

mitsubishi

Changes for the Better

FATEC

INVERTER SCHOOL TEXT
INVERTER PRACTICAL COURSE

● SAFETY PRECAUTIONS ●

(Always read these instructions before the exercise.)

When designing a system, always read the relevant manuals and give sufficient consideration to safety. During the exercise, pay full attention to the following points and handle the equipments correctly.

[Precautions for Demonstration]

WARNING

- Do not touch the terminals while the power is on, to prevent an electric shock.
- When opening the safety cover, turn the power off or conduct a sufficient check of safety before operation.
- Do not put your hand in the movable part.

CAUTION

- Follow the instructor's directions during the exercise.
- Do not remove the units of a demonstration machine or change the wiring without permission. Doing so may cause a failure, malfunction, injury and/or fire.
- Turn the power off before installing or removing a unit.
Failure to do so may result in a malfunction of the unit or an electric shock.
- When the demonstration machine (X/Y table, etc.) emits an abnormal odor or noise, stop it by pressing the "power supply switch" or "emergency switch".
- When an error occurs, notify the instructor immediately.

Memo

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1. MOTOR CHARACTERISTICS AT INVERTER DRIVE

This chapter describes the basic characteristics to be focused on for performing the capacity selection or the operation when the squirrel-cage three-phase induction motor is driven by the inverter.

The motor characteristics differ between the commercial power supply operation and the inverter operation. This is important for the user to understand.

POINTS for understanding!

1. Relationship between motor speed, current and torque
2. V/f (Voltage/frequency ratio) pattern and motor basic characteristics
3. Difference of motor characteristics between inverter operation and commercial power supply operation
Torque, current, temperature, etc.
4. Concept of torque boost

1.1 Type of Motor

Although there are many methods to classify motors, the motors can be mainly classified into the following types when distinguished by the principle and structure. Within these motor types, the motor driven by the inverter is a mainly three-phase squirrel-cage motor.

In addition, there is an energy-saving drive high-efficiency magnetic motor (IPM) for further energy saving.

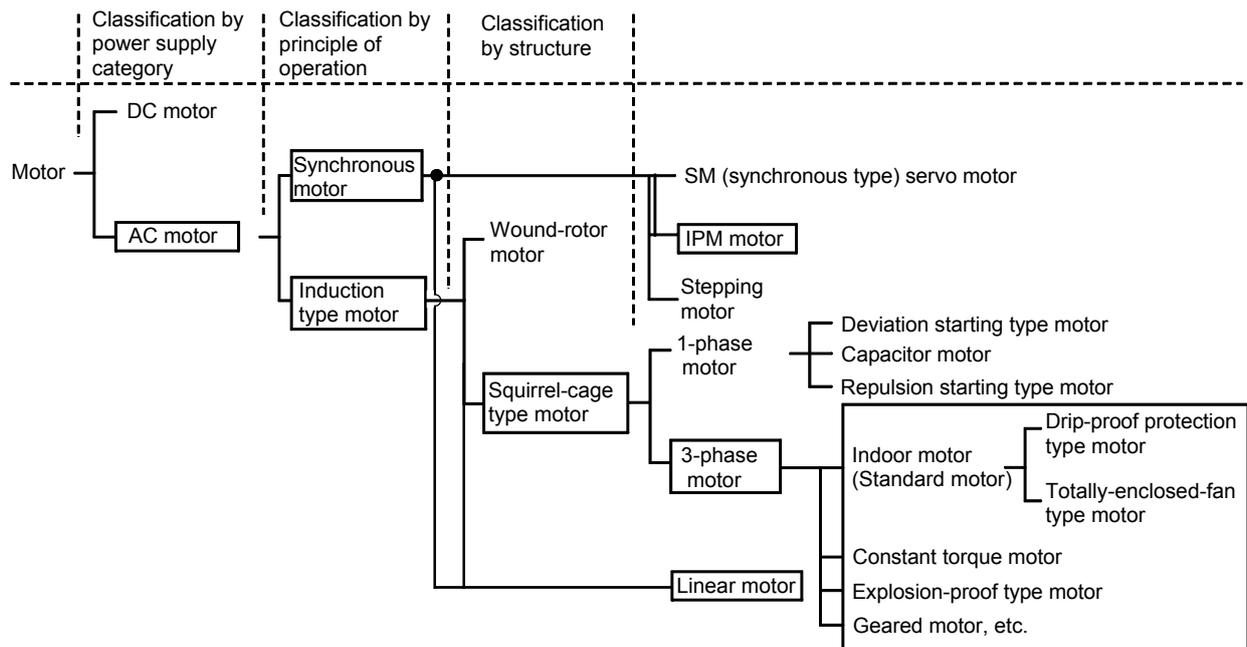


Table 1.1

Motor types		Model	Capacity	Structure/ specification	Application
Induction type motor	Standard motor	SB-JR	0.4 to 55kW	Drip-proof protection type	Various speed controls can be performed in combination with the inverter.
		SF-HR	0.2 to 55kW	Totally-enclosed- fan type	
		SF-JR	0.2 to 55kW		
	Constant torque motor	SF-HRCA	0.2 to 55kW	Totally-enclosed- fan type	Most suitable for the applications to continuously operate with the rated torque at low speed.
		SF-JRC	0.4 to 22kW		
		SF-JRCA	0.4 to 45kW		
		SF-JRC-FV	30 to 45kW	Totally-enclosed strong cooling type	
		SF-JRCA-FV	55kW		
	Explosion -proof type motor	XE-NE	0.2kW	Explosion-proof type	Used in the environment with flammable gas, mist, etc. Approved by the Ministry of Health, Labor and Welfare.
		XF-NE	0.75 to 7.5kW		
		XF-E	11 to 45kW		
	Geared motor	GM-S	0.1 to 2.2kW	For constant load	Large torque can be obtained at low speed. Used in various industries such as a transport machinery and a food machinery.
		GM-D	0.4 to 7.5kW	For middle load	
		GM-LJ	3.7 to 37kW		
		GM-PJ	3.7 to 55kW	For constant load or middle load	
GM-J		25 to 90kW	For constant load		
Synchronous motor	IPM motor	MM-EF	0.4 to 15kW	Totally-enclosed- fan type	More efficient than the induction type motor.
		MM-CF	0.4 to 7.0kW	Totally-enclosed self-cooling	High reliability improved with sensorless.
		MM-BF	0.4 to 3.7kW		High-speed operation is available.

1.2 Structure of Motor

Since the squirrel-cage motor is robust and has a simple structure, it can be used in various environments such as outdoor, underwater and explosive atmosphere.

When the motor types are roughly classified by the structure, there are two types: the totally-enclosed-fan type and the drip-proof protection type. The structure example of the totally-enclosed-fan type is shown in Fig. 1.1. The structure is roughly divided into the fixed part and rotary part, and they are comprised of the machine part and electric part respectively. The external fan connected to the shaft is designed for cooling the heat generation of the motor itself.

When the low-speed operation is performed by the inverter, the motor speed becomes slower and the cooling effect by the external fan decreases. To keep the rise of the motor temperature within the specified value, it is necessary to use the permissible load torque suppressed.

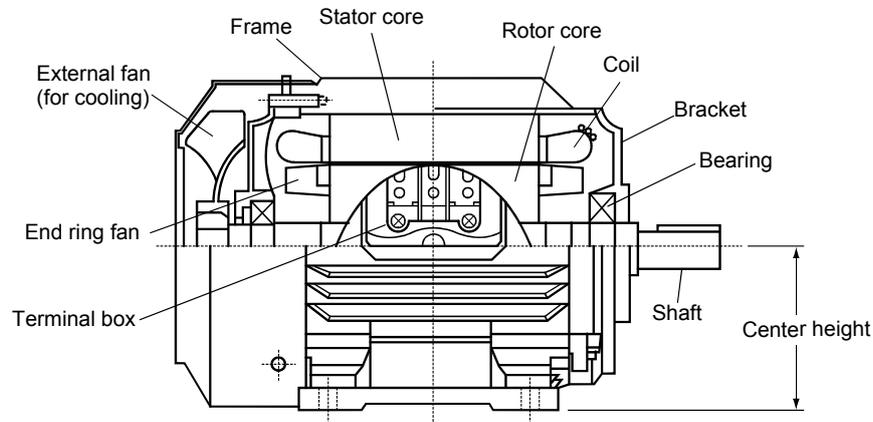


Fig. 1.1 Structure example of totally-enclosed-fan type motor

1.3 Basic Characteristics

1.3.1 Torque and current curve

The characteristics when the motor is directly started are shown in Fig. 1.2.

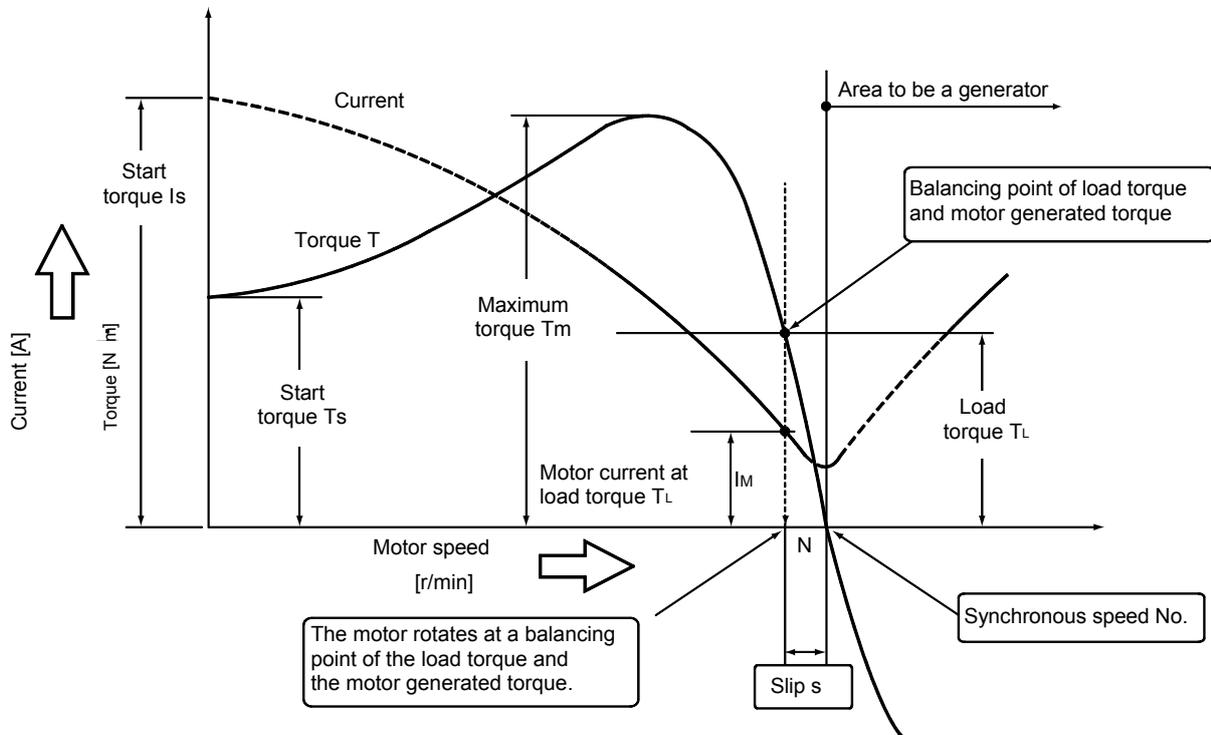


Fig. 1.2 Relationship of motor speed, current, and torque

1.3.2 Motor speed

The motor speed is determined by the number of poles and the magnitude of the power supply frequency to be applied in addition to the load torque. This is represented by the following formula.

$$\text{Motor speed } N = \frac{120 \times \text{Frequency } f \text{ [Hz]}}{\text{Pole number } P} \cdot (1-S) \quad [\text{r/min}] \dots \dots \dots (1.1)$$

↓
Determined by the specification of the motor.

↓
Determined by the load specification (load torque).

This magnitude is called Synchronous speed N₀.

To change the motor speed, it is only necessary to change the power supply frequency to be applied to the motor or the number of poles as understood from the Formula (1.1). In addition to this, there is a method to change the applied voltage of the motor.

To change the frequency..... Inverter

To change the number of poles..... Pole number conversion motor

To change the voltage PS motor (Primary voltage control)

To change the slip Wound-rotor motor

The variable speed motor (Mitsubishi AS motor) of the eddy current joint system has an electric joint of the eddy current system between the output shaft and the drive motor, and the drive motor always rotates at the rated speed. Since the motor speed of the output shaft is slipped at the joint part, it is similar to the system to change the slip S.

1.3.3 Slip

When the load is applied to the motor speed, it becomes a speed mismatched with (or reduced from) the synchronous speed in Section 1.3.1. The indicated degree of the gap with the synchronous speed is called "Slip".

"Slip" is derived by Formula (1.2) as shown below.

$\text{Slip } S = \frac{\text{Synchronous speed } N_0 - \text{Motor speed } N}{\text{Synchronous speed } N_0} \times 100[\%] \dots\dots\dots(1.2)$
--

- (1) At a start (the motor speed is 0), the "slip" is 100%. (Normally it is indicated as "Slip 1".) When the frequency gradually increased with the inverter (called the frequency start), the "slip" is about a few percents.
- (2) For operation at the rated torque, the "slip" is generally 3 to 5%. When the load torque increases (overload), the "slip" and the motor current also increase.
- (3) When the slip becomes a minus value, it means that the motor speed has exceeded the synchronous speed ($N > N_0$).

<p>Good to know for checking a motor</p> <p>The torque generated from the motor is not fixed. When the load is small even if the motor capacity is large, the motor generated torque also becomes smaller proportional to the load.</p> <p>The motor generated torque constantly varies according to the load torque. The motor speed also varies according to the load fluctuation.</p>

1.3.4 Motor current

As shown in Fig. 1.2, the faster the motor speed (i.e. the larger slip) is, the larger the current flows. When the current at slip 0 is the no load current, it may be approximately 50% of the rated current with a small capacity motor. Also for the minus torque (regenerative brake area), the larger the (absolute value of) slip is, the larger the regenerative current becomes.

1.3.5 Motor speed fluctuation and motor load current

The motor speed is determined by the relationship between the load torque T_L and the motor generated torque as shown in Fig. 1.2.

(1) When the load torque varies (constant motor torque)

As the load torque increases, the motor speed (N_2) slows down, and as the load torque increases, the motor speed (N_1) becomes faster. Therefore, the larger the load torque is, the larger the motor current becomes.

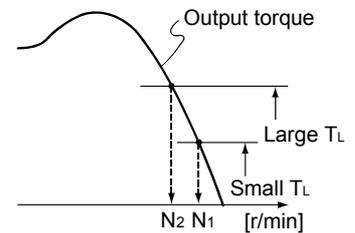


Fig. 1.3 Load fluctuation and motor speed

(2) When the motor applied voltage (power supply voltage) varies (constant load torque)

Since the motor torque varies as the square of the voltage to be applied, the motor speed also varies when the voltage varies. When the voltage increases, the current decreases.

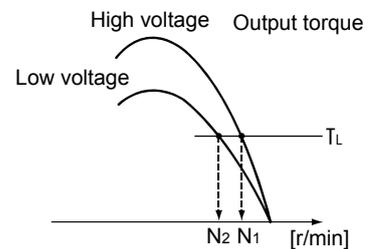


Fig. 1.4 Voltage fluctuation and motor speed

1.3.6 Rated motor torque

The "power" generated by the motor is called torque. Normally a "power" is represented as [N] in a linear operation. For the motor, however, the "power" is generated by turning the shaft. Therefore, the expression of "power" will be "Power in the rotational operation" = torque [N ·m].

The value of the rated motor torque can be calculated by Formula (1.3).

$$\text{Rated torque } T_M = 9550 \times \frac{\text{Rated motor output } P \text{ [kW]}}{\text{Rated motor speed } N \text{ [r/min]}} \text{ [N} \cdot \text{m]} \dots\dots\dots [1.3]$$



Indicated on the name plates of motors or in test reports.

(Note) The "rated motor speed" is a motor speed at the rated motor torque when the rated voltage and frequency are applied.

Example
What is the rated torque of 3.7kW 4P rated motor speed 1730 [r/min]?
$\text{Rated torque } T_M = 9550 \times \frac{3.7}{1730} = 20.4 \text{ [N} \cdot \text{m]}$

During the inverter operation, the calculation of the rated torque is not affected even if the synchronous speed N_0 is used.

For precisely calculating, use the rated motor speed.

Good to know for checking a motor
The rated motor torque is not a torque generated from the motor. It is a load torque which is permissible in the continuous operation at the rated motor speed.

