	20Ω
	55		HND	125	200	125	200		
		FRN0150G2□-4G	HHD					100mA	20Ω
	75		HND	175	–	175	–		
		FRN0180G2□-4G	HHD					100mA	20Ω
	90		HND	200		200			
		FRN0216G2□-4G	HHD					200mA	20Ω
	110		HND	250		250			
		FRN0260G2□-4G	HHD					200mA	20Ω
	132		HND	300		300			
		FRN0325G2□-4G	HHD					200mA	20Ω
	160		HND	350		350			
		FRN0377G2□-4G	HHD					200mA	20Ω
	200		HND	500		500			
		FRN0432G2□-4G	HHD					200mA	20Ω
	220		HND						
		FRN0520G2□-4G	HHD					500mA	20Ω
	280		HND	600		600			
		FRN0650G2□-4G	HHD					500mA	20Ω
	355		HND	800		800			
	315	FRN0740G2□-4G	HHD					500mA	20Ω
	400		HND	1200		1200			
	355	FRN0960G2□-4G	HHD	800		800		500mA	20Ω
	500		HND	1200		1200			
	400	FRN1040G2□-4G	HHD					500mA	20Ω
	560		HND						
	500	FRN1170G2□-4G	HHD					500mA	20Ω
	630		HND	1400		1400			
		FRN1386G2□-4G	HHD					500mA	20Ω
	710		HND	1600		1600			

Note: A box (□) in the above table replaces S (Basic type) or E (EMC filter built-in type) depending on the enclosure.

*1 The frame size and model of the MCCB or RCD/ELCB (with overcurrent protection) will vary, depending on the power transformer capacity. Refer to the related technical documentation for details.

*2 Sensitivity current settings in the TT-system vary each country, so follow the instructions of the authorities.

(cont.)

Compliance with European Low Voltage Directive (cont.)

⚠WARNING⚠

5. The inverter should be used in an environment that does not exceed Pollution Degree 2 requirements. If the environment has a Pollution Degree 3 or 4, install the inverter in an enclosure of IP54 or higher.
6. Install the inverter, AC or DC reactor, input or output filter in an enclosure with minimum degree of protection of IP2X (Top surface of enclosure shall be minimum IP4X when it can be easily accessed), to prevent human body from touching directly to live parts of these equipment.
7. Do not connect any copper wire directly to grounding terminals. Use crimp terminals with tin or equivalent plating to connect them.
8. When you use an inverter at an altitude of more than 2000 m, you should apply basic insulation for the control circuits of the inverter. The inverter cannot be used at altitudes of more than 3000 m.
9. Use the wires indicated in IEC60364-5-52.

Power supply voltage	Nominal applied motors	Inverter type	HHD / HND mode	Molded-case circuit-breaker (MCCB) or earth leakage circuit breaker (RCD/ELCB) *1 rated current		Recommended wire size (mm^2) Main terminal: Main power supply input [L1/R, L2/S, L3/T] *2 Grounding for inverter [⏚] *3		Inverter output [U, V, W] *2	DC reactor [P1, P(+)] *2	Braking resistor [P(+), DB] *2	Control circuit terminal	Aux.control power supply R0,T0
				With DC reactor	Without DC reactor	With DC reactor	Without DC reactor					
Three-phase 200 V	0.4	FRN0003G2S-2G	HHD	5	5	2.5	2.5	2.5	2.5	2.5	0.75	-
Three-phase 200 V	0.75	FRN0005G2S-2G	HHD	5	10	2.5	2.5	2.5	2.5	2.5	0.75	-
Three-phase 200 V	1.5	FRN0008G2S-2G	HHD	10	15	2.5	2.5	2.5	2.5	2.5	0.75	2.5
Three-phase 200 V	2.2	FRN0011G2S-2G	HHD	10	20	2.5	2.5	2.5	2.5	2.5	0.75	2.5
Three-phase 200 V	3.7	FRN0018G2S-2G	HHD	20	30	2.5	4	2.5	2.5	2.5	0.75	2.5
Three-phase 200 V	5.5	FRN0032G2S-2G	HHD	30	50	4	6	4	4	2.5	0.75	2.5
Three-phase 200 V	7.5	FRN0032G2S-2G	HND	40	75	6	10	6	6	2.5	0.75	2.5
Three-phase 200 V	7.5	FRN0046G2S-2G	HHD	40	75	6	10	10	6	2.5	0.75	2.5
Three-phase 200 V	11	FRN0046G2S-2G	HND	50	100	10	16	10	16	2.5	0.75	2.5
Three-phase 200 V	11	FRN0059G2S-2G	HHD	50	100	10	16	10	16	2.5	0.75	2.5
Three-phase 200 V	15	FRN0059G2S-2G	HND	75	125	16	25	16	25	2.5	0.75	2.5
Three-phase 200 V	15	FRN0075G2S-2G	HHD	75	125	16	25	16	25	2.5	0.75	2.5
Three-phase 200 V	18.5	FRN0075G2S-2G	HND	100	150	25	35	25	35	2.5	0.75	2.5
Three-phase 200 V	18.5	FRN0088G2S-2G	HHD	100	150	25	35	25	35	2.5	0.75	2.5
Three-phase 200 V	22	FRN0088G2S-2G	HND	100	175	35	50	35	35	2.5	0.75	2.5
Three-phase 200 V	22	FRN0115G2S -2G	HHD	100	175	35	50	35	35	2.5	0.75	2.5
Three-phase 200 V	30	FRN0115G2S -2G	HND	150	200	50	70	50	70	2.5	0.75	2.5
Three-phase 200 V	30	FRN0146G2S-2G	HHD	150	200	50	70	50	70	2.5	0.75	2.5
Three-phase 200 V	37	FRN0146G2S-2G	HND	175	250	70	95	70	95	2.5	0.75	2.5
Three-phase 200 V	37	FRN0180G2S-2G	HHD	175	250	70	95	70	95	4	0.75	2.5
Three-phase 200 V	45	FRN0180G2S-2G	HND	200	300	70	50 x 2	95	35×2	4	0.75	2.5
Three-phase 200 V	45	FRN0215G2S-2G	HHD	200	300	70	50 x 2	95	35×2	6	0.75	2.5
Three-phase 200 V	55	FRN0215G2S-2G	HND	250	350	35×2	70 x 2	35×2	50×2	6	0.75	2.5
Three-phase 200 V	55	FRN0288G2S-2G	HHD	250	350	35×2	70 x 2	35×2	50×2	10	0.75	2.5
Three-phase 200 V	75	FRN0288G2S-2G	HND	350	-	70×2	-	70×2	95 x 2	10	0.75	2.5
Three-phase 200 V	75	FRN0346G2S-2G	HHD	350	-	70×2	-	70×2	95 x 2	-	0.75	2.5
Three-phase 200 V	90	FRN0346G2S-2G	HND	400	-	70×2	-	95×2	120 x 2	-	0.75	2.5
Three-phase 200 V	90	FRN0432G2S-2G	HHD	400	-	70×2	-	95×2	120 x 2	-	0.75	2.5
Three-phase 200 V	110	FRN0432G2S-2G	HND	500	-	120×2	-	120×2	150 x 2	-	0.75	2.5

Note:

*1 The frame size and type of a MCCB or RCD/ELCB (with overcurrent protection) vary with the capacity of the power supply transformer. Refer to the related technical documents for detailed selection.

*2 The recommended wire sizes for the main circuit terminals are examples of using a PVC wire (for 70ºC, 600 V) at a surrounding temperature of 40ºC.

*3 Only one piece of wire with a recommended size can be connected to a ground terminal.

(cont.)

Compliance with European Low Voltage Directive (cont.)

⚠WARNING⚠

Power supply voltage	Nominal applied motors	Inverter type	HHD / HND mode	MCCB or RCD/ELCB *1 rated current: With DC reactor	MCCB or RCD/ELCB *1 rated current: Without DC reactor	Main circuit power inputs [L1/R, L2/S, L3/T] *2, Grounding for inverter [⏚] *3: With DC reactor	Main circuit power inputs [L1/R, L2/S, L3/T] *2, Grounding for inverter [⏚] *3: Without DC reactor	Inverter output [U, V, W] *2	DC reactor [P1, P(+)] *2	Braking resistor [P(+), DB] *2	Control circuit terminal	Aux.control power supply R0,T0
				Molded-case circuit-breaker (MCCB) or earth leakage circuit breaker (RCD/ELCB) *1 rated current		Recommended wire size (mm²) — Main terminal						
Three-phase 400 V	0.4	FRN0002G2□-4G	HHD	5	5	2.5	2.5	2.5	2.5	2.5	0.75	-
Three-phase 400 V	0.75	FRN0003G2□-4G	HHD	5	5	2.5	2.5	2.5	2.5	2.5	0.75	-
Three-phase 400 V	1.5	FRN0004G2□-4G	HHD	5	10	2.5	2.5	2.5	2.5	2.5	0.75	2.5
Three-phase 400 V	2.2	FRN0006G2□-4G	HHD	10	15	2.5	2.5	2.5	2.5	2.5	0.75	2.5
Three-phase 400 V	3.7	FRN0009G2□-4G	HHD	10	20	2.5	2.5	2.5	2.5	2.5	0.75	2.5
Three-phase 400 V	5.5	FRN0018G2□-4G	HHD	15	30	2.5	2.5	2.5	2.5	2.5	0.75	2.5
Three-phase 400 V	7.5	FRN0018G2□-4G	HND	20	40	2.5	4	2.5	2.5	2.5	0.75	2.5
Three-phase 400 V	7.5	FRN0023G2□-4G	HHD	20	40	2.5	4	2.5	2.5	2.5	0.75	2.5
Three-phase 400 V	11	FRN0023G2□-4G	HND	30	50	4	6	4	4	2.5	0.75	2.5
Three-phase 400 V	11	FRN0031G2□-4G	HHD	30	50	4	6	4	4	2.5	0.75	2.5
Three-phase 400 V	15	FRN0031G2□-4G	HND	40	60	6	10	6	6	2.5	0.75	2.5
Three-phase 400 V	15	FRN0038G2□-4G	HHD	40	60	6	10	6	6	2.5	0.75	2.5
Three-phase 400 V	18.5	FRN0038G2□-4G	HND	40	75	6	16	10	10	2.5	0.75	2.5
Three-phase 400 V	18.5	FRN0045G2□-4G	HHD	40	75	6	16	10	10	2.5	0.75	2.5
Three-phase 400 V	22	FRN0045G2□-4G	HND	50	100	10	16	10	16	2.5	0.75	2.5
Three-phase 400 V	22	FRN0060G2□-4G	HHD	50	100	10	16	10	16	2.5	0.75	2.5
Three-phase 400 V	30	FRN0060G2□-4G	HND	75	125	16	25	16	25	2.5	0.75	2.5
Three-phase 400 V	30	FRN0075G2□-4G	HHD	75	125	16	25	16	25	2.5	0.75	2.5
Three-phase 400 V	37	FRN0075G2□-4G	HND	100	125	25	35	25	25	2.5	0.75	2.5
Three-phase 400 V	37	FRN0091G2□-4G	HHD	100	125	25	35	25	25	2.5	0.75	2.5
Three-phase 400 V	45	FRN0091G2□-4G	HND	100	150	25	50	35	35	2.5	0.75	2.5
Three-phase 400 V	45	FRN0112G2□-4G	HHD	100	150	25	50	35	35	2.5	0.75	2.5
Three-phase 400 V	55	FRN0112G2□-4G	HND	125	200	35	70	50	50	2.5	0.75	2.5
Three-phase 400 V	55	FRN0150G2□-4G	HHD	125	200	35	70	50	50	2.5	0.75	2.5
Three-phase 400 V	75	FRN0150G2□-4G	HND	175	-	70	-	70	95	2.5	0.75	2.5
Three-phase 400 V	75	FRN0180G2□-4G	HHD	175	-	70	-	70	95	4	0.75	2.5
Three-phase 400 V	90	FRN0180G2□-4G	HND	200	-	70	-	95	95	4	0.75	2.5
Three-phase 400 V	90	FRN0216G2□-4G	HHD	200	-	70	-	95	95	-	0.75	2.5
Three-phase 400 V	110	FRN0216G2□-4G	HND	250	-	95	-	35×2	50×2	-	0.75	2.5
Three-phase 400 V	110	FRN0260G2□-4G	HHD	250	-	95	-	35×2	50×2	-	0.75	2.5
Three-phase 400 V	132	FRN0260G2□-4G	HND	300	-	50×2	-	50×2	70×2	-	0.75	2.5
Three-phase 400 V	132	FRN0325G2□-4G	HHD	300	-	50×2	-	50×2	185	-	0.75	2.5
Three-phase 400 V	160	FRN0325G2□-4G	HND	350	-	185	-	240	300	-	0.75	2.5
Three-phase 400 V	160	FRN0377G2□-4G	HHD	350	-	185	-	240	300	-	0.75	2.5
Three-phase 400 V	200	FRN0377G2□-4G	HND	500	-	300	-	300	120 x 2	-	0.75	2.5
Three-phase 400 V	200	FRN0432G2□-4G	HHD	500	-	300	-	300	120 x 2	-	0.75	2.5
Three-phase 400 V	220	FRN0432G2□-4G	HND	500	-	300	-	120×2	150 x 2	-	0.75	2.5
Three-phase 400 V	220	FRN0520G2□-4G	HHD	500	-	300	-	120×2	150 x 2	-	0.75	2.5
Three-phase 400 V	280	FRN0520G2□-4G	HND	600	-	150×2	-	150×2	240×2	-	0.75	2.5
Three-phase 400 V	280	FRN0650G2□-4G	HHD	600	-	150×2	-	150×2	240×2	-	0.75	2.5

Note: A box (□) in the above table replaces S (Basic type) or E (EMC filter built-in type) depending on the enclosure.

*1 The frame size and type of a MCCB or RCD/ELCB (with overcurrent protection) vary with the capacity of the power supply transformer. Refer to the related technical documents for detailed selection.

*2 The recommended wire sizes for the main circuit terminals are examples of using a PVC wire (for 70ºC, 600 V) at a surrounding temperature of 40ºC.

*3 Only one piece of wire with a recommended size can be connected to a ground terminal.

(cont.)

Compliance with European Low Voltage Directive (cont.)

⚠WARNING⚠

Power supply voltage	Nominal applied motors	Inverter type	HHD / HND mode	Molded case circuit breaker (MCCB) or Earth leakage breaker (RCD/ELCB) *1 Rated current		Recommended wire size (mm²)						
						Main terminal					Control circuit terminal	Aux.control power supply R0,T0
						Main circuit power inputs [L1/R, L2/S, L3/T] *2 Grounding for inverter[⏚]*3		Inverter outputs [U,V,W] *2	DC reactor connection [P1,P(+)] *2	Braking resistor [P(+),DB] *2		
				With DC reactor	Without DC reactor	With DC reactor	Without DC reactor					
Three-phase 400V	315	FRN0740G2□-4G	HHD	800	–	185×2	–	185×2	240×2	–	0.75	2.5
Three-phase 400V	355	FRN0650G2□-4G	HND	800	–	240×2	–	240×2	300×2	–	0.75	2.5
Three-phase 400V	355	FRN0960G2□-4G	HHD	800	–	240×2	–	240×2	300×2	–	0.75	2.5
Three-phase 400V	400	FRN0740G2□-4G	HND	1200	–	300×2	–	300×2	240×3	–	0.75	2.5
Three-phase 400V	400	FRN1040G2□-4G	HHD	1200	–	300×2	–	300×2	240×3	–	0.75	2.5
Three-phase 400V	500	FRN0960G2□-4G	HND	1200	–	240×3	–	300×3	240×4	–	0.75	2.5
Three-phase 400V	500	FRN1170G2□-4G	HHD	1200	–	240×3	–	300×3	240×4	–	0.75	2.5
Three-phase 400V	560	FRN1040G2□-4G	HND	1200	–	300×3	–	240×4	300×4	–	0.75	2.5
Three-phase 400V	630	FRN1170G2□-4G	HND	1400	–	300×4	–	300×4	300×5 (300×3) *4	–	0.75	2.5
Three-phase 400V	630	FRN1386G2□-4G	HHD	1400	–	300×4	–	300×4	300×5 (300×3) *4	–	0.75	2.5
Three-phase 400V	710	FRN1386G2□-4G	HND	1600	–	300×4	–	300×5 (300×3) *4	300×6 (300×4) *4	–	0.75	2.5

Note : A box (□) in the above table replaces S (Basic type) or E (EMC filter built-in type) depending on the enclosure.