1.4. Torque and Current Characteristics at Inverter Drive

The motor torque and current characteristics in the commercial power supply operation and the inverter operation are compared as shown in Fig. 1.5 [%] indicates the ratio to the rated torque and rated current. (Example: For four poles)

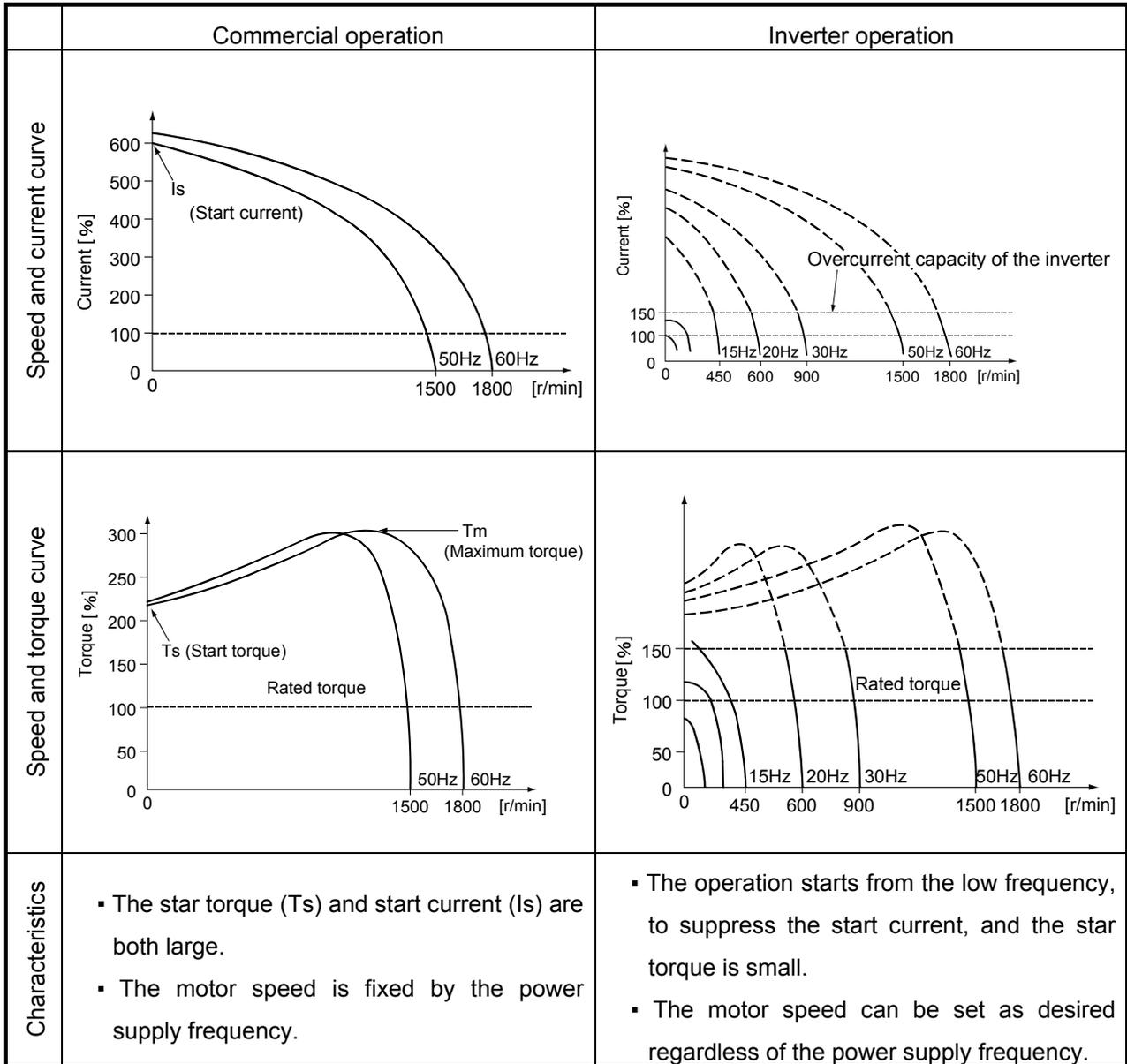


Fig. 1.5 Motor current and torque characteristics comparison (Example of V/f operation)

Approximate characteristic values when a standard motor is used in the commercial operation

- | | |
|----------------------------|--------------------------|
| (1) Start current | $I_s = 600$ to 700 [%] |
| (2) Start torque | $T_s = 150$ to 250 [%] |
| (3) Maximum torque | $T_m = 200$ to 300 [%] |
| (4) Slip at the rated load | $S = 3$ to 5 [%] |

1.5 Operating Standard Motor with Inverter

1.5.1 Difference between the rated torque of 50Hz and 60Hz

For the use at any domestic place, the standard motor is designed with the specifications for the common use at the following three rating: 200V 50Hz, 200V 60Hz, and 220V 60Hz. The comparison of the rated current, motor speed and torque to each power supply specification for the commercial power supply operation with SF-JR 3.7kW 4P is shown in Table 1.2.

Table 1.2 Comparison of common use 3 rated values

Power supply	Rated current [A]	Rated motor speed [r/min]	Rated torque [N•m]
200V 50Hz	14.6	1420	24.9
200V 60Hz	14.2	1710	20.7
220V 60Hz	13.4	1730	20.4

When the rated current at each power supply rating is assumed to be $I_{200/50}$, $I_{200/60}$, and $I_{220/60}$ respectively ($I_{400/50}$, $I_{400/60}$, and $I_{440/60}$ for a 400V power supply), the following relationship exists and the current will be the maximum at 50Hz.

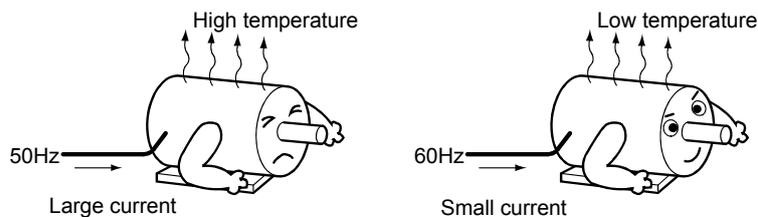
$$I_{200/50} > I_{200/60} > I_{220/60} \quad (I_{400/50} > I_{400/60} > I_{440/60})$$

As seen from Formula (1.3) in Section 1.3.6, the magnitude of the motor rated torque differs at 50Hz and 60Hz.

$$\begin{aligned} \text{Torque at 50Hz} \quad T_M &= 9550 \times \frac{P \text{ [kW]}}{N \text{ [r/min]}} = 9550 \times \frac{P}{1500} = 6.37 \times P \\ \text{Torque at 60Hz} \quad T_M &= 9550 \times \frac{P \text{ [kW]}}{N \text{ [r/min]}} = 9550 \times \frac{P}{1800} = 5.31 \times P \end{aligned}$$

← Increased by 20 %

The motor current as well as the torque (power) is large at 50Hz, and the rise of motor temperature is also higher compared to at 60Hz consequently.



1.5.2 Singularity in the inverter operation

As compared to the commercial operation, the inverter operation has the "increase of motor current". Since the waveform of the voltage to be applied to the motor is not the sine wave but a wave pattern with distortion, the motor current at the rated torque increases by approximately 10% compared to that with the commercial power supply. Consequently, the motor temperature will be also higher than that with the commercial power supply. At this time, the problem is that when there is not enough margin to the specified value at 50Hz.

This is why "Reduce the load torque to 85% at 50Hz" is indicated for the continuous operation in the catalog or instruction manual of the inverter.

Since there is enough margin to the specified value of the temperature at 60Hz, the current fits into the specified value even if increasing.

Note Here, "at 50Hz" should not be considered the magnitude of the power supply frequency but "when the rated torque calculated with 50Hz is output".

1.5.3 For the voltage change when the speed is changed by the inverter

The motor speed can be changed by changing only the frequency as shown in Formula (1.1). However, if the output frequency is set to 50Hz or less with the constant voltage (e.g. 200V), the motor magnetic flux increases (or is saturated), and the increased current causes the motor to be overheated and then burned out.

To prevent this, it is necessary to make the rule constant. Since the magnetic flux is proportional to the voltage and inversely proportional to the frequency as shown in Formula (1.4), this problem can be resolved by applying the voltage with which this relationship is always satisfied.

$\text{Magnetic flux} \propto \frac{\text{Voltage } V}{\text{Frequency } f} = \text{Constant} \dots\dots\dots (1.4)$
--

In the case that the speed is set to a half (60Hz to 30Hz), V/f is as shown below.

$\frac{V}{f} = \frac{220 \text{ [V]}}{60 \text{ [Hz]}} = \frac{110 \text{ [V]}^*}{30 \text{ [Hz]}} = \text{Constant}$	<p>* Increased more for the voltage drop compensation inside the motor in practice.</p>
---	---

As above, the rise of the motor temperature can be avoided by changing the voltage. However, it is important to care about the torque status.

1.5.4 Motor generated torque

The relationship between the motor applied voltage (V), the frequency (f) and the torque is represented by Formula (1.5).

$\text{Torque } T = K \cdot \frac{V}{f} \cdot I \dots\dots\dots (1.5)$ <p>K: Constant I: Current</p>

- (1) If the ratio of V/f is constant, the torque is constant.
- (2) When the voltage (V) is constant and only the frequency (f) varies, the torque is inversely proportional to the frequency if the motor current is constant.
 - The relationship between the voltage and the torque to the change of frequency described as above is shown in Fig. 1.6. The relationship between the output voltage and output frequency of the inverter is called "V/f pattern". This is an important factor to control the motor.

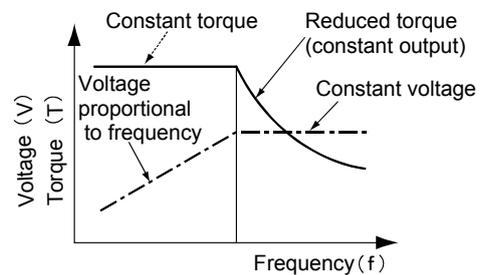


Fig. 1.6 Constant torque and constant output range

1.5.5 Operation which exceeds 50Hz or 60Hz

Since the inverter output voltage cannot output more than the power supply voltage, the output voltage, which exceeds the frequency of 50Hz or 60 Hz (Base frequency...Refer to the following figure.), is constant.

Since only the frequency is changed, the torque is reduced inversely proportional to the frequency if the motor current value is constant as shown in Formula (1.5). This area is called "constant output" range.

Good to know for checking an inverter

Base frequency

This frequency represents the frequency at the rated torque of the motor.

Since the standard motor is designed for the use at either 50Hz or 60Hz, set the base frequency either 50Hz or 60Hz. Considering the rise of the motor temperature in Section 1.5.2, it is recommended to use the motor set at 60Hz regardless of the power supply frequency. For a machine of which motor rated torque is designed at 50Hz, the setting at 60Hz of the base frequency is also applicable if the load current at 50Hz is below 60Hz of the motor rated current.

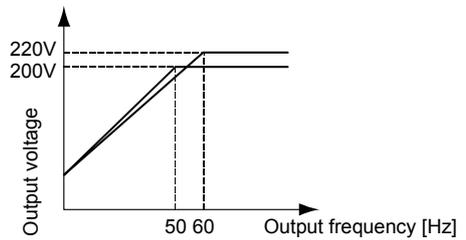


Fig. 1.7 V/f pattern and base frequency

1.6. Standard Motor Output Characteristics in Inverter Operation

The output characteristics for the combination of the Mitsubishi standard squirrel-cage motor (4 poles) and an inverter of the same capacity is as shown below.

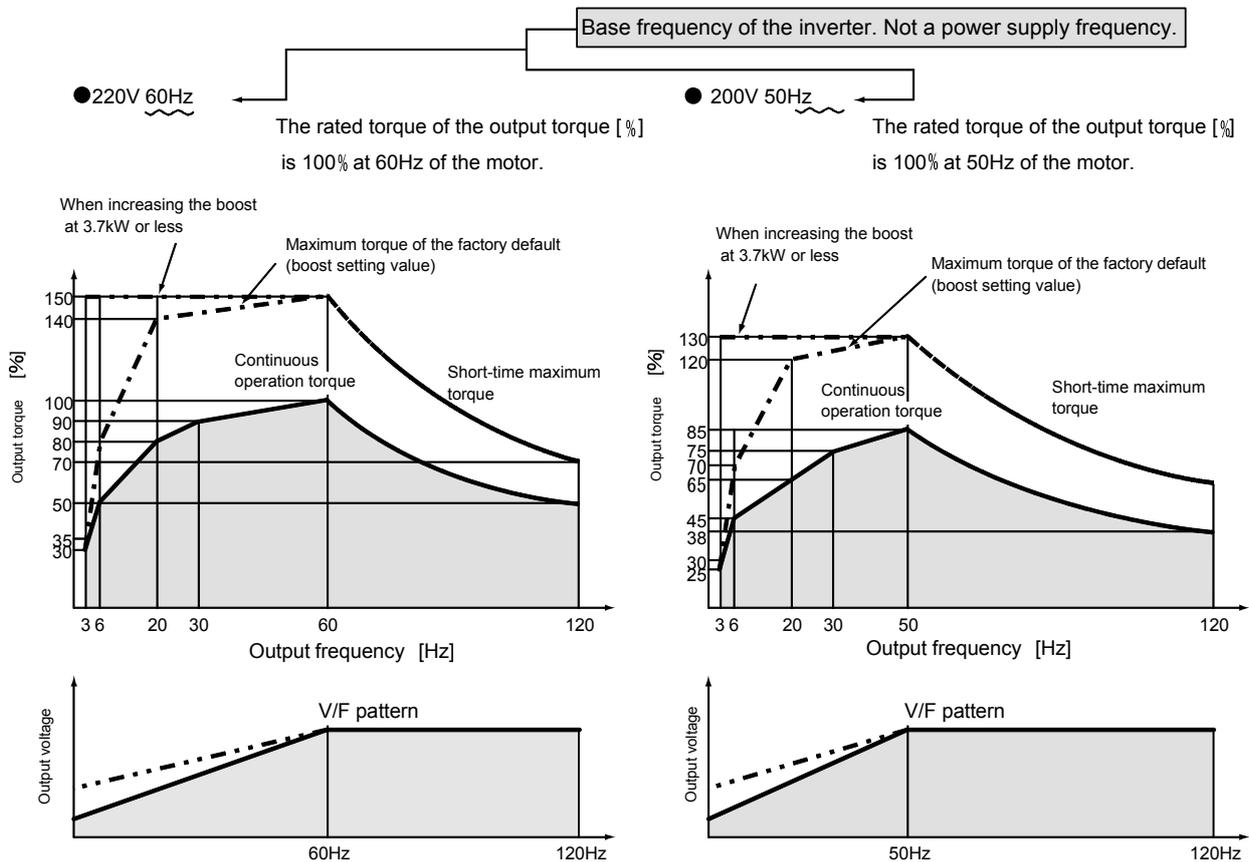


Fig. 1.8 Output characteristics of a standard motor (in V/f control)

- (1) The continuous operation torque is a permissible load torque which is regulated by the rise of the motor temperature. It is not the maximum value of the motor generated torque.
- (2) The short-time maximum torque is the maximum torque generated by the motor within the overload current rating (150%) of the inverter. Therefore, if the capacity of the inverter is increased, the maximum torque becomes larger.

The short-time of the short-time maximum torque is the overload current permissible energization time and within one minute.

* There is a constant torque motor, which is available for a continuous high torque operation at low speed, of which frame number is made larger by the inverter drive, and which is designed with the coil of which heat generation is suppressed.

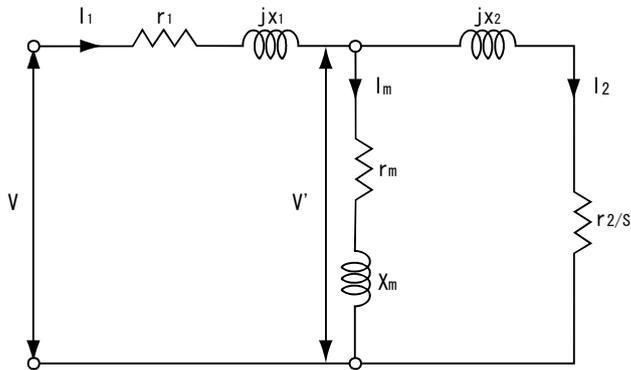
Good to know for checking an inverter

The standard motor can be operated at high speed of the maximum 120Hz. However, the usable frequency range is restricted depending on the motor size. For example, it is 120 Hz or less for up to the 4-pole 132 frame, 100Hz or less for 160 and 180 frames, 65Hz or less for 200 and 225 frames. It is restricted due to the bearing permissible speed and the structural strength of the motor depending on the motor size.

1.7 V/f Pattern and Torque Boost

1.7.1 Fundamental equivalent circuit of motor

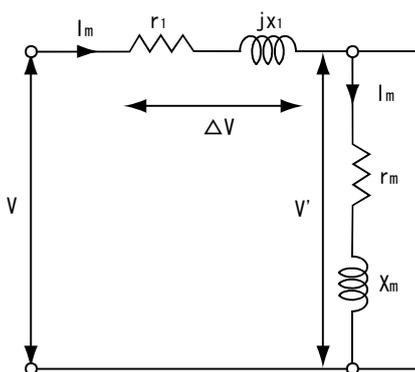
For your understanding of the torque boost, first the fundamental equivalent circuit of motor is described. Fig. 1.9 is an equivalent circuit which is generally used for a motor.



- V Primary voltage
- V' Primary induced voltage
- I₁ Primary current
- I₂ Secondary current (primary converted value)
- r₁ Primary resistance
- r₂ Secondary resistance (primary converted value)
- r_m Iron loss resistance
- X_m Excitation reactance
- X₁ Primary magnetic leakage reactance
- X₂ Secondary leakage reactance
- S Slip

Fig. 1.9 Equivalent circuit of motor

In addition, the equivalent circuit is as Fig. 1.10 in the condition that the circuit is open on the secondary side during the motor operation without load.