*1 The frame size and type of a MCCB or RCD/ELCB (with overcurrent protection) vary with the capacity of the power supply transformer. Refer to the related technical documents for detailed selection.

*2 The recommended wire sizes for the main circuit terminals are examples of using a PVC wire (for 70ºC, 600 V) at a surrounding temperature of 40ºC.

*3 Only one piece of wire with a recommended size can be connected to a ground terminal.

*4 In case of using a XLPE wire (for 90ºC, 600 V) at a surrounding temperature of 40ºC.

10. An IEC61800-5-1 5.2.3.6.3 Short-circuit Current Test has been carried out on this inverter under the following conditions.

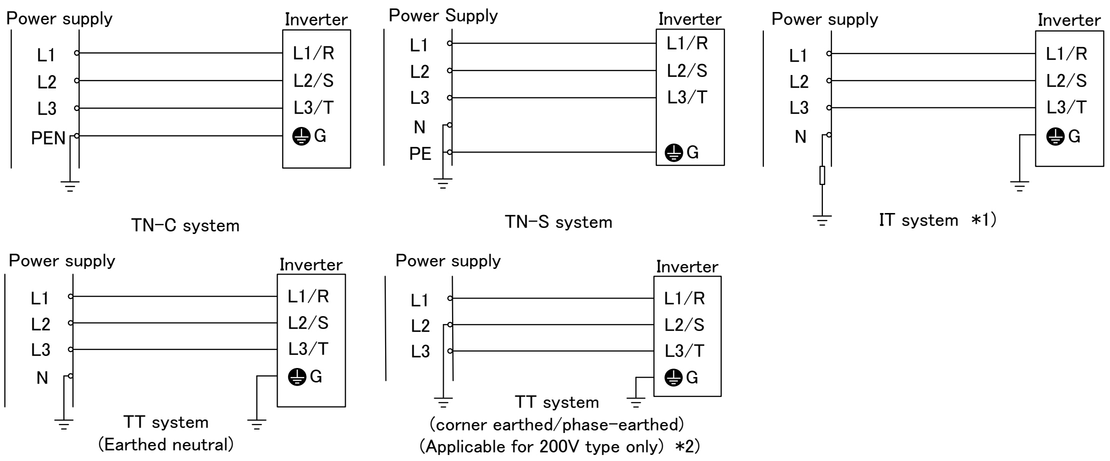
Current when shorted: 10,000 A

240 V or less (200V series, FRN0115G2S-2G or lower)

230 V or less (200V series, FRN0146G2S-2G or higher)

480 V or less (400V series)

11. Use this inverter at the following power supply system.



*1 Use this inverter at the following IT system.

Non-earthed (isolated from earth) IT system	Can be used. In this case the insulation between the control interface and the main circuit of the inverter is basic insulation. Thus do not connect SELV circuit from external controller directly (make connection using a supplementary insulation). Use an earth fault detector able to disconnect the power within 5s after the earth fault occurs.
IT system which earthed neutral by an impedance	
Corner earthed / Phase-earthed IT system by an impedance	Cannot be used.

*2 Cannot apply to Corner earthed / Phase-earthed TT system of 400V type

12. Solid state motor overload protection (motor protection by electronic thermal overload relay) is provided in each model. Use function codes F10 to F12 to set the protection level.

(Finished)

■ Compatibility with Revised EMC and Low Voltage Directive

In the revised EMC Directive (2014/30/EU) and Low Voltage Directive (2014/35/EU), it is necessary to clearly state the name and the address of manufacturers and importers to enhance traceability. Importers shall be indicated as follows when exporting products from Fuji Electric to Europe.

(Manufacturer)
Fuji Electric Co., Ltd.
5520, Minami Tamagaki-cho, Suzuka-city, Mie 513-8633, Japan

(Importer in Europe)
Fuji Electric Europe GmbH
Goethering 58, 63067 Offenbach / Main, Germany

<Precaution when exporting to Europe>

- Not all Fuji Electric products in Europe are necessarily imported by the above importer. If any Fuji Electric products are exported to Europe via another importer, please ensure that the importer is clearly stated by the customer.

G.2 Harmonic Component Regulations in EU

[1] General comments

When you use general-purpose industrial inverters in the EU, the harmonics emitted from the inverter to power lines are strictly regulated as stated below.

If an inverter whose rated input is 1 kW or less is connected to public low-voltage power supply, it is regulated by the harmonics emission regulations from inverters to power lines (with the exception of industrial low-voltage power lines). (Refer to Fig. G.2-1.)

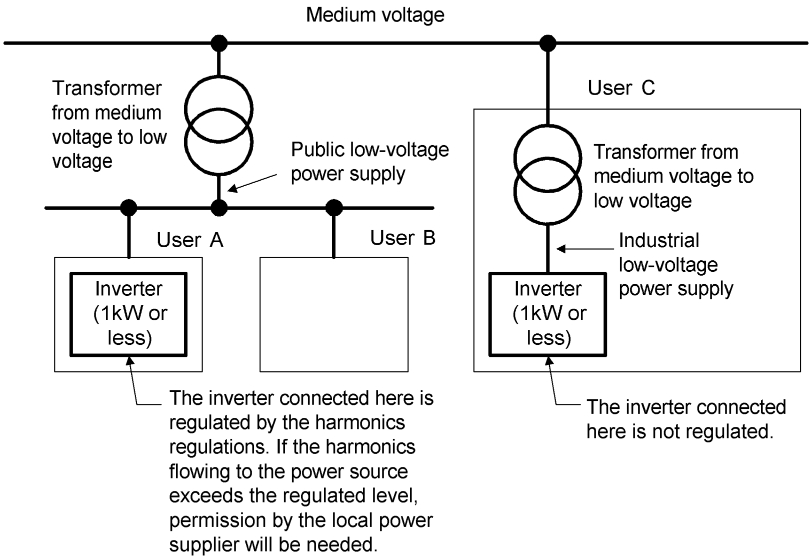


Fig. G.2-1 Power supply system

[2] Compliance with the harmonic component regulation

Table G.2-1 Compliance with harmonic component regulations

Power supply voltage	Inverter type *1	w/o DCR	w/ DCR	Applicable DC reactor type
Three-phase 200 V	FRN0003G2S-2G	Y *2	Y *2	DCR2-0.4
	FRN0005G2S-2G	Y *2	Y *2	DCR2-0.75
Three-phase 400 V	FRN0002G2□-4G	N	Y	DCR4-0.4
	FRN0003G2□-4G	N	Y	DCR4-0.75

Y: Meets EN61000-3-2 (+A14) standard, and therefore the product may be connected to a commercial voltage power supply.

N: Does not meet EN61000-3-2 (+A14) standard. If connecting the product to a commercial low voltage power supply, it will be necessary to obtain the permission of the local power company. When harmonic current data is necessary, consult your Fuji Electric representative.

*1: The □ in the inverter type is replaced by a letter of the alphabet indicating the type.