Excitation current

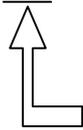
Fig. 1.10 Equivalent circuit (secondary open without load)

Voltage equation is as Formula (1.6).

$$V' = V - (-jIm)(r_1 + jX_1) \dots \dots \dots (1.6)$$

If it is replaced with $\Delta V = (-jIm)(r_1 + jX_1)$, the formula can be simplified as Formula (1.7).

$$V' = V - \underline{\Delta V} \dots \dots \dots (1.7)$$



The torque generated torque affects due to the primary resistance and primary leak reactance inside the motor or the voltage drop caused by the cable impedance of the motor wiring.

1.7.2 Torque boost

The output voltage of the inverter must be $V/f = \text{Constant}$ at the base frequency or lower as shown in Section 1.5 (Fig. 1.11). However, the primary wiring of the motor includes the amounts of resistance and reactance (collectively called impedance) as shown in the equivalent circuit of Fig. 1.9., and the torque generated by the motor decreases due to the voltage drop caused by the impedance.

A standard motor is designed with a winding in consideration for the amount of the voltage drop at 50Hz or 60Hz.

When a standard motor is operated with an inverter, the voltage varies in proportion to the change of the output frequency f . Especially the voltage drop is large in the low-frequency range with low voltage, and the motor generated torque is extremely small compared to the one with the commercial power supply. Therefore, the decrease of the motor output torque is suppressed in the low-frequency range by increasing the voltage in the amount of ΔV in Formula (1.7) to balance with the voltage drop. As shown in Fig 1.12, the compensation of the voltage in the amount of ΔV is called torque boost.

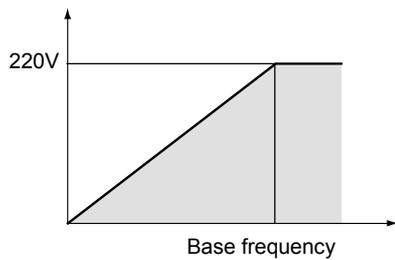


Fig. 1.11 Ideal V/f pattern of motor

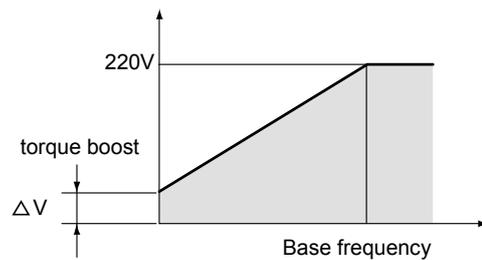


Fig. 1.12 Actual inverter V/f pattern

The manual torque boost is as shown in Fig. 1.13.

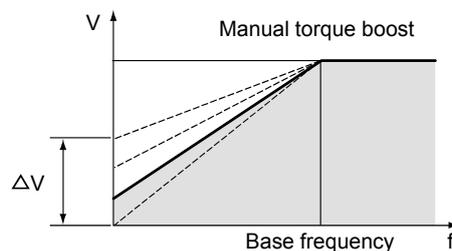


Fig. 1.13 Manual torque boost

The increase of the voltage is constant by f . (It is not relevant to the motor current.)

1.7.3 Torque boost setting

When the large start torque or acceleration torque is necessary, the motor torque of about 100 to 150% can be generated in the low frequency area by adjusting the torque boost.

(1) The standard torque boost (factory default) is adjusted to the characteristics of the Mitsubishi standard motor.

(When the motor winding specifications are different as a special motor, it may be better to adjust the torque boost.)

(2) If the torque boost is increased too much under light load, the current become rather large and the inverter may trip due to the overcurrent.

(3) For the constant operation under light load, the motor efficiency is improved by reducing the torque boost.

(Refer to Section 1.8 Reduced- torque load pattern.)

(4) Likewise, the torque boost adjustment is effective against the voltage drop due to the cable between the motor and the inverter.

The relationship between the motor torque and the current when the voltage is increased by the torque boost is shown in Fig. 1.14.

Since there is a current limit (150% of the rated current) for the inverter drive, the maximum value of the start torque is determined within the current range. If the torque boost setting value is too large, the current exceeds the limit and the overcurrent protection function is activated.

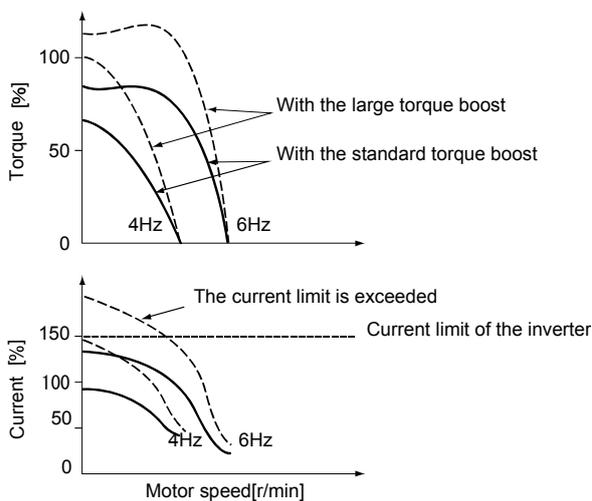
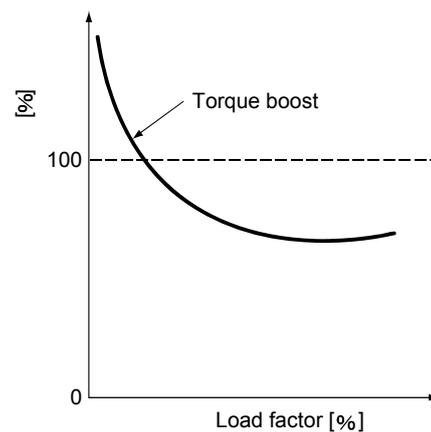


Fig. 1.14. Example of motor torque and current at a start



(Fig. 1.15 Example of load factor and motor current)

When the torque boost setting value is increased, the change of the current for each load condition is as described below.

- 1) For the light load..... Since the magnetic flux of the motor iron core is saturated, the current increases and the overcurrent protection function can be operated more easily.
- 2) For the heavy load With the torque boost, the amount of the voltage drop caused by the motor primary winding and cable is compensated, and the large motor torque is generated. This reduces the motor slip, and the current decreases compared to that for the light load. (Refer to Fig. 1.15 Example of load factor and current)

Good to know for checking a motor

The inverter dedicated constant torque motor is a motor specially designed for the continuous use with 100% torque at low speed. When the motor is used under light load unavoidably, the motor current may exceed the rated motor current in the low-frequency range. Therefore, use the motor with reducing the manual torque boost.

Example

How does the motor current change if the torque boost setting value of the inverter is increased?

Although it differs depending on the load condition (light load or heavy load), the motor current increases by increasing the torque boost and the large start torque is generated. During the acceleration under heavy load, the motor slip decreases when the torque is increased. As a result, the average current during the acceleration can be suppressed.

If the setting value is too large, the overcurrent protection function is activated since the motor current right after the start exceeds the current limit.

1.8 Load Torque Types and V/f Patterns

The load torque characteristics vary depending on applications. The following shows the typical examples and the V/f patterns to be applied.

For the inverter operation, The V/f characteristics according to the load characteristics can be selected.

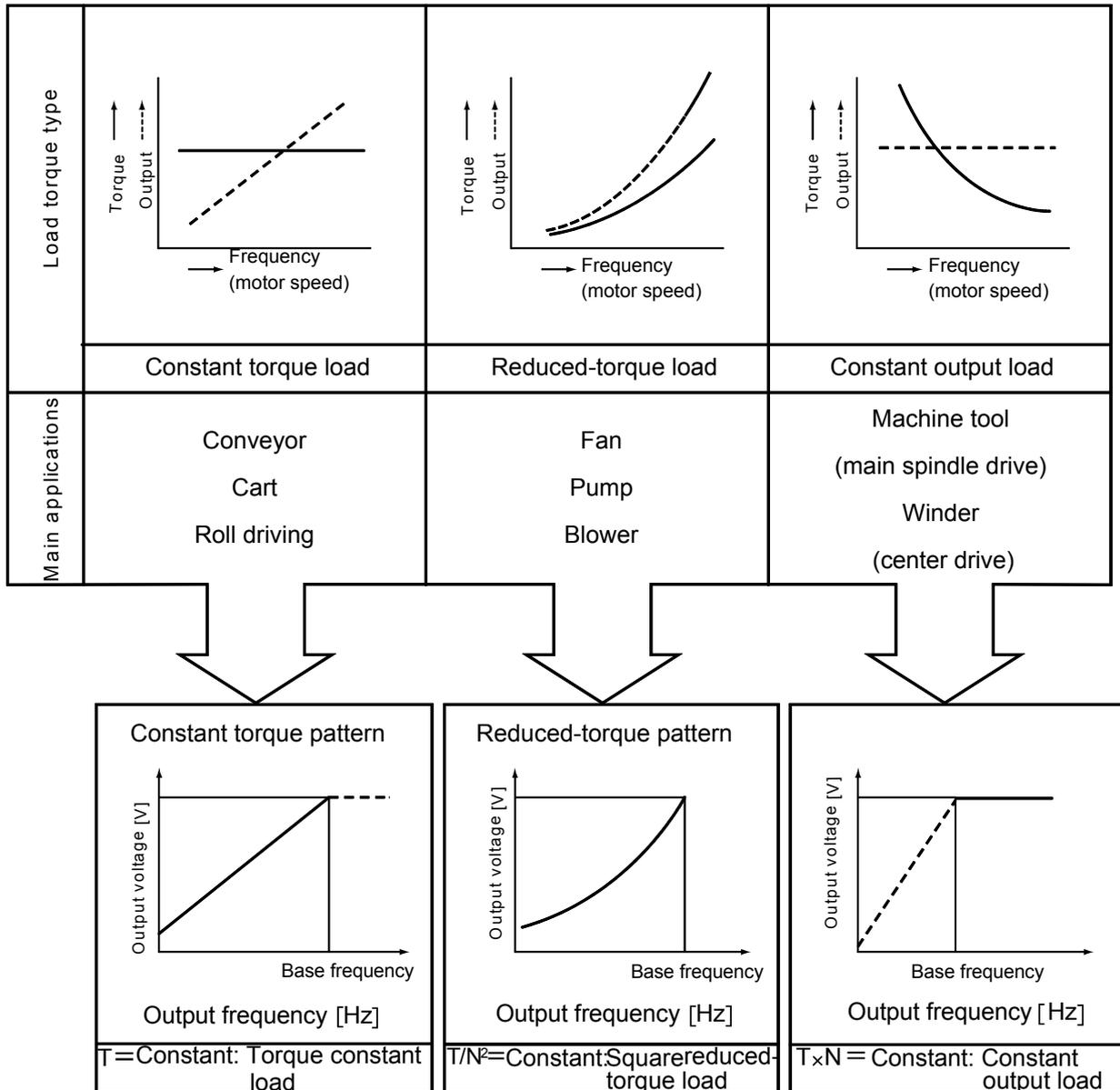


Fig. 1.18 Load torque types and V/f patterns

Good to know for checking an inverter

When the reduced-torque load is operated, the V/f pattern of the constant torque can be used for the operation. However, the reduced-torque pattern is more efficient, provides the energy saving operation and can additionally expect the low-noise operation.

1.9 Acceleration/Deceleration Time and Inertia Moment J

1.9.1 Acceleration/deceleration time

The acceleration/deceleration time differs between the commercial operation and the inverter operation as shown below.

Operation	Acceleration time	Deceleration time
Commercial operation	$t_a = \frac{\text{Entire } J \times N}{9.55 \times \{T_M \times (1.5 \sim 2) - T_L\}} \text{ [s]}$ <p> N : motor speed [r/min] T_M : Rated motor torque [N·m] T_L : Load torque [N·m] </p>	$t_d = \frac{\text{Entire } J \times N}{9.55 \times T_L} \text{ [s]}$ <p> N : Rated motor speed [r/min] T_L : Load torque [N·m] </p>
Inverter operation	$t_a = \frac{\text{Entire } J \times \Delta N}{9.55 \times (T_M \times \alpha - T_L)} \text{ [s]}$ <p> ΔN : Difference of the motor speed between before and after acceleration [r/min] T_L : Maximum load torque [N·m] α : Average acceleration torque ratio (Approximately 1.1 boost standard) </p>	$t_d = \frac{\text{Entire } J \times \Delta N}{9.55 \times (T_M \times \beta + T_L)} \text{ [s]}$ <p> ΔN : Difference of the motor speed between before and after deceleration [r/min] T_L : Minimum load torque [N·m] β : Average deceleration torque ratio (Regenerative control torque ratio) </p>
$\text{Entire } J = \text{Motor } J_M + \text{Load } J_L \text{ [kg} \cdot \text{m}^2\text{]}$		

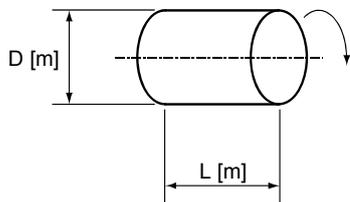
- (1) Depending on the difference of the average acceleration torque coefficient, the acceleration time for the commercial operation is shorter.
- (2) The motor coasts to stop for the commercial operation, whereas the motor stops with the regenerative brake activated for the inverter operation. Therefore, the deceleration (stop) time for the inverter operation is greatly shorter compared to that for the commercial operation.
To suddenly stop the motor for the commercial operation, the mechanical brake is used. Alternatively, the DC dynamic brake or the electric brake method by reversed-phase breaking is adopted.

1.9.2 Inertia moment J

(1) The inertia moment J is a numerical value of an object's inertia. A heavy object with a large diameter has a large inertia, and a light object has a light inertia.



(2) How to calculate the inertia moment J of a rotator



$$J = \frac{1}{8} \times W \cdot D^2 = \frac{\pi}{32} \times \rho \cdot L \cdot D^4 \quad [\text{kgm}^2]$$

W : Weight [kg]
 ρ : Gravity [kg/m³]

Examples of the gravity	
Aluminum 2.7×10 ³
Iron 7.8×10 ³
Cast iron 7.2×10 ³

(3) For the calculation of the acceleration/deceleration time, the load inertia moment (J_L) must be converted to the motor shaft.

Motor shaft conversion $J = J_L \times i^2$ (i = Reduction ratio)

(4) The load with large inertia moment J takes time to accelerate or decelerate. Therefore, the large motor torque is required to accelerate or decelerate in a short time.

(5) The conversion formula of the inertia moment J and GD² is expressed with the following formula.

$$J = (1/4) \times GD^2$$

2. PRINCIPLE OF INVERTER AND ACCELERATION/ DECELERATION CHARACTERISTICS

This chapter describes the principle of how the basic circuits in an inverter operate to create variable frequency and variable voltage. These frequency and voltage are output from an inverter to a motor to change the motor speed.

An inverter can be thought of as a power supply converter (converts from constant frequency/voltage to variable frequency/voltage) for motors. Although an inverter is powered from a commercial power supply, a waveform of the input current is different from that of a sine wave. Furthermore, the output waveform greatly differs from this input waveform. This discriminative waveform, which is generated due to the operation principle of an inverter, is highly relevant to the choice of a motor/peripheral devices and to the measurement of a current/voltage. For this reason, it is important to understand how the discriminative waveform correlates to the operation of each circuit in an inverter.

POINTS for understanding!

1. Principle of creating the output waveform (variable voltage/variable frequency)
2. Operation flow from start to stop
3. Concept of the inverter power factor

2.1 Configuration of Inverter

Fig. 2.1 shows the configuration of a general-purpose inverter, which uses a commercial power supply (AC 50Hz or 60Hz) to create an AC power supply that generates various, needed frequencies to rotate a motor at various speeds. More precisely, a general-purpose inverter consists of two significant sections, the main circuit and the control circuit. The main circuit is subdivided into the converter, which converts a current from a commercial power supply to DC and then smoothes pulsation included in the converted DC, and the inverter part, which converts the smoothed DC to AC with variable frequency. The control circuit controls the main circuit.

Basically, a converter refers to a unit that performs forward conversion from AC to DC whereas an inverter refers to a unit that performs reverse conversion from DC to AC. However, with general-purpose inverters, the whole unit including the converter is referred to as an inverter.

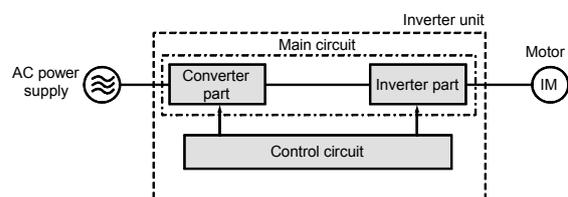


Fig. 2.1 Configuration of inverter

As described above, the main circuit part in an inverter consists of two power supply converters that are largely different from each other in elements and characteristics. The next section describes the individual principles of how the inverter part and converter part operate.

2.2 Operation of Converter

The converter consists of the following parts as Fig. 2.2 shows:

- 1) Converter
- 2) Smoothing capacitor
- 3) Inrush current control circuit

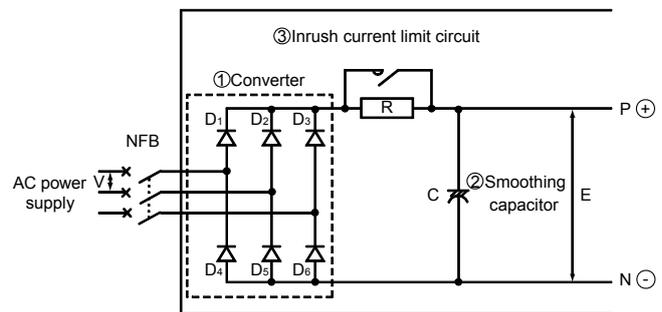


Fig. 2.2 Converter circuit

(1) Principle of converter

The following describes the waveform of an AC input current that is generated when creating DC from a single-phase AC power supply as shown in Fig. 2.3.

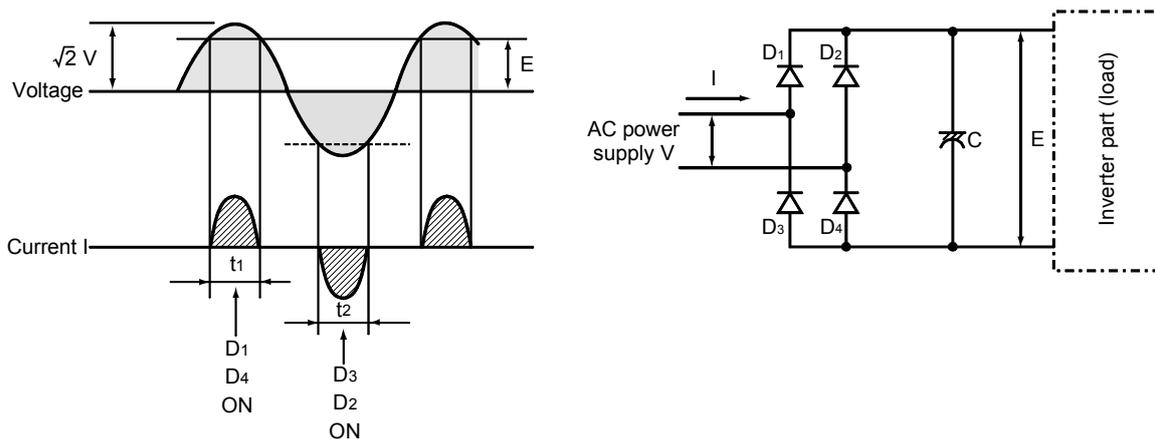


Fig. 2.3 Principle of converter

- When a sine wave voltage with an effective value V (wave height $\sqrt{2} \times V$) is input from an AC power supply to the converter, the current flows through the diodes D_1 and D_4 only at t_1 , which has higher potential than the voltage E generated at the converter's output part (DC).
- In the half cycle where AC voltage is negative, the diodes D_2 and D_3 are conducted at t_2 , allowing a negative input current to flow to the AC side.

This means that a waveform of the AC input current for the converter has changed from a sine waveform to a distorted waveform with harmonics.

(2) AC input current in normal status (during motor operation)

For the three-phase AC input, six diodes can be used in combination to rectify all the waveforms of the AC power supply. Doing so conducts the diodes in the respective timings as shown in Fig 2.4, allowing the input current to be in the same distorted waveform as created with the single-phase power supply. The diode-rectified waveforms of all the three phases are further smoothed to DC with less pulsation by the smoothing capacitor C.

When the inverter is stopped, the DC voltage can be up to $\sqrt{2}$ times larger (approx. 280VDC with 200VAC) than the AC input voltage.

Note that while an inverter is in operation the DC voltage slightly fluctuates depending on the output (torque/rotation speed).

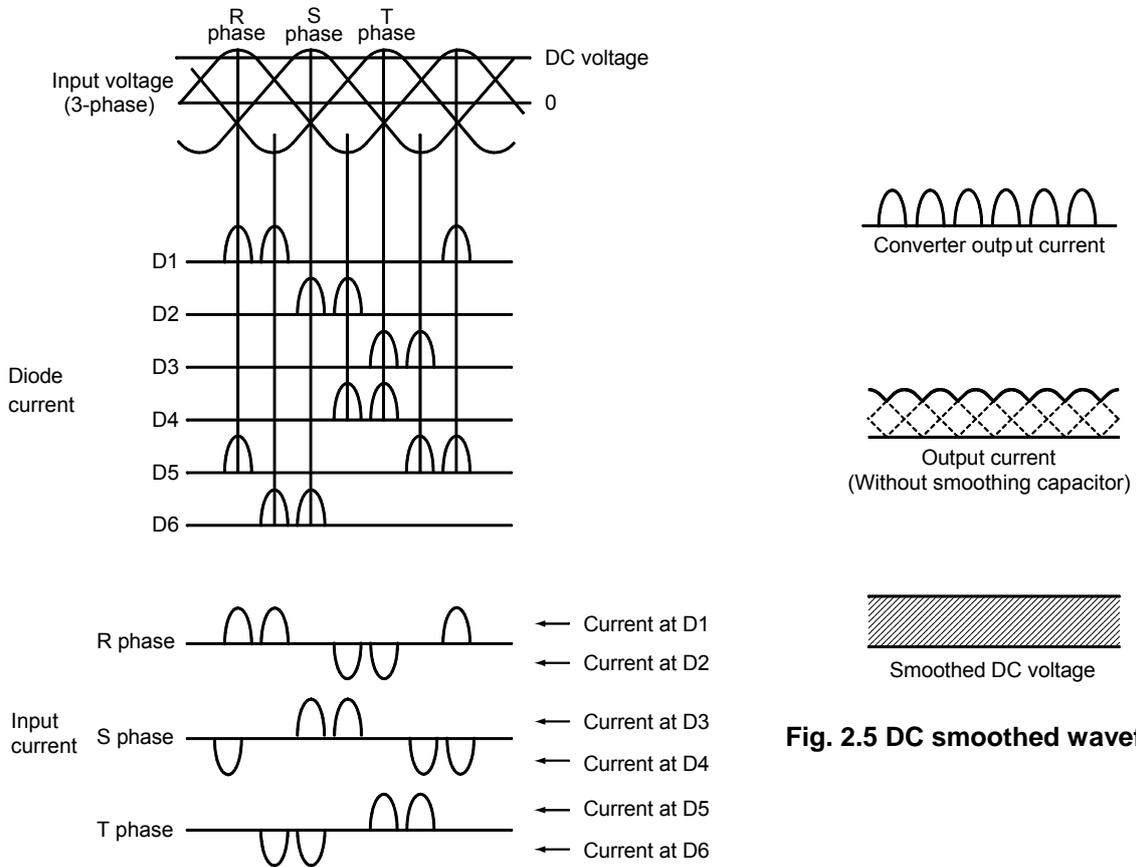


Fig. 2.4 Principle of input current

Fig. 2.5 DC smoothed waveform

Good to know for checking an inverter

When the three-phase AC input voltage becomes imbalanced, the AC input current may become significantly imbalanced.

This is most likely to happen when a light load is used with a large DC bus voltage. A phase may open in an extreme case, and however this is not an error of the inverter.

As the three phases of the inverter input current become imbalanced, compare the currents in all the three phases when measuring. To measure the DC bus voltage, measure the inverter terminals P[⊕]-N[⊖] with a tester.

Be careful when measuring the DC bus voltage for 400V (200V) inverters. The voltage can be up to 800VDC (400VDC).

(3) AC input current at power on

When an inverter is powered on, a large inrush current flows for charging a smoothing capacitor. To control the peak value of the inrush current, use the control resistor shown in Fig. 2.6.

After the smoothing capacitor is charged, short the both ends of the control resistor with a relay, etc.

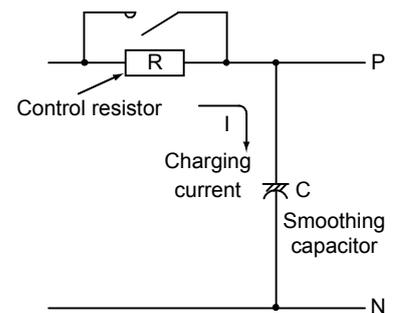


Fig. 2.6 Inrush DC control resistor

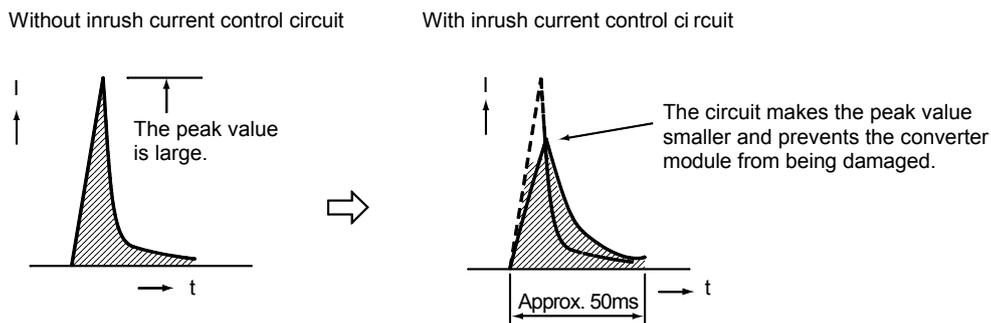


Fig. 2.7 Inrush current

Do not switch an inverter between on and off too often with a magnetic contactor (MC), etc. Doing so lets the peak current to flow to the converter every time the inverter is switched, shortening the lives of the diodes. It may also shorten a switching life of the inrush current control circuit, and therefore the number of switching times should be limited within several times a day.

The purpose of the converter part is to create DC power supply. Apply the base current to a transistor to rotate a motor. (Turn the control start input terminal STF or STR on.)

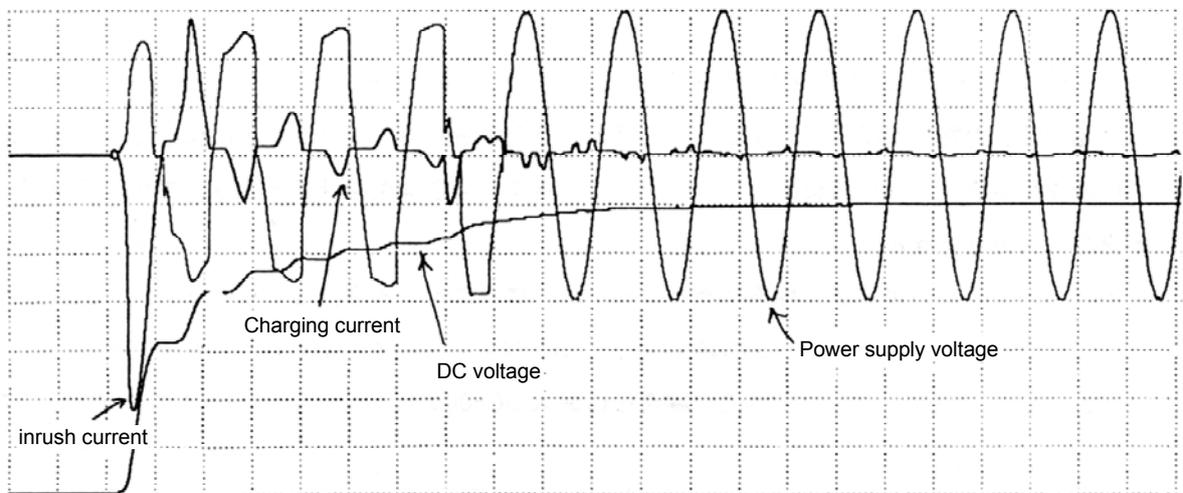


Fig. 2.8 Actual measurement example of inverter input current/voltage waveform

2.3 Principle of Inverter

(1) Method to create AC from DC

An inverter is a device to create the AC from the DC power supply. See the basic principle with the single-phase DC as the simplest example.

Fig. 2.9 shows the example of the method to convert the DC to the AC by utilizing a lamp for the load in place of a motor.

If the four switches S1 to S4, which are connected to the DC power supply, are alternately turned on/off, the AC is created as shown in Fig. 2.10.

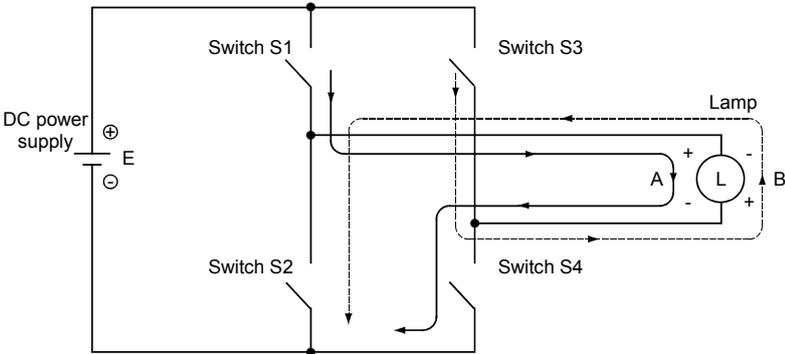


Fig. 2.9 Method to create AC

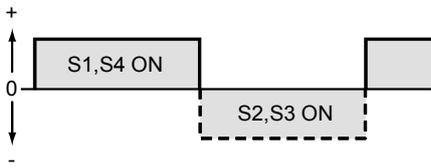


Fig. 2.10 Current waveform

- When the switches S1 and S4 are turned on, the current flows in the lamp L in the arrow A direction.
 - When the switches S2 and S3 are turned on, the current flows in the lamp L in the arrow B direction.
- Therefore, if the switches are alternately turned on/off with the combinations of the switches S1 and S4 and the switches S2 and S3, the AC is created since the direction of the current flowing in the lamp L alters.

(2) Method to change frequency

The frequency is changed by changing the period to turn on and off the switches.

For example, if the switches S1 and S4 are turned on for 0.5 second and S2 and S3 for 0.5 second and this operation is repeated, the AC with one alternation per second, i.e., the AC with a frequency of 1[Hz] is created.

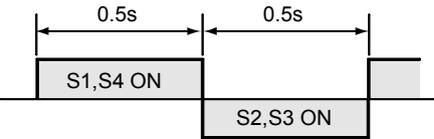


Fig. 2.11 1Hz AC waveform

Generally, under the condition that S1/S4 and S2/S3 are turned on for the same period of time and that the total time of one cycle is t_0 seconds, the frequency f can be obtained as follows:

$$f = \frac{1}{t_0} \text{ [Hz]}$$

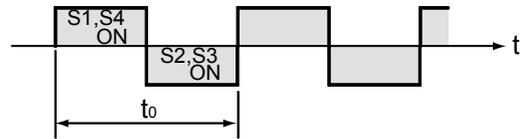


Fig. 2.12 Frequency

(3) Three-phase AC

Fig. 2.13 shows the basic circuit of a three-phase inverter.

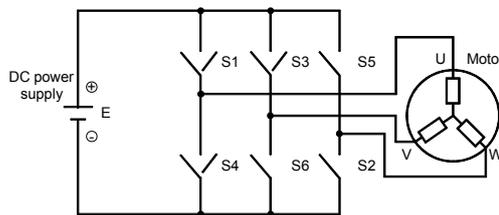


Fig 2.13 Three-phase inverter basic circuit

Turn on/off the switches S1 to S6 in the order shown in Fig. 2.14. Doing so obtains pulse waveforms at sections U-V, V-W and W-U in the same cycle, and applies AC voltage in a rectangular waveform to a motor.

Changing the on/off cycles of the switches outputs a needed frequency to a motor, and changing the DC voltage E changes the input voltage at the same time.

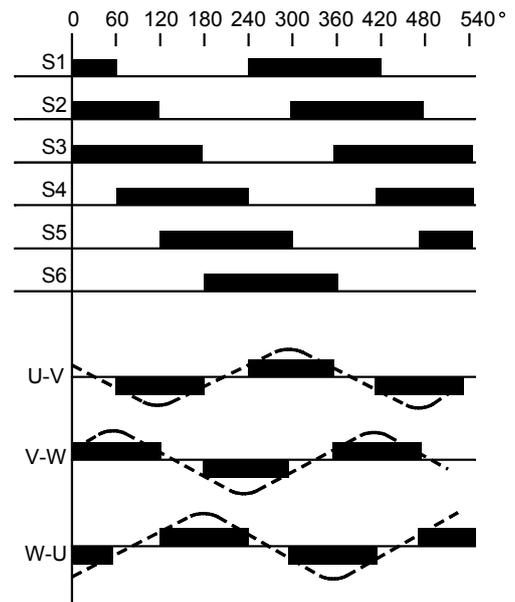


Fig. 2.14 Method to create hree-phase AC

(4) Configuration of inverter part

Instead of switches, six transistors are used as shown in the configuration of Fig. 2.15. The connected motor is a three-phase motor, and this motor is rotated by turning the transistors on/off alternately.

To change the motor rotation direction, change the order that the transistors are turned on/off.

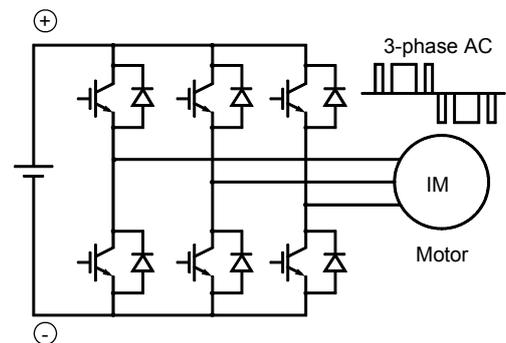


Fig. 2.15 Transistor inverter

Good to know for checking an inverter

If an AC power supply is applied to the output terminals of the inverter part, an inrush current flows for charging the smoothing capacitor C through the diodes that are connected in parallel with the transistors, as mentioned in Fig. 2.7. In this example, control resistors are not installed in the circuit on the transistors side and therefore the diodes of the transistor section will be damaged. Never connect the power supply to the output terminals U, V and W of the inverter.