*2: Evaluated by the level of harmonics flow to the 400 VAC line when three-phase 200 VAC power is supplied from the three-phase 400 VAC power via a step-down transformer.

G.3 Compliance with UL Standards and Canadian Standards (cUL certification)

[1] General comments

UL Standards (Underwriters Laboratories Inc. standards) are North American safety standards used to prevent fire and other such accidents, and offer protection to users, service technicians, and the general public.

cUL indicates that products which comply with CSA standards are certified by UL. cUL certified products are as effective as those certified as complying with CSA standards.

[2] UL Standards and Canadian Standards (cUL Certification) Compatibility

Compatibility with UL Standards and Canadian Standards (cUL certification) is ensured by installing inverters with UL/cUL marking in accordance with the following. (Products with no standards indicated do not comply with European Standards.)

UL Standards and Canadian Standards (cUL Certification) Compatibility

⚠WARNING⚠

High available fault current – damage warning:
The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. To reduce the risk of fire or electric shock, current-carrying parts and other components of the controller should be examined and replaced if damaged. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced.

⚠CAUTION

1. Solid state motor overload protection (motor protection by electronic thermal overload relay) is provided in each model.
   Use function codes F10 to F12 to set the protection level. Refer to the description below.

2. Use Cu wire only.
   Use copper wire for wiring.

3. Use Class 1 wire only for control circuits.
   Use Class 1 wire for control circuits.

4. Short circuit rating
   "Suitable For Use On A Circuit Of Delivering Not More Than 100,000 rms Symmetrical Amperes, 240 Volts Maximum for 200 V class input when protected by Semiconductor Protection Fuses having an interrupting rating not less than 100,000 rms Symmetrical Amperes, 240 Volts Maximum." Models FRN; rated for 200V class input.
   "Suitable For Use On A Circuit Of Delivering Not More Than 100,000 rms Symmetrical Amperes, 480 Volts Maximum when protected by Semiconductor Protection Fuses having an interrupting rating not less than 100,000 rms Symmetrical Amperes, 480 Volts Maximum." Models FRN; rated for 400V class input.
   "Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes."

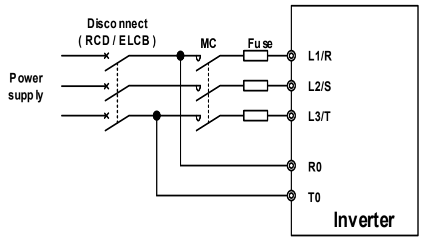
5. Field wiring connections must be made by a UL Listed and CSA Certified closed-loop terminal connector sized for the wire gauge involved. Connector must be fixed using the crimp tool specified by the connector manufacturer.
   When wiring terminals, refer to the recommended wire sizes, and use UL/CSA certified round crimp terminals. Crimp terminals should be crimped using the crimping tool recommended by the manufacturer.

(cont.)

UL Standards and Canadian Standards (cUL Certification) Compatibility (cont.)

⚠CAUTION

6.All circuits with terminals L1/R, L2/S, L3/T, R0, T0 must have a common disconnect and be connected to the same pole of the disconnect if the terminals are connected to the power supply.



7.Environmental requirements

・ Surrounding/ambient temperature

Maximum surrounding air temperature 50 °C

・ Atmosphere

For use in pollution degree 2 environments. (for Open-Type models)

(cont.)

UL Standards and Canadian Standards (cUL Certification) Compatibility (cont.)

⚠CAUTION

8. Install UL certified fuses between the power supply and the inverter, referring to the table below.

Power supply voltage	Nominal applied motor	Inverter type	HHD/HND mode	Semiconductor Protection Fuse Cat No. Manufacturer: Mersen/Bussmann (Eaton)	Required torque lb-in (N・m)		Wire size AWG (mm^2)						
					Main terminal	Aux. control power supply	Main terminal Cu Wire						Aux. control power supply
							L1/R, L2/S, L3/T			U, V, W			
							60°C wire	75 °C wire	Remarks	60°C wire	75 °C wire	Remarks	
Three-phase 200V	0.4	FRN0003G2S-2G	HHD	PC30UD69V50□ /170M3458	10.6 (1.2)	–	14 (2.1)	14 (2.1)	*1	14 (2.1)	14 (2.1)	*1	—
	0.75	FRN0005G2S-2G		PC30UD69V50□ /170M3460									
	1.5	FRN0008G2S-2G		PC30UD69V80□ /170M3462	15.9 (1.8)	10.6 (1.2)							14 (2.1) *1 *2
	2.2	FRN0011G2S-2G		PC30UD69V125□ /170M3462									
	3.7	FRN0018G2S-2G		PC30UD69V125□ /170M3463			10 (5.3)	10 (5.3)		12 (3.3)	12 (3.3)		
	5.5	FRN0032G2S-2G	HHD	PC30UD69V160□ /170M3464	30.9 (3.5)		–	8 (8.4)	*1 *2 *3	–	8 (8.4)	*1 *2 *3	
	7.5		HND										
		FRN0046G2S-2G	HHD	PC30UD69V200□ /170M3465									
	11		HND					6 (13.3)	*2 *3				
		FRN0059G2S-2G	HHD	PC30UD69V200□ /170M3465									
	15		HND					4 (21.2)	–		6 (13.3)	*2 *3	
		FRN0075G2S-2G	HHD	PC30UD69V250□ /170M3466	51.3 (5.8)		3 (26.7)			4 (21.2)			
	18.5		HND				1 (42.4)	3 (26.7)		3 (26.7)	4 (21.2)	–	
		FRN0088G2S-2G	HHD	PC30UD69V250□ /170M3466									
	22		HND				–	2 (33.6)	*2 *3	2 (33.6)	3 (26.7)		
		FRN0115G2S-2G	HHD	PC30UD69V315□ /170M3467						–			
	30		HND					2/0 (67.4)			2 (33.6)	*2 *3	
		FRN0146G2S-2G	HHD	PC30UD69V450□ /170M3469	119.4 (13.5)						1 (42.4)		
	37		HND					3/0 (85)			1/0 (53.5)		
		FRN0180G2S-2G	HHD	PC30UD69V500□ /170M3470	238.9 (27)								
	45		HND					4/0 (107.2)			3/0 (85)		
		FRN0215G2S-2G	HHD	PC30UD69V550□ /170M3472									
	55		HND					2/0×2 (67.4×2)			4/0 (107.2)		
		FRN0288G2S-2G	HHD	PC30UD69V550□ /170M3473									
	75		HND					3/0×2 (85×2)			3/0×2 (85×2)		
		FRN0346G2S-2G	HHD	PC30UD69V550□ /170M3473	424.7 (48)								
	90		HND					4/0×2 (107.2×2)			4/0×2 (107.2×2)		
		FRN0432G2S-2G	HHD	PC31UD69V700□ /170M4467									
	110		HND					300×2 (152×2)			300×2 (152×2)		

Note: Control circuit terminal tightening torque: 6.1 lb-in (0.7 N·m), recommended wire size: AWG18 (0.8 mm^2)

*1 No terminal end treatment is required for connection.

*2 Use 75 °C (167 °F) Cu wire only.
Use copper wire with maximum permissible temperature of 75 °C.

*3 The wire size of UL Open Type and Enclosed Type are common. Please contact us if UL Open Type exclusive wire is necessary.

(cont.)

UL Standards and Canadian Standards (cUL Certification) Compatibility (cont.)

⚠CAUTION

Power supply voltage	Nominal applied motor	Inverter type	HHD/HND mode	Semiconductor Protection Fuse Cat No. Manufacturer: Mersen/Bussmann (Eaton)	Required torque lb-in (N・m)		Wire size AWG (mm²)						
					Main terminal	Aux. control power supply	Main terminal Cu Wire						Aux. control power supply
							L1/R, L2/S, L3/T			U, V, W			
							60°C wire	75 °C wire	Remarks	60°C wire	75 °C wire	Remarks	
Three-phase 400 V	0.4	FRN0002G2□-4G	HHD	PC30UD69V50□ /170M3458	10.6 (1.2)	–	14 (2.1)	14 (2.1)	*1	14 (2.1)	14 (2.1)	*1	–
	0.75	FRN0003G2□-4G											14 (2.1) *1 *2
	1.5	FRN0004G2□-4G		PC30UD69V50□ /170M3459	15.9 (1.8)	10.6 (1.2)							
	2.2	FRN0006G2□-4G		PC30UD69V63□ /170M3460									
	3.7	FRN0009G2□-4G		PC30UD69V63□ /170M3461									
	5.5	FRN0018G2□-4G	HHD	PC30UD69V100□ /170M3462	30.9 (3.5)		–	12 (3.3)	*1 *2 *3	–	12 (3.3)	*1 *2 *3	
	7.5		HND					10 (5.3)					
		FRN0023G2□-4G	HHD	PC30UD69V100□ /170M3462									
	11		HND					8 (8.4)			10 (5.3)		
		FRN0031G2□-4G	HHD	PC30UD69V125□ /170M3463									
	15		HND								8 (8.4)		
		FRN0038G2□-4G	HHD	PC30UD69V160□ /170M3464	51.3 (5.8)		6 (13.3)	6 (13.3)	*3	6 (13.3)	6 (13.3)	*3	
	18.5		HND										
		FRN0045G2□-4G	HHD	PC30UD69V160□ /170M3464									
	22		HND				4 (21.2)						
		FRN0060G2□-4G	HHD	PC30UD69V200□ /170M3465									
	30		HND				3 (26.7)	4 (21.2)		4 (21.2)			
		FRN0075G2□-4G	HHD	PC30UD69V315□ /170M3467	119.4 (13.5)								
	37		HND				2 (33.6)	3 (26.7)		3 (26.7)	4 (21.2)		
		FRN0091G2□-4G	HHD	PC30UD69V315□ /170M3468									
	45		HND				–	2 (33.6)	*2 *3	2 (33.6)	3 (26.7)		
		FRN0112G2□-4G	HHD	PC30UD69V350□ /170M3469									
	55		HND					1/0 (53.5)		–	2 (33.6)	*2 *3	
		FRN0150G2□-4G	HHD	PC30UD69V400□ /170M3469									
	75		HND								1/0 (53.5)		
		FRN0180G2□-4G	HHD	PC30UD69V350□ /170M3469	238.9 (27)								
	90		HND					2/0 (67.4)			3/0 (85)		
		FRN0216G2□-4G	HHD	PC30UD69V350□ /170M3469									
	110		HND					4/0 (107.2)			1/0×2 (53.5×2)		
		FRN0260G2□-4G	HHD	PC30UD69V400□ /170M3470									
	132		HND					1/0×2 (53.5×2)			2/0×2 (67.4×2)		
		FRN0325G2□-4G	HHD	PC30UD69V500□ /170M3472	424.7 (48)								
	160		HND					3/0×2 (85×2)			4/0×2 (107.2×2)		
		FRN0377G2□-4G	HHD	PC30UD69V550□ /170M3473									
	200		HND					4/0×2 (107.2×2)			250×2 (127×2)		
		FRN0432G2□-4G	HHD	PC31UD69V700□ /170M4467									
	220		HND					250×2 (127×2)			300×2 (152×2)		
		FRN0520G2□-4G	HHD	PC31UD69V800□ /170M4468									

Note 1) Control circuit terminal tightening torque: 6.1 lb-in (0.7 N·m), recommended wire size: AWG18 (0.8 mm^2)

Note 2) The □ in the inverter type is replaced by a letter of the alphabet indicating the type.

*1 No terminal end treatment is required for connection.

*2 Use 75 °C (167 °F) Cu wire only.
Use copper wire with maximum permissible temperature of 75 °C.

*3 The wire size of UL Open Type and Enclosed Type are common. Please contact us if UL Open Type exclusive wire is necessary.

(cont.)

UL Standards and Canadian Standards (cUL Certification) Compatibility (cont.)

⚠CAUTION

Power supply voltage	Nominal applied motor	Inverter type	HHD/HND mode	Semiconductor Protection Fuse Cat No. Manufacturer: Mersen/Bussmann (Eaton)	Required torque lb-in (N・m): Main terminal	Required torque lb-in (N・m): Aux. control power supply	Wire size AWG (mm²), Main terminal Cu Wire, L1/R, L2/S, L3/T: 60°C wire	L1/R, L2/S, L3/T: 75 °C wire	L1/R, L2/S, L3/T: Remarks	U, V, W: 60°C wire	U, V, W: 75 °C wire	U, V, W: Remarks	Wire size: Aux. control power supply
Three-phase 400 V	280	FRN0520G2□-4G	HND	PC31UD69V800□ /170M4468	424.7 (48)	10.6 (1.2)	–	400×2 (203×2)	*2 *3	–	400×2 (203×2)	*2 *3	14 (2.1) *1 *2
		FRN0650G2□-4G	HHD	PC32UD69V1000□ /170M5466				250×2 (127×2)	*2 *4		300×2 (152×2)	*2 *4	
	315	FRN0740G2□-4G	HHD	PC32UD69V1100□ /170M5467				300×2 (152×2)			350×2 (177×2)		
	355	FRN0650G2□-4G	HND	PC32UD69V1000□ /170M5466				400×2 (203×2)			400×2 (203×2)		
		FRN0960G2□-4G	HHD	PC33UD69V1250□ /170M5468									
	400	FRN0740G2□-4G	HND	PC32UD60V1100□ /170M5467				500×2 (253×2)			500×2 (253×2)		
		FRN1040G2□-4G	HHD	PC33UD60V1500□ /170M5468									
	500	FRN0960G2□-4G	HND	PC33UD69V1250□ /–				350×3 (177×3)			400×3 (203×3)		
		FRN1170G2□-4G	HHD	PC33UD55V2000□ /170M6469									
	560	FRN1040G2□-4G	HND	PC33UD60V1500□ /–				400×3 (203×3)			500×3 (253×3)		
	630	FRN1170G2□-4G	HND	PC33UD55V2000□ /–				500×3 (253×3)			600×3 (304×3)		
		FRN1386G2□-4G	HHD										
	710		HND					600×3 (304×3)			500×4 (253×4)		

Note 1) Control circuit terminal tightening torque: 6.1 lb-in (0.7 N·m), recommended wire size: AWG18 (0.8 mm²)
Note 2) The □ in the inverter type is replaced by a letter of the alphabet indicating the type.

*1 No terminal end treatment is required for connection.

*2 Use 75 °C (167 °F) Cu wire only.
Use copper wire with maximum permissible temperature of 75 °C.

*3 The wire size of UL Open Type and Enclosed Type are common. Please contact us if UL Open Type exclusive wire is necessary.

*4 It is showing the wire size for UL Open Type.
See additional material INR-SI47-1365 for UL Enclosed Type (Pack with TYPE1 kit).

(Finished)

G.4 Compliance with Functional Safety Standards

[1] General

With FRENIC-MEGA Series, the motor coasts to a stop by turning off (opening) the connection between terminals [EN1]-[PLC] or [EN2]-[PLC]. This is a safe shutdown function of Cat. 0 (uncontrolled stop) specified in EN 60204-1 and complies with the functional safety standards.

When constructing a safety system, a safety shut-off device was required outside the inverter, but using safe torque-off (STO) eliminates the need for an external safety shut-off device.