(5) Role of transistors

A transistor is composed of three terminals, a collector (C), emitter (E) and base (B) (substituted by a gate (G) in IGBT.). The line C-E is not conducted (switched off) when a base signal is off, and conducted (switched on) when a current is applied to the base. In other words, transistors function as the switches S (ON-OFF) with faster operation.

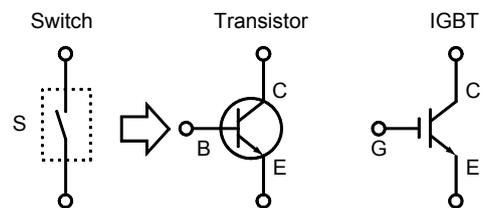


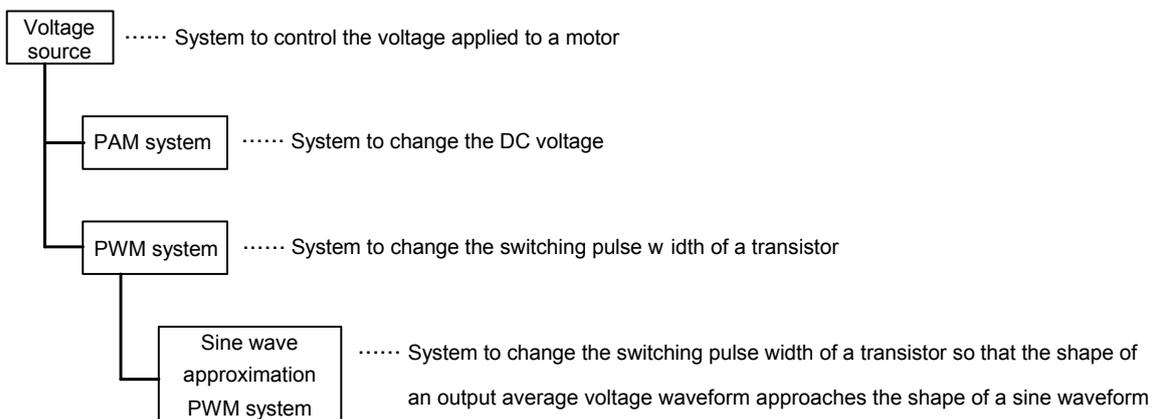
Fig. 2.16 Transistor

To turn off this base signal (substituted by a gate signal in IGBT.) is referred to as "transistor base shut-off", which appears in the explanation for the protective function of the inverter. When the transistor base shut-off is performed, the six transistors are turned off simultaneously, disconnecting the inverter from the motor. In other words, the motor coasts to stop.

(6) Methods to change AC voltage

To rotate a standard motor through an inverter, it is necessary to change voltages according to the V/F pattern as described in "MOTOR CHARACTERISTICS AT INVERTER DRIVE".

The control system of general-purpose inverters is referred to as "voltage source" system since the inverter part is their voltage source. The voltage source system is subclassified into the following types in accordance with the voltage change method.



Differences between these control systems affect motor characteristics (vibration, noise, torque ripple, motor current ripple, torque response level, etc.). (Refer to Table 2.1)

Table 2.1 Control systems for voltage source inverters

(E: DC voltage)

Control system	Output frequency Low (low voltage)	Output frequency High (high voltage)	Characteristics
<p>PAM system</p> <p>(PAM: Pulse Amplitude Modulation)</p>			<ul style="list-style-type: none"> ▪ Low motor noises ▪ Low noise ▪ High efficiency ▪ Converter is required for voltage control. ▪ Low response speed ▪ Smooth operation not possible at low speed
<p>PWM system</p> <p>(PWM: Pulse Width Modulation)</p>	<p>Output voltage waveform</p> <p>Output average voltage</p>		<ul style="list-style-type: none"> ▪ Frequency/voltage control by the inverter part alone ▪ Harmonic noises from a motor
<p>Sine wave approximation PWM system</p>	<p>Output voltage waveform</p> <p>Output average voltage</p> <p>One carrier</p>		<ul style="list-style-type: none"> ▪ Smooth operation at low speed ▪ Lower cost than PAM ▪ Low-degree high-frequency is less. ▪ Harmonic noises from a motor

The PWM system is a system that changes the output voltage by generating switching pulses within one cycle and changing the pulse width. The sine wave approximation PWM system is a system that makes the average output voltage shape a sine wave by changing the switching pulse width within one carrier. Most of general-purpose inverters use the sine wave approximation PWM system. The number of switching pulses generated per second is referred to as carrier frequency.

With the PWM system, the frequency components of the generated motor vibration and motor noise are proportional to the carrier frequency.

If there is a reference saying high carrier frequency PWM control, this means that the carrier frequency is high.

Also note that the Soft-PWM control is a control system that suppresses the increase of generated noise and reduces the motor magnetic noise by preventing the carrier frequency from being higher and dispersing the components of the motor magnetic noise.

Good to know for checking an inverter

If a machine generates large vibrations and noises only within a specific motor speed range, the cause may be a resonance with the carrier frequency. With the Mitsubishi general-purpose inverter FREQROL-A700 series, these vibrations and noises may be reduced by changing the carrier frequency pattern (parameter 72 "PWM frequency selection"). Also note that doing so changes the motor noise sound.

The high carrier frequency is higher than the human audible frequency range. Therefore the electromagnetic noises are hardly heard from a motor, realizing the low noise rotation. However, transistors used in the inverter part are normally limited for use at approximately up to 2kHz. For this reason, recently IGBTs (Insulated Gate Bipolar Transistor) are used more commonly.

Good to know for checking an inverter

Lower noise operation may result in a larger leakage current between the inverter and the motor. Pay attention when selecting an earth leakage current breaker and be careful when earthing (grounding).

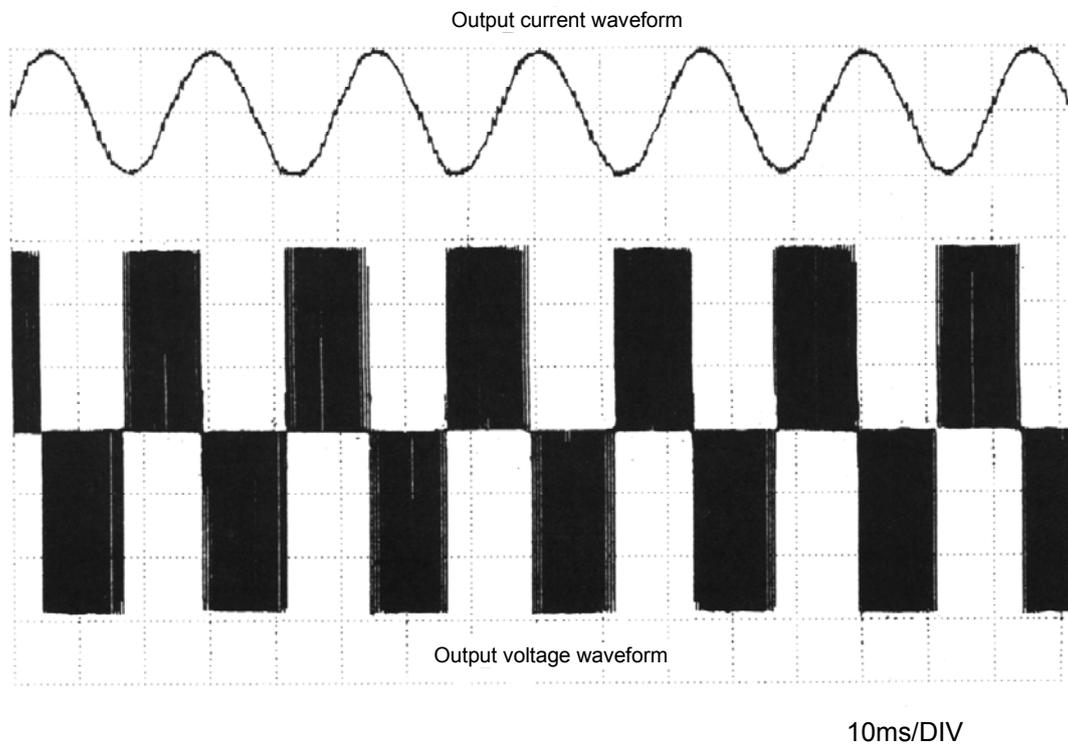


Fig. 2.17 Measurement example of the inverter FREQROL-A700 series output current/voltage waveform (at 40Hz)

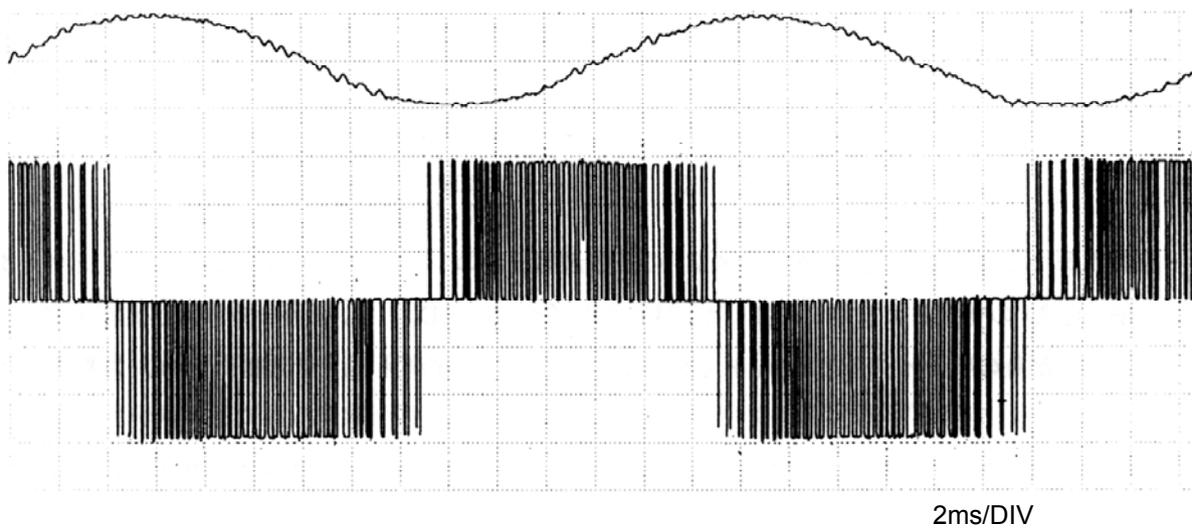


Fig. 2.18 Measurement example of the inverter FREQROL-A700 series output current/voltage waveform (500% of Fig 2.17) (at carrier frequency 2kHz)

2.4 Inverter Control Systems and Auto Tuning Function

2.4.1 V/F control

All models

With conventional general-purpose inverters, when f (frequency) is changed, V (output voltage) is changed in the constant ratio (V/f) as shown with the dotted line in the figure below.

For this reason, this system is called V/F control.

In this system, the voltage to be actually valid decreases due to a voltage drop in a wiring or the primary coil of a motor, and enough amount of torque cannot be output.

The slower the speed is, the more this phenomenon affects.

(Low-speed torque becomes insufficient.)

Therefore, the amount of voltage drop estimated in advance is set higher (torque boost *) as indicated with the solid line in the figure to cover the shortage of the torque at low speed.

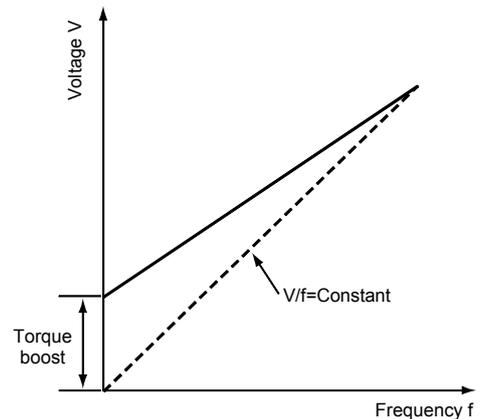


Fig. 2.19 V/F control

* As described in Section 1.7.3, when the torque boost is increased too much, the sufficient torque is provided securely. However, it may cause overcurrent to be generated, and the inverter is likely to have an OCT (overcurrent) trip.

To solve this, there are other control systems available such as the real sensorless vector control, advanced magnetic flux vector control and general-purpose magnetic flux vector control.

2.4.2 General-purpose magnetic flux vector control

E500

This control divides the inverter output current into an excitation current and a torque current by vector calculation and makes voltage compensation to flow a motor current which meets the load torque. By this, the low-speed torque can be improved and a high torque of 200% can be obtained at 6Hz. Even if the motor constant becomes somewhat unstable (due to use with other manufacturer's motors), large, stable low speed torque can be provided without any special settings of a motor constant or tuning. This feature realizes the wide versatility.

- Based on the output frequency and each current phase to the output voltage, this control divides the inverter output current (motor current) into an excitation current (a current necessary to generate a magnetic flux) and a torque current (a current proportional to the load torque) by vector calculation. (Refer to the figure on the right.)
- When a motor current is changed due to the load fluctuation, the amount of a voltage drop on the primary side of the motor (including the wiring) is changed. This affects the amount of the excitation current.

The amount of the voltage drop is calculated from the motor and primary wiring constants and the magnitude of the torque current. By this, the output voltage from the inverter is compensated (increased or decreased) so that the primary magnetic flux of the motor stays constant.

- A motor constant necessary for the calculation is preset to the inverter. The remaining task to perform the general-purpose magnetic flux vector control is just to set a motor capacity.

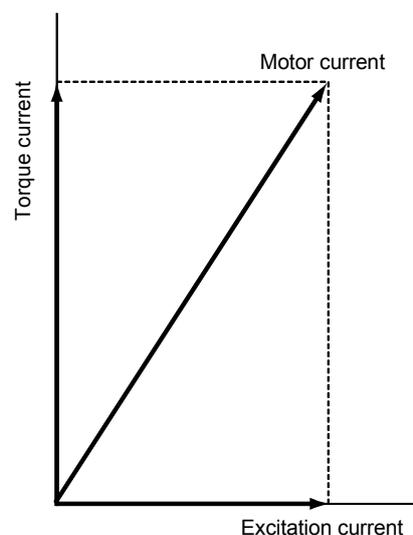


Fig. 2.20 General-purpose magnetic flux vector control

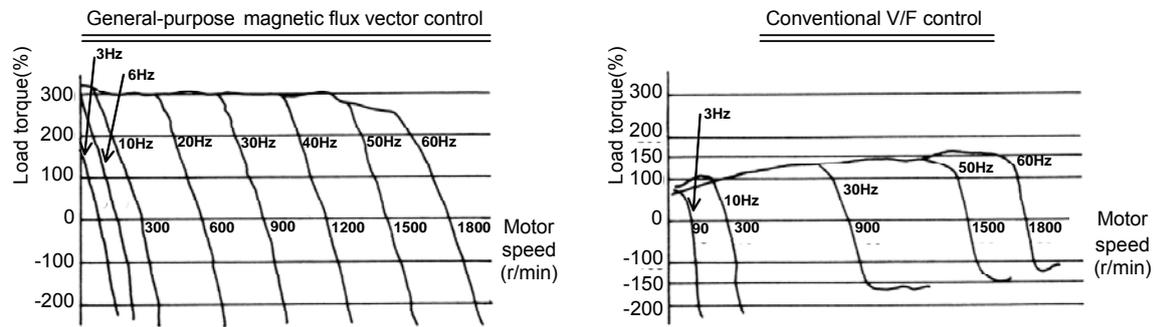


Fig. 2.21 Example of speed-torque characteristics during general-purpose magnetic flux vector control

2.4.3 Advanced magnetic flux vector control

A500

A700

This control divides the inverter output current into an excitation current and a torque current by vector calculation and makes frequency and voltage compensation to flow a motor current which meets the load torque. By this, the low-speed torque and speed control range can be improved, and a high torque of 150% can be obtained at 0.5Hz.

- Based on the output frequency and each current phase to the output voltage, this control divides the inverter output current (motor current) into an excitation current (a current necessary to generate a magnetic flux) and a torque current (a current proportional to the load torque) by vector calculation. (Refer to the figure on the right.)

• The actual motor speed is estimated based on the torque current, and the output frequency is compensated (increased or decreased) so that this estimated speed becomes the preset speed.
<<Slip compensation>>

- When a motor current is changed due to the load fluctuation, the amount of a voltage drop on the primary side of the motor (including the wiring) is changed. This affects the amount of the excitation current. The amount of the voltage drop is calculated from the motor and primary wiring constants and the magnitude of the torque current. By this, the output voltage from the inverter is compensated (increased or decreased) so that the primary magnetic flux of the motor stays constant.

★The portions highlighted in gray are the features added to the general-purpose magnetic flux vector control. These additional features allow a large torque to be generated at lower speed. Also, the auto tuning function allows an inverter to measure and store the motor circuit constant. With this feature, the inverter can perform highly accuracy calculation and supports wider speed control ranges.