Table G.4-1 Functional safety performance

EN ISO 13849-1		
	Category	3
	Performance Level	e
	Average Diagnostic Coverage	Medium (DCavg)
	Response time	50 ms or less (Response time)
	Mean dangerous failure time for each channel	>62 years (MTTFd)
EN 61508-1 to -7 EN 61800-5-2		
	Safety function	Safe Torque Off (STO)
	Safety integrity level	SIL3
	Hardware Fault Tolerance	1 (HFT)
	Safe failure fraction	90 % or more (SFF)
	Average probability of failure of a hazardous function upon request for actuation	1.58E-05 (PFDavg)
	Mean frequency of hazardous failures [h^{-1}]	2.60E-09 (PFH)

⚠WARNING⚠

- Although the specified STO is used for EN 61800-5-2 for the output breaker-off function of this inverter, it does not completely shut off the power supply and the motor electrically. Therefore, depending on the application of the inverter, for the safety of the final user, for example, a mechanically locking brake and motor terminal protection to prevent electric shock are required.
- The output breaker-off function of this inverter does not completely shut off the power supply and the motor electrically. Therefore, turn off the power supply of the inverter securely and wait at least 5 minutes (FRN0115G2S-2G/FRN0060G2□-4G or less)/10 minutes (FRN0146G2S-2G/FRN0075G2□-4G or more) before wiring or maintenance work.
- For the synchronous motor (synchronous motor), voltage is generated at the terminal during coasting with the output shut-off function. Make sure that the synchronous motor is stopped securely before performing maintenance, inspection, and wiring.

Caution, risk of electric shock

Pin [EN1][EN2] and Peripheral Circuit and Internal Circuit Configuration

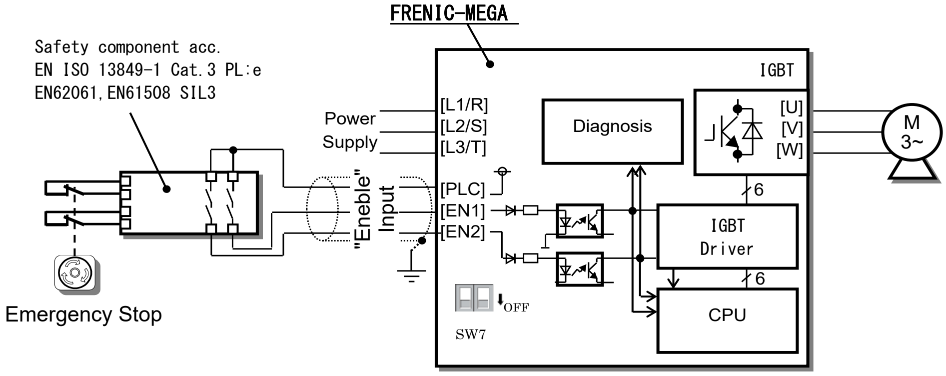


Fig. G.4-1 FRENIC-MEGA

Note: When the terminal [EN1] and [EN2] are used as functional safety, turn off both SW7 on the control PCB.

Table G.4-2 State of terminals [EN1][EN2]-[PLC] and inverters

Digital input signal		ECF alarm *	Inverter status	Remarks
[EN1]	[EN2]			
ON (short circuit)	ON (short circuit)	None	Completion of operation preparation	
		Yes	Output shutdown (STO)	Logical mismatch detecttion *
OFF (open circuit)	OFF (open circuit)	None	Output shutdown (STO)	
		Yes	Output shutdown (STO)	Logical mismatch detection *
ON (short circuit)	OFF (open circuit)	Yes	Output shutdown (STO)	Logical mismatch detection *
OFF (open circuit)	ON (short circuit)	Yes	Output shutdown (STO)	Logical mismatch detection *

*See G.4.[4]

[2] Notes for compliance with functional safety standards

1) Safety Requirements

All of the following requirements must be met in order to comply with functional safety.

1-1) Installation

- Turn off both SW7 on the control PCB.
- Install the inverter in a cabinet with a protective enclosure IP54 or higher.
- Also comply with the European standard EN 61800-5-1 and EN 61800-3 as inverters or mechanical equipment.
- To ensure redundancy, wire the terminals [EN1] and [EN2] independently.
- For ON/OFF of terminals [EN1] and [EN2], use a safety component with EN ISO 13849-1 Cat.3 PL：e or higher.
- When using an external power supply, use a SELV power supply.

1-2) STO test

- Check that STO operates properly once every three months.

2) Notes for using STO

- When constructing a product safety system in STO, the machinery manufacturer is responsible for the product safety system required by the machinery manufacturer to conduct a risk assessment of the entire machinery equipment, including other equipment, devices, and wires, as well as the external equipment and wires connected to the terminals [EN1][EN2], to ensure that the entire machinery equipment conforms to that product safety system. Also, for preventive maintenance, be sure to perform periodic inspections to confirm that the product safety system operates properly.
- Input short pulses to terminal [EN1] and [EN2] for less than 1 ms when performing a diagnosis with the safety PLC.

  If a single fault is detected in the inverter, an alarm is output to the external device and the inverter coasts the motor even if the terminal [EN1] and [EN2] are ON. (The alarm outputting function is not guaranteed to be outputted with all single faults, but can be adapted to EN ISO 13849-1 Cat.3 PL:e.)
- The logical discrepancy due to the signal delay between the terminals [EN1] and [EN2] should be 50ms or less. Outputs an ECF alarm when it exceeds 50 ms.

3) Wiring for terminal [EN1], [EN2]

- The terminal [EN1] and [EN2] are used to wire the safety circuitry. Since the reliability is obtained by connecting each signal independently, be careful not to short-circuit the signal in the middle of wiring.

[3] Inverter output status when STO is activated

When the terminal [EN1] and [EN2] are turned OFF, the inverter enters the STO state.

Fig. G.4-2 shows the inverter output status when terminal [EN1] and [EN2] are turned OFF while the inverter is stopped.

The inverter ready status will be complete when the terminal [EN1] and [EN2] inputs turn ON.

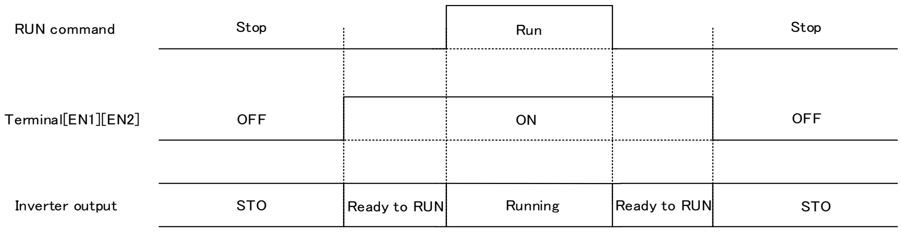


Fig. G.4-2 Inverter output status when terminal [EN1], [EN2] is turned OFF while the inverter is stopped

Fig. G.4-3 shows the timing chart when terminal [EN1] and [EN2] are turned OFF while the inverter is running. Input to terminal [EN1] and [EN2] turns OFF, the inverter enters the STO condition, and the motor coasts to a stop.

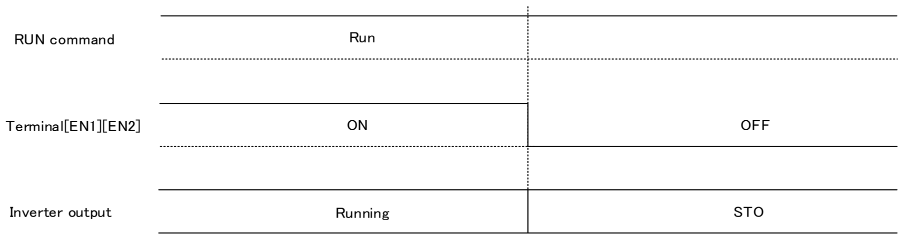


Fig. G.4-3 Inverter output status when terminal [EN1], [EN2] is turned OFF during inverter operation

[4] ECF alarm and inverter-output status

FRENIC-MEGA monitors the logical discrepancy of the signal input to the terminal [EN1] and [EN2], and continuously diagnoses the failure of the safety circuit.