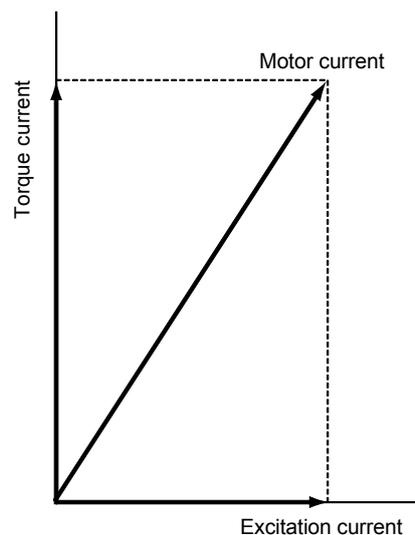


Fig. 2.22 Advanced magnetic flux vector control

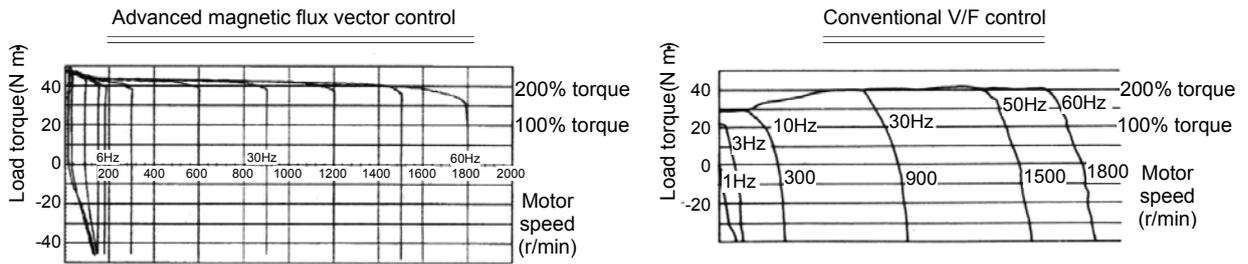


Fig. 2.23 Example of speed-torque characteristics during advanced magnetic flux vector control

Item		Advanced magnetic flux vector control	General-purpose magnetic flux vector control
The number of motors in combination use		1:1	1:1
Motor available for combination	Standard motor	Two-pole, four-pole, six-pole	Two-pole, four-pole, six-pole
	Constant torque motor	Four-pole	Four-pole
Inverter capacity available for combination		Same as or one rank higher than the motor capacity	
Supported model		FREQROL-A500, A700	FREQROL-E500
Speed control range (at driving)		1:120	1:15

2.4.4 Real sensorless vector control

This control divides the inverter output current into an excitation current and a torque current by vector calculation and controls frequency and voltage optimally to flow a motor current which meets the load torque. By this, the low-speed torque, speed control range and speed response can be improved, and a high torque of up to 200% (3.7kW or less) can be obtained at 0.3Hz.

- This control uses the estimated speed, which is calculated from the motor current and output voltage, as a speed feedback value. Also, this control has the current control loop as the vector control does, which separately allows the calculations for a necessary excitation current (a current necessary to generate a magnetic flux) and a torque current (a current proportional to the load torque).

By controlling a torque current, responses to load changes become faster (fast response). Also, by issuing torque commands, the torque control is possible.

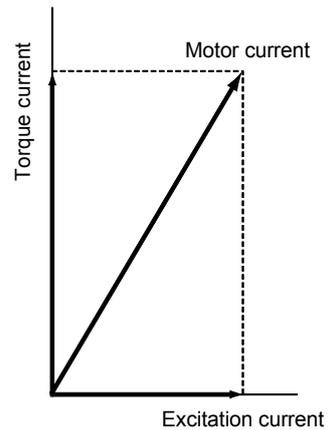


Fig. 2.24 Real sensorless vector control

- ★ Using the real sensorless vector control, high accuracy/fast response speed operation by the vector control can be performed with a general-purpose motor without encoder.

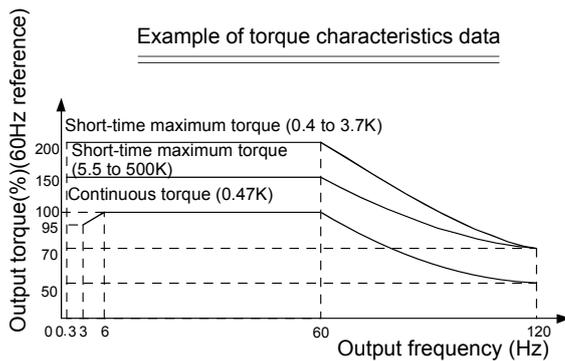


Fig. 2.25 Torque characteristics example For the motor SF-JR4P (with 220V input)

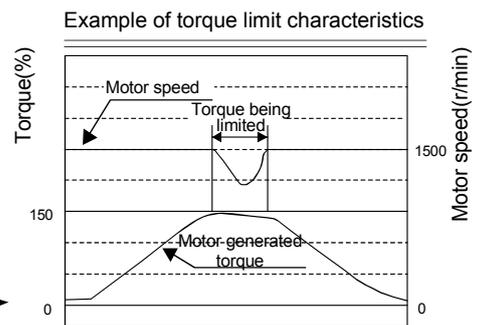


Fig. 2.26 Torque limit characteristics example For the motor SF-JR4P 3.7kW

Item		Real sensorless vector control	Advanced magnetic flux vector control
The number of motors in combination use		1:1	1:1
Motor available for combination	Standard motor	Two-pole, four-pole, six-pole	Two-pole, four-pole, six-pole
	Constant torque motor	Four-pole	Four-pole
Inverter capacity available for combination		Same as or one rank higher than the motor capacity	
Supported model		FREQROL-A700	FREQROL-A700, A500
Speed control range (at driving)		1:200	1:120
Speed control		○	○
Torque control		○	×
Position control		×	×

2.4.5 Vector control

V500

A700+A7AP

Detect a motor speed with an encoder and calculate a motor slip to identify the load magnitude.

This control is a system which divides the inverter output current into an excitation current (a current necessary to generate a magnetic flux) and a torque current (a current proportional to the load torque) by vector calculation and controls a frequency and voltage optimally to flow a necessary current individually according to this load magnitude.

The vector control has the current control loop, which separately allows the calculations for a necessary excitation current and a torque current.

By controlling a torque current, responses to load changes become faster (fast response). Also, by issuing torque commands, the torque control is possible.

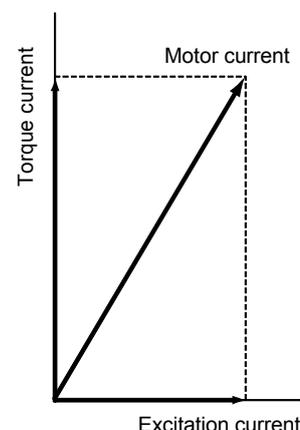


Fig. 2.27 Vector control

To accurately calculate them, when using the vector control, use a dedicated motor featuring stable constants with an encoder featuring high accuracy.

For the vector control, a standard motor can also be used with an encoder installed on it. However, torque control is less accurate in such case.

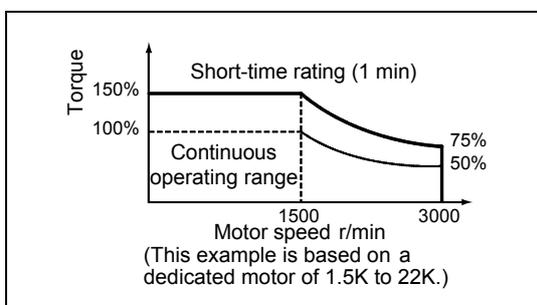


Fig. 2.28 Example of vector control dedicated motor output characteristics

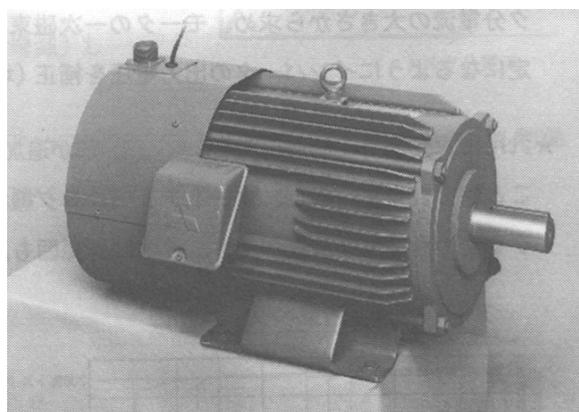


Fig. 2.29 Appearance of vector control dedicated motor (SF-V5R)

Item	Real sensorless vector control	Vector control
Motor	Standard motor	Dedicated motor, standard motor
Encoder	Not required	Required
Speed control range (at driving)	1:200	1:1500
Parameter setting	Simple	Not simple (detailed data required)
Response	○	◎
Speed control	○	○
Torque control	○	○
Position control	×	○

Real sensorless vector control

The vector control is a system that rotates and controls a dedicated squirrel-cage motor with an encoder or a standard squirrel-cage motor with an encoder in virtually the same manner for rotating and controlling a DC motor.

On the other hand, the real sensorless vector control is a system developed to rotate a standard squirrel-cage motor in the condition similar to that for the vector control.

Features of the real sensorless vector control system

- (1) In the vector control, the motor speed of the rotor is detected by the encoder installed at the shaft end and therefore the motor speed detection can be made accurately. On the other hand, in the real sensorless vector control, the motor speed of the rotor is estimated based on the motor voltage and current. This is why the detection is less accurate, but a standard motor can be used.
- (2) The real sensorless vector control is applicable for the applications such as to minimize speed fluctuation, needs for low speed torque, to prevent machine from damage due to too large torque (torque limit), and torque control.

Note that with a severe load fluctuation, systems may become unstable for some equipment. In such cases, use the advanced magnetic flux vector control.

Also note that speed cannot be estimated at nearly 0Hz of the output frequency. To perform torque control in the low speed region or at a low speed with light load, perform the vector control using an encoder.

2.4.6 Auto tuning function

With this function, an off-line inverter itself measures and stores motor circuit constants necessary for rotating in the general-purpose magnetic flux vector control, advanced magnetic flux vector control, real sensorless vector control and vector control.

More precisely, by turning the auto tuning command on, an inverter outputs the motor excitation signal with certain conditions. From values obtained at this time, such as a value of the current that flew, the inverter internally calculates the motor resistance values r_1/r_2 , inductance values $L_1/L_2/M$, etc. and then saves them to the memory.

Note that in the general-purpose magnetic flux vector control, the motor resistance value r_1 is calculated inside the inverter.

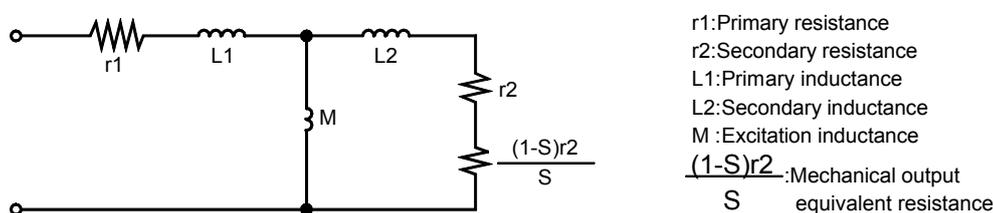


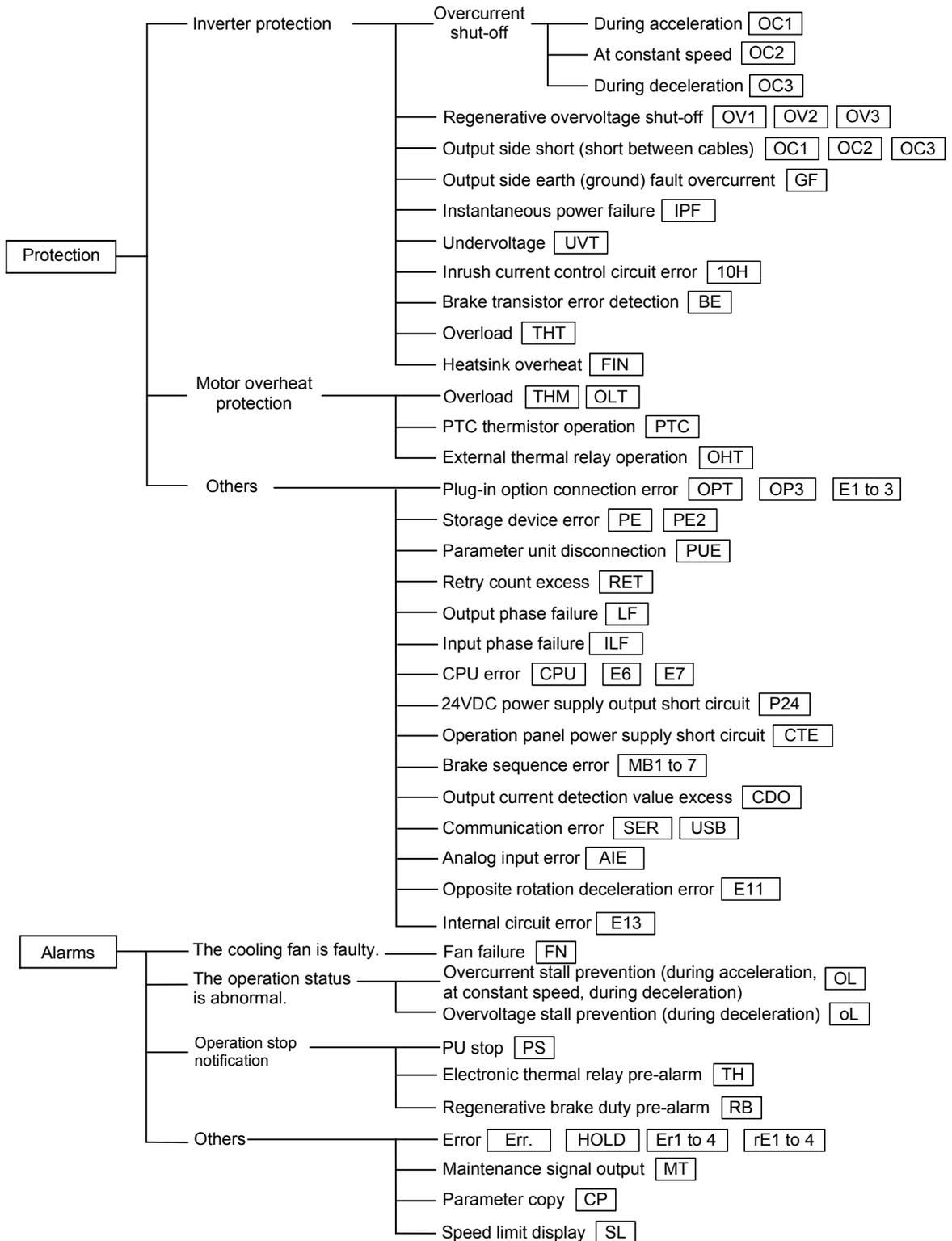
Fig. 2.30 Equivalent circuit of an induction motor

- An inverter itself measures the motor constants even with a special motor or other manufacturer's motor. This extends an application range and improves ease of use.
- The accurate measurement of the motor constants allows starting torque and low-speed torque to be improved.
- Wiring lengths of over 30m are supported by the advanced magnetic flux vector control, real sensorless vector control and vector control.
- Two types of the off-line auto tuning modes (FREQROL-A700 series) are available, and the tuning that matches your machinery can be performed.
 - Simpler and quicker constant measurement without motor rotation
 - Better magnetic flux vector control by more accurate constant measurement with motor rotation
- Online auto tuning (FREQROL-A700 series)
 - By quickly tuning the motor status at a start, high accuracy operation unaffected by the motor temperature and stable operation with high torque down to ultra low speed can be performed.

2.5 Protective Function

2.5.1 Purposes and types of protective functions

An inverter provides various protective functions whose purposes are largely classified into those to "protect the inverter" and those to "protect a motor from overheat". In addition to the protective functions, an inverter is equipped with alarm functions to inform that the operation status is abnormal. The following explanations are made based on the FREQROL-A700 series inverter.