Fig. G.4-4 shows the timing chart for the ECF alarm following a terminal [EN1] or [EN2] input mismatch. A STO condition occurs at the inverter when terminal [EN1] and [EN2] are turned OFF. If the terminal [EN1] and [EN2] input mismatch lasts longer than 50 ms, the inverter will interpret that there is an abnormality with the safely system and output an ECF alarm.

To operate the EN terminal circuit correctly by operating the terminal [EN1] and [EN2], hold ON/OFF of [EN1] and [EN2] for 2 s or more. If it is not held for more than 2 s, an ECF alarm may occur.

In the event of an ECF alarm, it will be necessary the power supply shut off or the alarm reset to cancel the safety status.

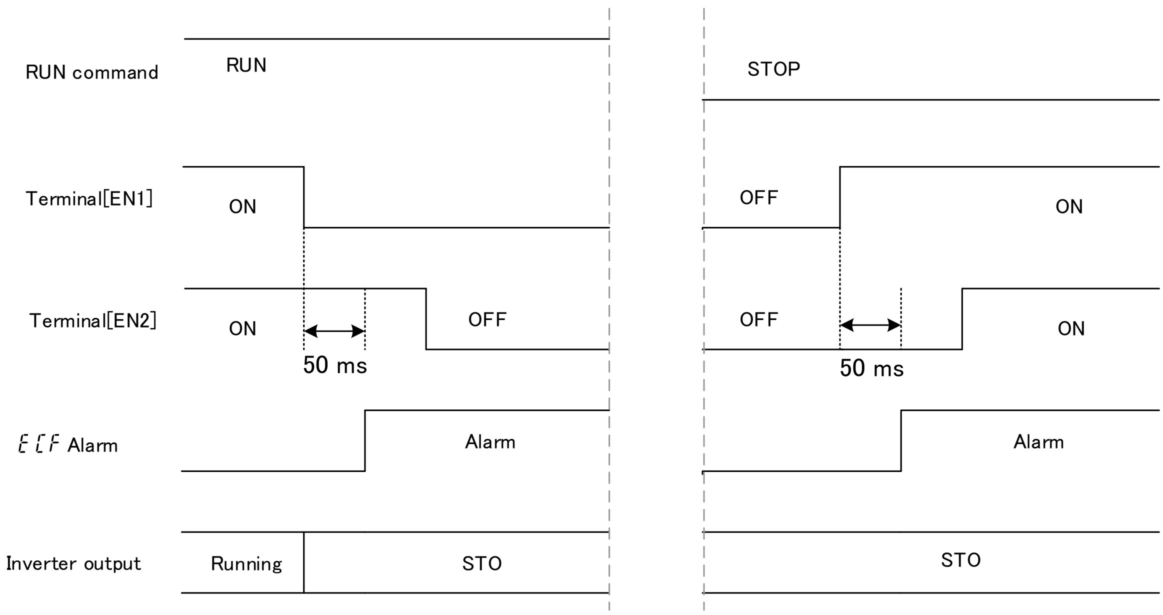


Fig. G. 4-4 ECF alarm (logical mismatch) and inverter-output status

[5] Precautions for releasing STO

If the terminal [EN1] and [EN2] are turned OFF during inverter operation, the inverter forcibly coasts to a stop.

After that, if [EN1] and [EN2] are turned ON with the operation command being input, the inverter restarts the output. Be careful when resetting the safety components. (Fig. G.4-5)

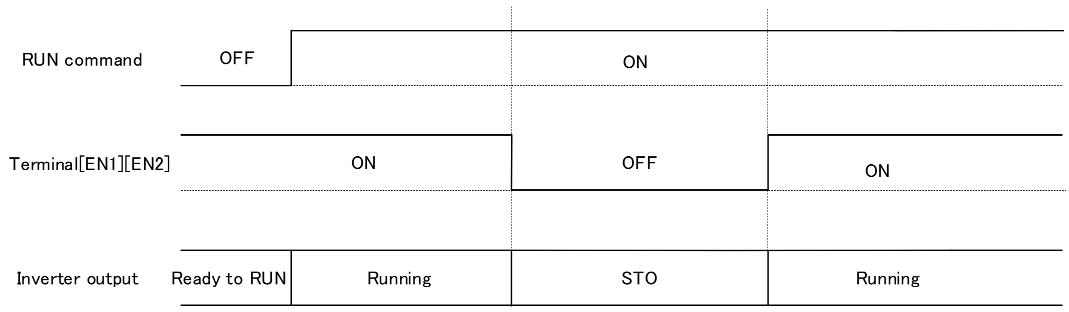


Figure G.4-5 When STO is released

Appendix H Inverter Replacement Precautions (When Using PWM Converter (RHC series))

If using the RHC series and replacing the following inverters, it is necessary to change the connection method for the inverter control power auxiliary input terminals (R0, T0). The replaced inverter may not function normally if the connection method is not changed. Be sure to change the connection method.

H.1 Applicable inverters

Table H.1-1

Applicable inverter (before change)	Replacement inverter (after change)
<FRENIC5000G11S series> · FRN30G11S-2, FRN30P11S-2 inverter or higher · FRN30G11S-4, FRN30P11S-4 inverter or higher <FRENIC-VG7S series> · FRN18.5VG7S-2, FRN18.5VG7S-4 inverter or higher <FRENIC-MEGA series> · FRN G1	FRENIC-MEGA series (FRENIC-VG series) (FRENIC-Eco series) (FRENIC-Ace series) (FRENIC-Lift series)

H.2 Changing the connection method (inverter control power auxiliary input terminals (R0, T0))

(1) RHC series: if using ■ RHC7.5-2C to RHC90-2C, ■ RHC7.5-4C to RHC220-4C

Applicable inverter (before change) connection diagram

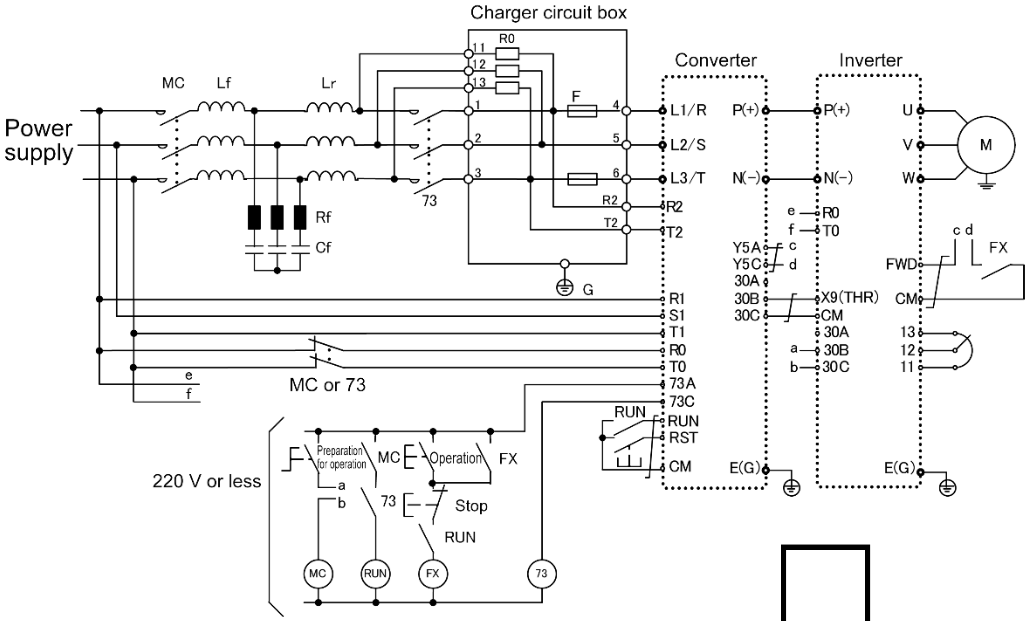


Fig. H.2-1

Replacement inverter (after change) connection diagram

Change the [dashed box] section.