2.5.2 Mechanism of protective functions

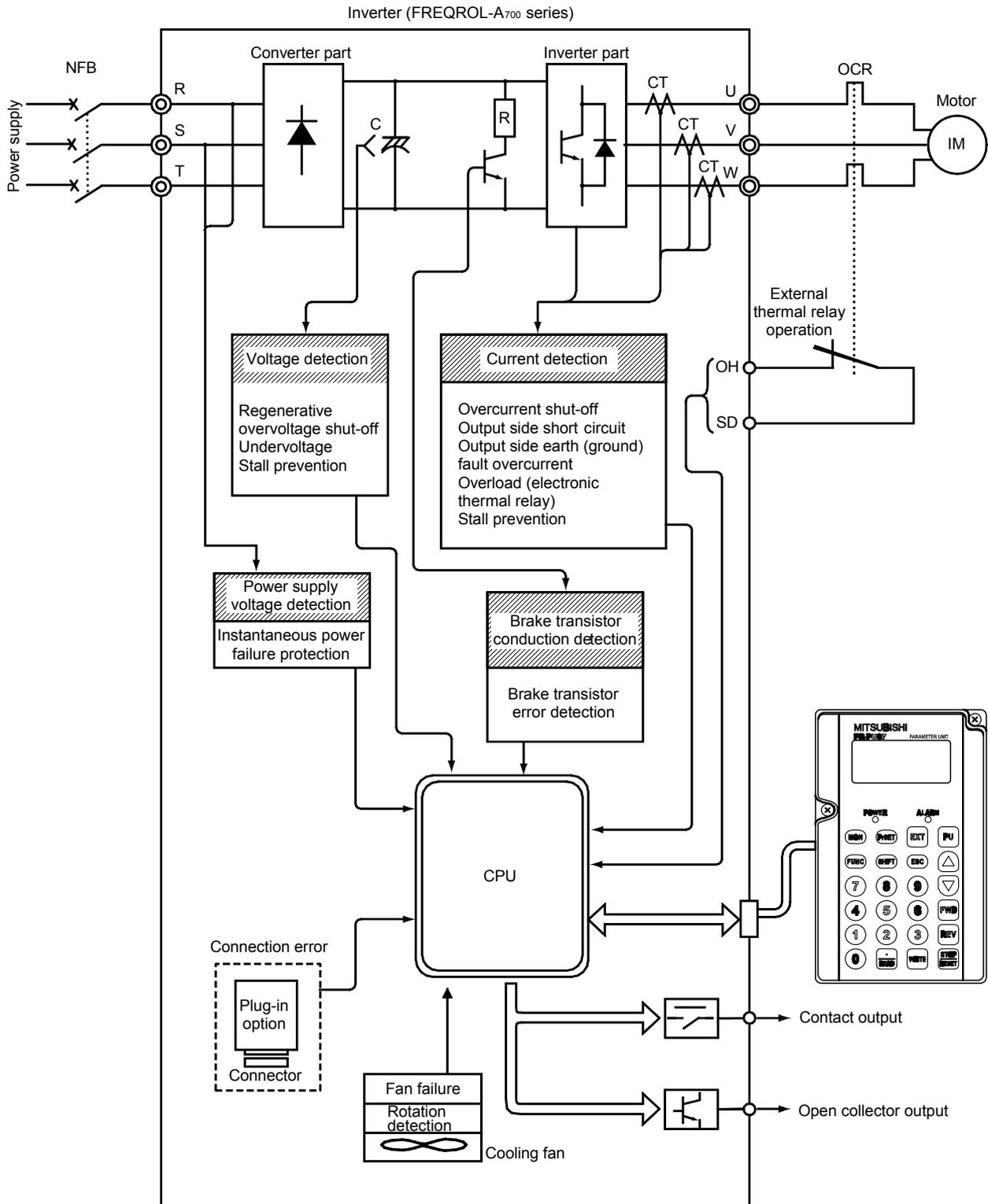
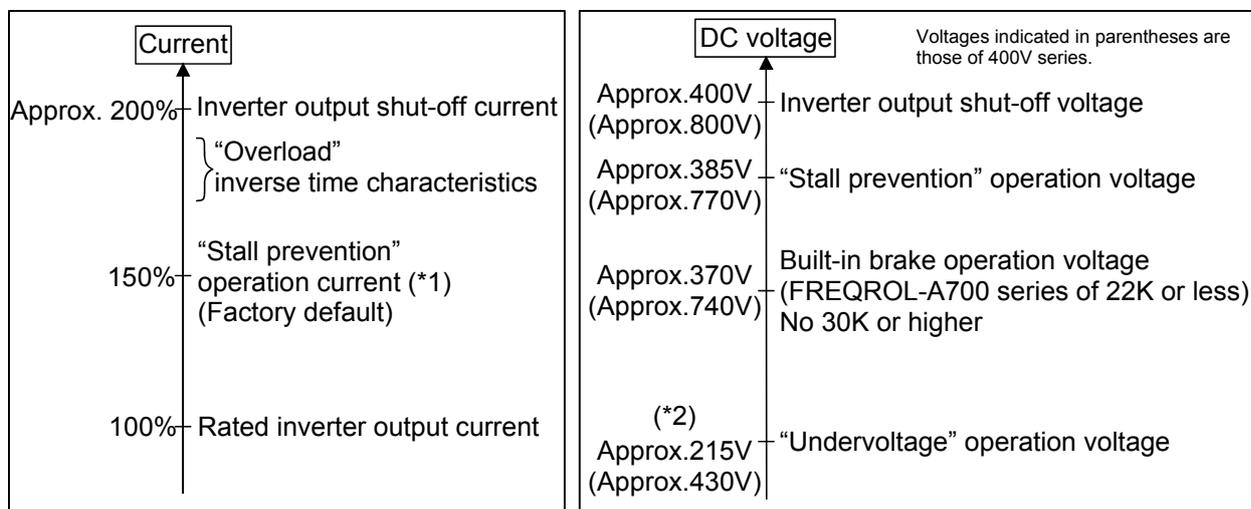


Fig. 2.31 Protective functions related circuit

2.5.3 Current/voltage level at which protective functions operate

The protective functions operate when the detected current or voltage is at the level shown below.



(*1) Replaced by changed operation current (%) if the operation current level is changed.

(*2) Approx. 150V (Approx. 300V) in the AC input voltage

Good to know for checking an inverter

A regenerative overvoltage shut-off (OV1 to OV3) is a phenomenon that occurs only when a regenerative power from a motor is large. Note, however, that an inverter occasionally trips while a motor is at stop due to overvoltage. This phenomenon occurs in the following process: surge voltage is applied from the power supply side, the smoothing capacitor is charged, and the voltage level reaches the output shut-off voltage level. The most possible source of this phenomenon is the switching operation of the power factor adjustment capacitor in the power supply system (high or low pressure). To avoid this phenomenon, install an AC reactor (or power factor improving reactor).

2.5.4 Display and output signals when protective functions operate

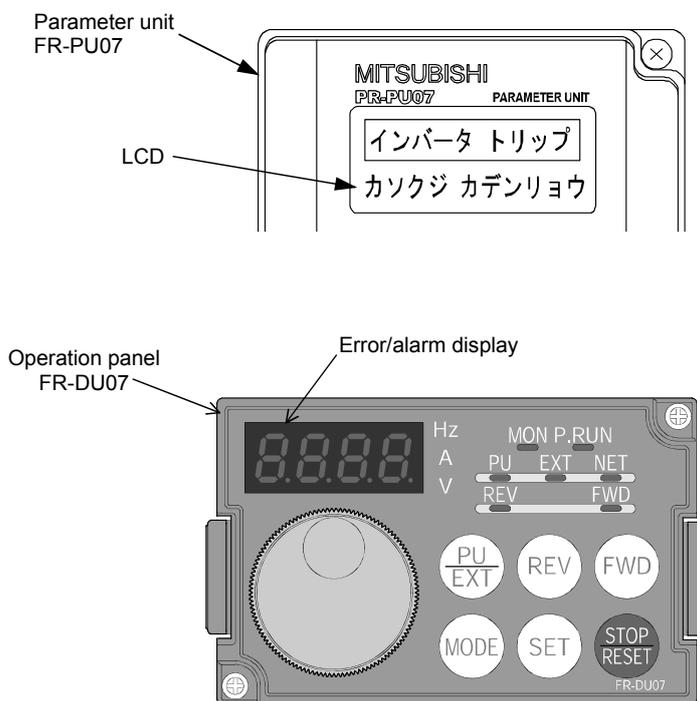
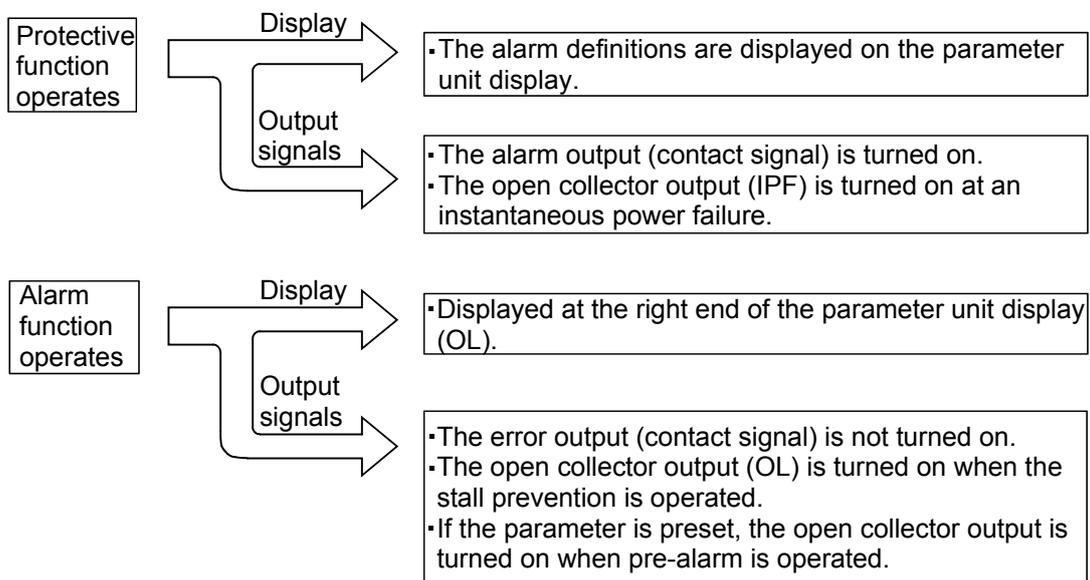


Fig. 2.32 Display example at error occurrence

2.5.5 Reset method

(1) When a protective function operates, the parameter unit indicates an error on its display and the inverter outputs an alarm signal to disable its outputs.

(2) Reset the inverter to restart it. The inverter holds the abnormal status until reset.

Follow the procedure below to reset the inverter.

1) Short the reset terminals RES-SD, which are provided with the inverter, for 0.1 second or longer, and then open the terminals.

(The inverter cannot be restarted with the terminals shortened.)

2) Open the power supply terminals (R, S, T) once, wait 0.1 second or longer, and then close them.

3) Use the inverter reset function provided in the help functions of the parameter unit.

4) Press the RESET key of the parameter unit (operation panel).

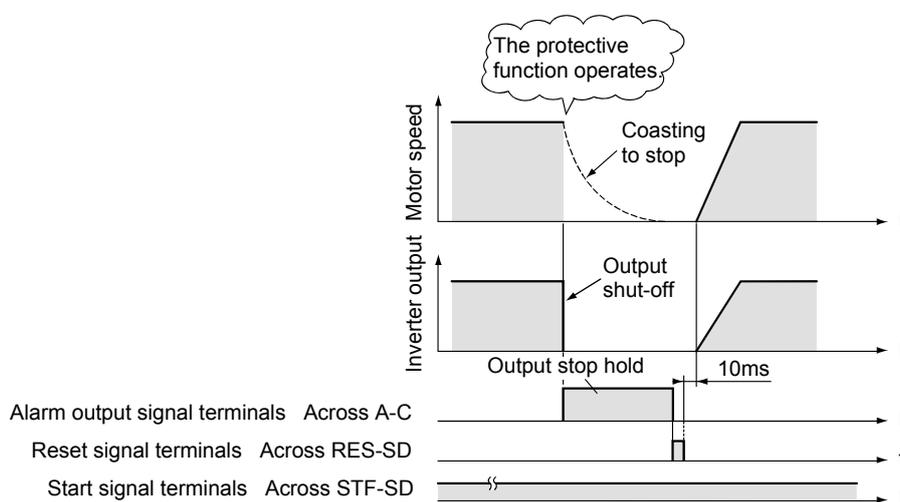


Fig. 2.33 Timing chart of the reset operation

Good to know for checking an inverter

If the reset is performed with the inverter while the motor is rotating, the transistor base shut-off is performed, and then the motor starts coasting. If the reset signal is turned off, the motor, which is currently coasting, restarts rotating (the inverter restarts from the starting frequency). This may cause an overcurrent trip. For this reason, do not reset the inverter while the motor is rotating.

2.5.6 Retry function

When an alarm occurred in an inverter, if the retry function is enabled, the inverter can automatically reset the alarm, restart and continue the operation. When this function is selected, stay away from the inverter as it will restart suddenly after an alarm stop.

2.6 Acceleration/Operating Characteristics of Inverter

2.6.1 Start

Input the inverter start signal (turn on the terminals STF-SD or STR-SD) and the frequency command signal to the inverter. Then the inverter outputs the starting frequency, and the motor generates torque.

If the motor start torque in the starting frequency is larger than the load start torque, the motor starts rotating. If the load torque is larger than the motor start torque, the motor stays locked. In such a case, increase the output frequency gradually. The motor starts rotating when the motor start torque exceeds the load torque T_L as shown in Fig. 2.34.

Note that high motor starting frequency generates a large motor lock current. If this current exceeds the current limit, overcurrent (OC1) or overload (THT) may occur, resulting in a trip.

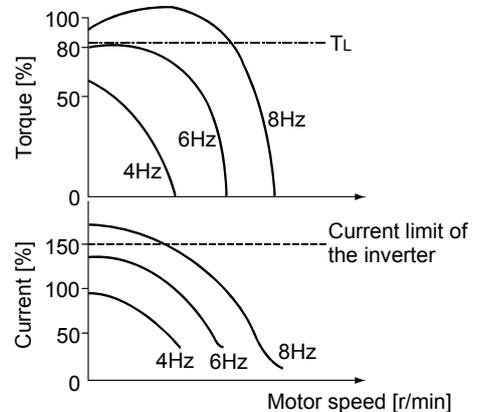


Fig. 2.34 Start torque

When a motor is rotated by an inverter (V/F control), the definition of motor start torque differs from that of when rotated by a commercial power supply and is as follows.

In the low-frequency range, the start torque refers to the maximum torque that can be generated with up to 150% larger capacity than the inverter overcurrent capacity. The term start torque in this context differs in definition from start torque used in commercial power supply related context. Accordingly, start torque with the definition introduced in this section is referred to as "maximum start torque".

Refer to Fig. 2.34 to understand the maximum start torque. The figure shows that the maximum output frequency within the current limit of the inverter is 6Hz. Therefore, the maximum start torque is the maximum torque at 6Hz.

In frequencies lower than 6Hz, locking the motor shaft does not cause an overcurrent trip on the inverter. Note, however, that locking for a long time may cause an overload shut-off (THM).

Good to know for checking an inverter

An inverter is provided with a function that sets the starting frequency (0 to 60Hz).

The higher the starting frequency is, the larger the motor start torque and starting current are. Do not change the default start frequency unless there is a load such as a vertical lift load whose load torque is larger than the motor torque at start, causing the motor to rotate in the reverse direction.

To increase the start torque, adjust the manual torque boost.

2.6.2 Acceleration

After started up, an inverter gradually increases the output frequency to the frequency command value in accordance with the acceleration time setting value.

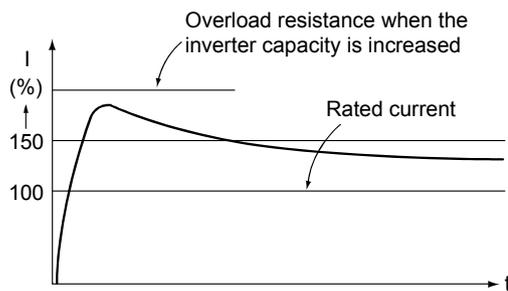
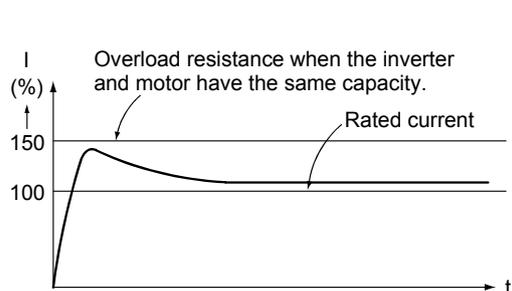
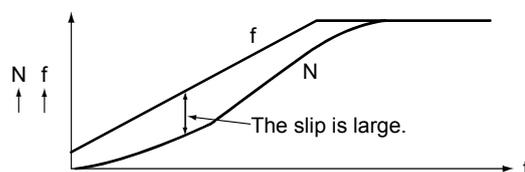
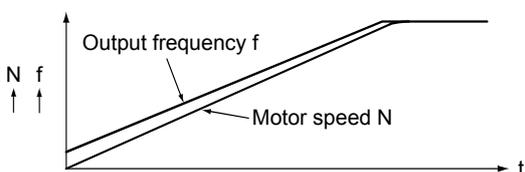
As described in Section 1.3.3 Slip, the motor accelerates with a delay of the slip compared to the synchronous speed, which is proportional to the motor output frequency f .

A value of this slip depends on values of the load inertia moment, load torque and motor generated torque. If the acceleration time is set sufficiently long, the output frequency f and motor speed N increase in proportion to each other.

(Refer to Table 2.35.)

Note that too short acceleration time causes a large gap between f and N , by which f and N increase with a large slip value (refer to Fig. 2.36.). This makes a motor current larger and may generate overcurrent, resulting in protective functions, such as the stall prevention function or the overcurrent shut-off function, to operate. (If an inverter capacity is increased whereas a motor capacity is not increased, the overcurrent resistance becomes relatively higher. Accordingly, the protective functions will be hard to operate.)

With a general-purpose inverter, to minimize the start current, the acceleration time must be set in accordance with the load as described above.



**Fig. 2.35 Acceleration characteristics
(with sufficient acceleration time)**

**Fig. 2.36 Acceleration characteristics
(with insufficient acceleration time)**

Good to know for checking an inverter

Generally, if a motor is powered directly from a commercial power supply, a current that is 6 to 7 times larger than the rated current flows in the motor (refer to Section 1.4). The motor starts in the acceleration time that is defined by the load characteristics (refer to Section 1.9.1).

If an inverter with the same capacity as the motor capacity is used to directly start the motor (e.g. On the inverter output side, turn MC on.) in the same manner, a trip occurs with the start current. Therefore, an inverter must start with a low frequency to start a motor. (At approximately 3 to 6Hz, the start current does not exceed 150% of the rated current.)

The reason that nothing must be turned on or off on the inverter output side is that the start current is directly input and flows as described above.

2.6.3 Overcurrent stall prevention

During acceleration, if a motor current exceeds 150% (overload resistance of an inverter), the inverter stops increasing or decreases the output frequency. This is to avoid the overcurrent shut-off protective function being operated.