1) Inverter control power auxiliary input terminals (R0, T0)
   Be sure to connect to the main power supply via contact b on the power supply circuit electromagnetic contactor (73 or MC).
2) Fan power auxiliary input terminals (R1, T1) * Only on models equipped with R1, T1 terminals
   Be sure to connect to the main power supply without going via contact b on the power supply circuit electromagnetic contactor (73 or MC).

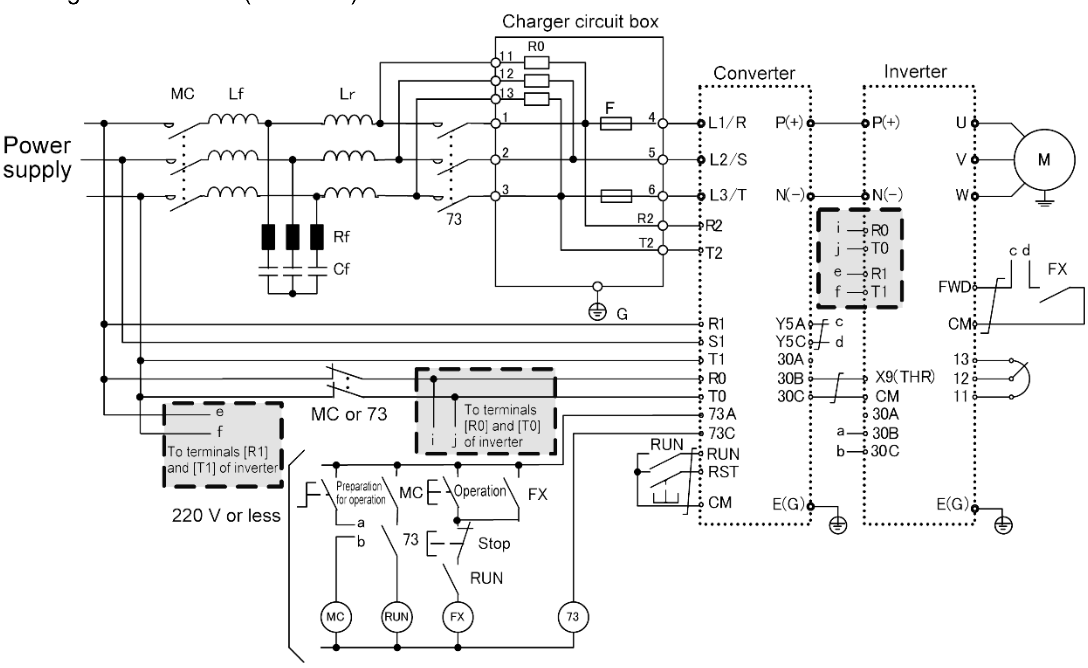


Fig. H.2-2

(2) RHC series: If using when ■ RHC280-4C to RHC630-4C, ■ RHC400-4C VT specification applied
If using ■RHC500B to RHC800B-4C

Applicable inverter (before change) connection diagram

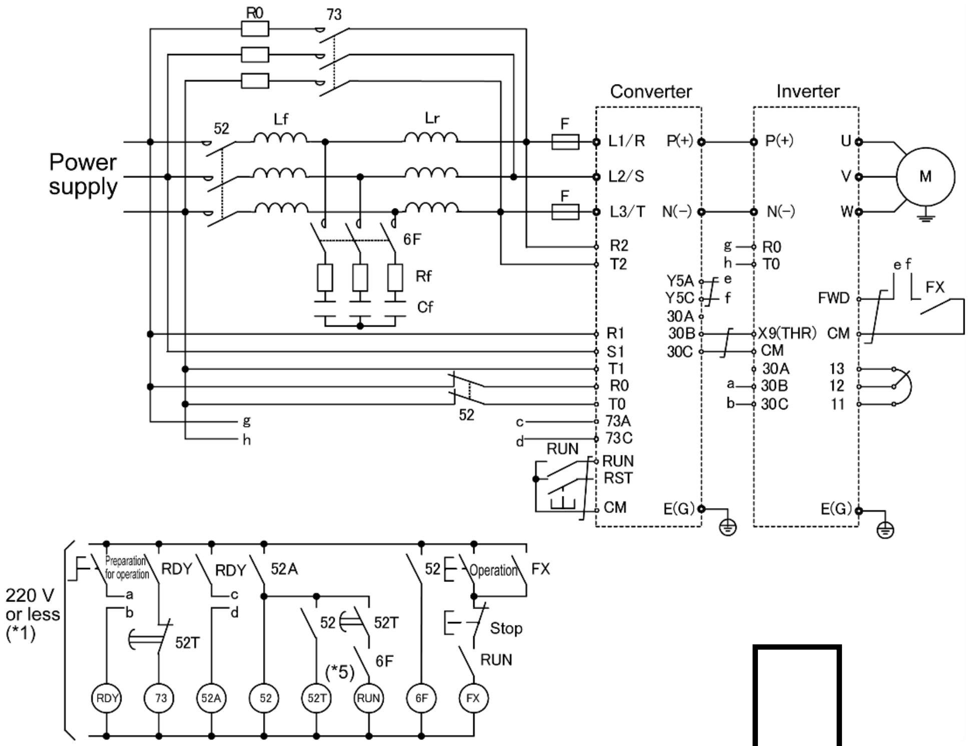


Fig. H.2-3

Replacement inverter (after change) connection diagram

Change the [dashed box] section.

1) Inverter control power auxiliary input terminals (R0, T0)
Be sure to connect to the main power supply via contact b on the power supply circuit electromagnetic contactor (52).

2) Fan power auxiliary input terminals (R1, T1) * Only on models equipped with R1, T1 terminals
Be sure to connect to the main power supply without going via contact b on the power supply circuit electromagnetic contactor (73 or 52).

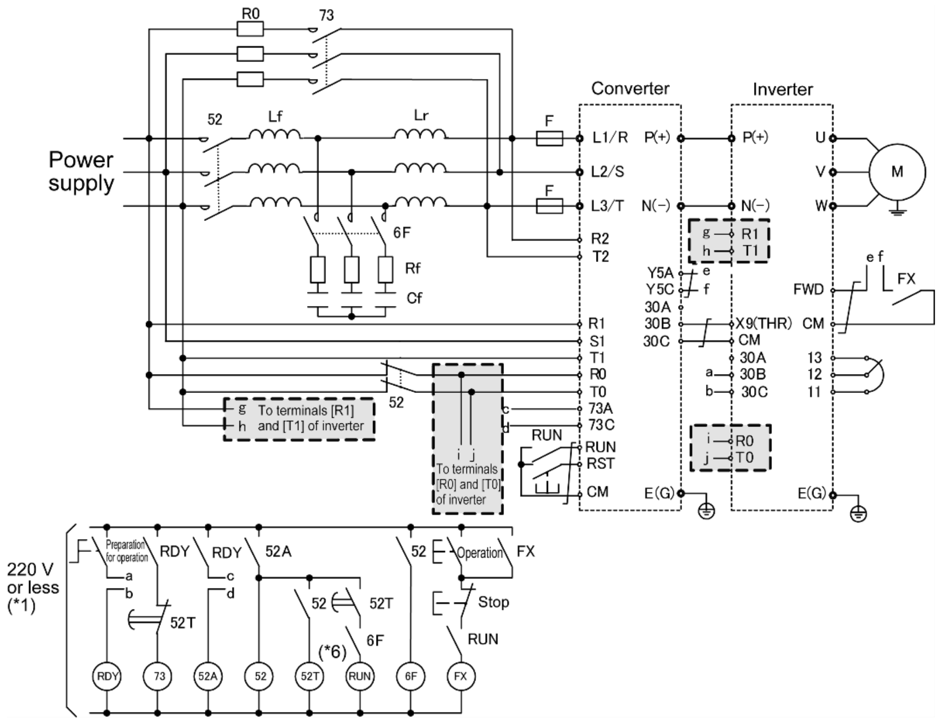


Fig. H.2-4

APPENDICES