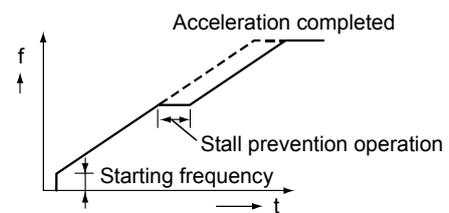


Fig. 2.37 Stall prevention operation during acceleration

Good to know for checking an inverter

Measures for when the overcurrent shut-off **OC1** operated during acceleration

- (a) When a trip occurs right after the start signal is turned on
 - Decrease the manual torque boost.
 - Increase the manual torque boost. Or, increase the starting frequency.
 - ***This measure is applied to when the motor is rotating in the reverse direction (such as when a vertical lift load is used).
- (b) When the motor trips and does not accelerate after its rotation is started
 - Set a longer value to the acceleration time.
 - Increase the manual torque boost.
 - Modify mechanical looseness. *** This measure is applied to when the machine does not start even though the motor rotates.
- (c) When a trip occurs at 10-odd Hz or higher
 - Set a longer value to the acceleration time.

* With the FREQROL-A700 series, the inverter output frequency at a trip can be read by the monitor function of the parameter unit.

The parameter unit shows the alarm contents when a trip occurred. To display the frequency, output current and output voltage at the trip, switch the display with the shift key.

2.6.4 Constant-speed operation

When the output frequency matches the frequency command value, the acceleration ends and the motor continues to rotate at a constant speed.

Overcurrent stall prevention

During the constant-speed operation, if a motor current exceeds 150% (overload resistance of an inverter), the inverter decreases the output frequency once to prevent an overcurrent-caused trip from occurring.

The inverter returns the output frequency to the original value when a motor current becomes smaller than 150%.

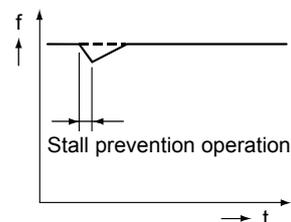


Fig. 2.38 Stall prevention operation at a constant speed

Good to know for checking an inverter

Measures for when the overcurrent shut-off **OC2** operated during the constant-speed operation

- (a) When the operation is performed at the base frequency or lower
 - Increase the manual torque boost.
- (b) When the operation is performed at 10Hz or lower
 - Decrease the manual torque boost.
- (c) Increase the inverter capacity if the load torque is temporary larger than 150% of the rated motor torque.

2.7 Deceleration/Stop Characteristics of Inverter

2.7.1 Deceleration

When the inverter start signals (STF and STR) are turned off or when the frequency command signal is set to a value below the output frequency, an inverter decreases the output frequency in accordance with the deceleration time setting value.

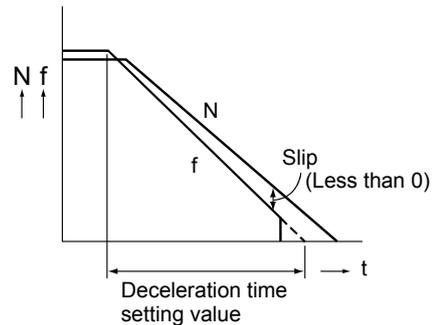


Fig. 2.39 Deceleration characteristics

During deceleration, the motor speed is faster than the synchronous speed, which is equivalent to the inverter output frequency. In this condition, the motor functions as a generator and returns the energy to the inverter. This is why DC voltage (voltage of the smoothing capacitor) increases.

↳ This operation is called regeneration.

To stop a motor rotating with a commercial power supply, turn off the magnetic contactor used for stopping a motor. The motor coasts to stop using the load torque as a braking force. (Refer to Section 1.9.1 for stop time.)

With an inverter used, the motor does not coast to stop by turning the start signal off but decelerates to stop in accordance with the deceleration time setting value.

Depending on the deceleration time setting value, the motor goes into the following status.

Table 2.2 Relationship between deceleration time and regeneration

Deceleration time condition	Motor status	Motor slip
Deceleration time setting value > Coasting stop time	Driving (motor)	3 to 5% or less
Deceleration time setting value < Coasting stop time	Regeneration (generator)	Less than 0

During regeneration, a motor functions as a generator, charging the smoothing capacitor on the converter part. Therefore DC voltages of this smoothing capacitor increase at its both ends (voltage between the terminals P-N).

If the set deceleration time is too short, the regenerative overvoltage protection function or overcurrent (regenerative current) protection function operates. Set longer deceleration time to avoid this. If the inverter does not have a regenerative brake circuit, install the optional product FR-BU type brake unit or FR-CV/FR-RC type power regeneration converter.

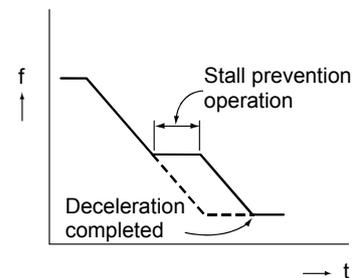


Fig. 2.40 Stall prevention operation during deceleration

▪ Overvoltage stall prevention

If the DC voltage becomes even higher, the inverter stops decreasing the output frequency. This is to avoid the regenerative overvoltage shut-off protective function being operated.

- Overcurrent stall prevention

During deceleration, if a motor current exceeds the specified value, the inverter stops decreasing or increases the output frequency. This is to avoid the overcurrent protective function being operated.

2.7.2 Stop

- (1) When the inverter start signal (STF/STR) is turned off, the motor decelerates as shown in Fig. 2.40. When the output frequency goes down to the DC injection brake operation frequency or lower, the DC voltage is applied to the motor, and then the motor stops. This is called DC injection brake.

After the DC injection brake is performed for a certain time, the base signal of a transistor is turned off, by which the output is shut off.

- (2) If the magnetic contactor (MC) on the inverter input side is turned off, a power failure is detected and the base circuit of the transistors is shut off. As a result, the motor coasts to stop. Therefore, when using the inverter to make the motor stop through deceleration, do not turn off the input power supply of the inverter.

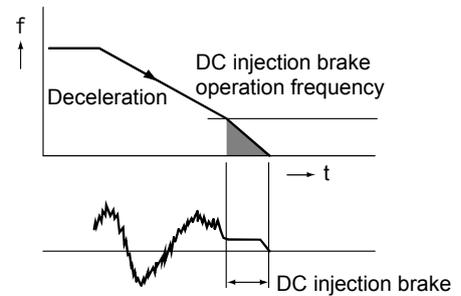


Fig. 2.41 DC injection operation

DC injection brake

When the DC voltage is applied to a motor which is rotating, a brake torque is generated. This brake torque becomes zero when the motor stops.

(The operation frequency, operation time and operation voltage can be changed.)

Good to know for checking an inverter

Measures for when the overcurrent shut-off OC3 operated during deceleration

- (a) When a motor with a brake is used and trips right after deceleration starts

Refer to Section 3.5.7.

- (b) When a trip occurs right before (while the DC injection brake is in operation) the motor stops

- Decrease the DC injection brake voltage.

- (c) Set a longer value to the deceleration time.

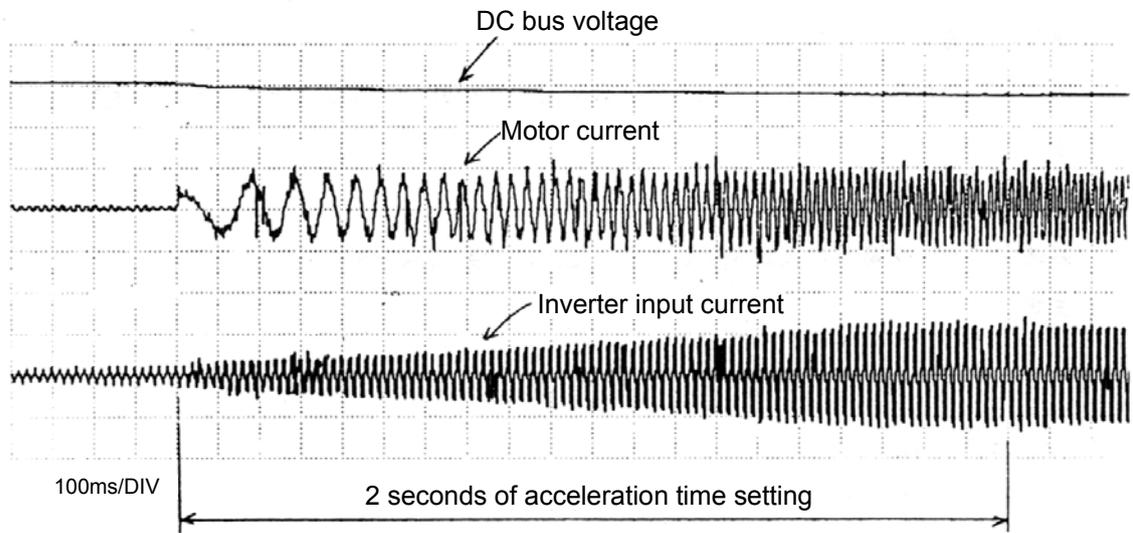


Fig. 2.42 Measurement example of acceleration characteristics

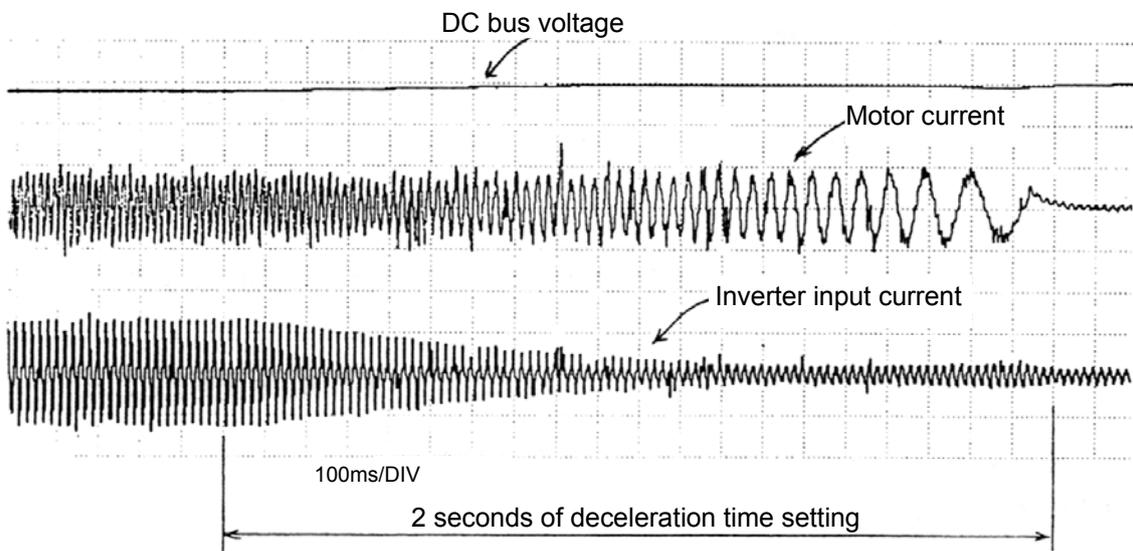


Fig. 2.43 Measurement example of deceleration characteristics

2.8 Efficiency and Power Factor of Inverter

2.8.1 Efficiency

As described in Section 2.1, an inverter is a power supply conversion unit consisting of a section that performs forward conversion (the converter part) and the other section that performs reverse conversion (the inverter part), and therefore a loss is unavoidable for such conversion sections. In spite of the loss, generally, inverters are said to improve power saving. The following describes the reason of this using the formula of an inverter input current and efficiency.

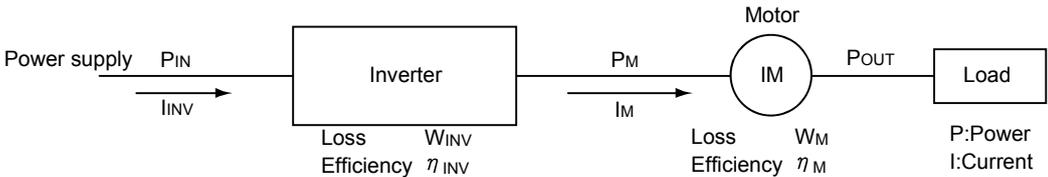


Fig. 2.44 I/O current relation chart

$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Output}}{\text{Output} + \text{Loss}} \dots\dots\dots (2.1)$
$\text{Inverter input power } P_{IN} = \text{Inverter output power (Motor input power)} + \text{Inverter loss } W_{INV} = \frac{\text{Inverter output power } P_M}{\text{Inverter efficiency } \eta_{INV}} \dots (2.2)$
$\text{Motor input power } P_M = \text{Motor output } P_{OUT} + \text{Motor loss } W_M = \frac{\text{Motor output } P_{OUT}}{\text{Motor efficiency } \eta_M} \dots\dots\dots (2.3)$
$\text{Motor output } P_{OUT} = \text{Motor output torque} \times \text{Motor speed} = \frac{\text{Machine force}}{\text{Machine efficiency}} \dots\dots\dots (2.4)$

From the above, the inverter input current can be calculated as follows:

$\text{Inverter input power} = \text{Motor output} + \text{Motor loss} + \text{Inverter loss} = \frac{\text{Motor output}}{\text{Total efficiency}} \dots\dots\dots (2.5)$
$\text{Total efficiency} = \text{Inverter efficiency } \eta_{INV} \times \text{Motor efficiency at inverter drive } \eta_M \dots\dots\dots (2.6)$

As shown in Formula (2.5), when a motor is rotating, a motor loss is larger with an inverter than with a commercial power supply due to harmonic, etc. In addition to this, there is an inverter loss if an inverter used. Therefore an inverter needs larger input power than a commercial power supply does to realize the same motor speed. However, if the motor speed is decreased by an inverter, the motor output decreases in the same manner. Accordingly, the lower the speed becomes, the less the input power is needed even if the load torque is constant. (Especially, if reduced-torque loads such as a fan or pump are the target, the input power needed decreases more greatly, realizing better energy saving.)

2.8.2 Power factor

Normally, as shown in Fig. 2.45, a power factor can be calculated from a phase angle ϕ between voltage and current. For an inverter, however, a power factor cannot be defined as $\cos\phi$ since the input current of an inverter is in a distorted waveform including harmonic as described in Section 2.2. (A power-factor meter indicates approximately 1 if used.) On the other hand, a power factor is equivalent to a ratio of the effective power to the apparent power. Therefore the power factor for an inverter can be calculated in Formula (2.7).

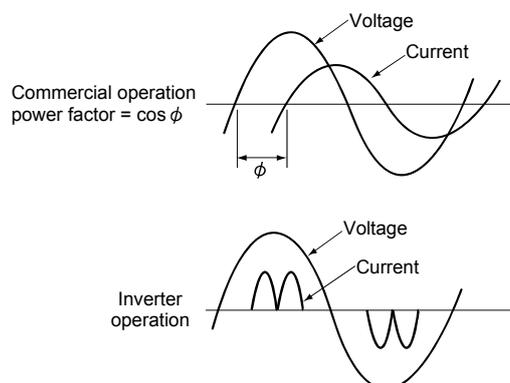


Fig. 2.45 Input voltage/current waveform (3-phase)

$$\begin{aligned}
 \text{Power factor} &= \frac{\text{Effective power}}{\text{Apparent power}} = \frac{\text{Effective power } P_{IN}}{\text{Effective power} + \text{Ineffective power}} \\
 &= \frac{\text{Inverter output power } P_{IN}}{\sqrt{3} \times \text{Power supply voltage} \times \text{Inverter input current } I_{INV}} \dots\dots\dots (2.7)
 \end{aligned}$$

2.8.3 Inverter input current and power factor improvement

In the waveform of inverter input current, a distortion ratio changes in accordance with the impedance (reactance of transformers or cables) on the power supply side, resulting in the change of input current (effective) value. However, as described in Section 2.8.1, the power supply voltage and inverter input power do not change as long as the motor output does not change. Therefore, Formula (2.7) is used to change a power factor. The smaller the reactance on the power supply side is, the smaller the current is (i.e. the better the power factor is). With an inverter installed near a large-capacity power supply converter, the current increases if the reactance is small, deteriorating the power factor.

Therefore, to improve a power factor, make the power supply reactance larger. To do so, install a reactor on the DC circuit of the inverter (improved to approximately 93% by a power factor improving DC reactor) or on the AC input side (improved to approximately 88% by a power factor improving AC reactor).

A power factor of commercial power supplies is in the range of 0.75 to 0.85, which is almost constant. This is why the formula of "current \doteq voltage" can be formed. In contrast, a power factor for inverters considerably changes from about 0.6 to 0.9 depending on the condition of the power supply reactance, and therefore the formula cannot be formed for inverters. Consequently, an inverter input current may become smaller than the motor current while the rated torque is output.

For further understanding, calculate actual numerical values in Example which follows.

1) Power factor improving AC reactor FR-HAL(H)

A power factor improving AC reactor improves a form factor of the inverter input current and a power factor, reducing the power supply capacity. Also, it is effective in reducing the input side harmonic current.

Improvement effect	Power supply power factor 88% (when load is 100%)
Operating environment	• Ambient temperature -10 to +50°C
	• Ambient humidity 90%RH • Vibration 5.9m/s ² or less
	• Ambiance No dust and dirt, corrosive gas, flammable gas
Voltage	3-phase 200 to 240VAC 50/60Hz (380 to 480V 50/60Hz)
Connecting method	Connect to the inverter input side.

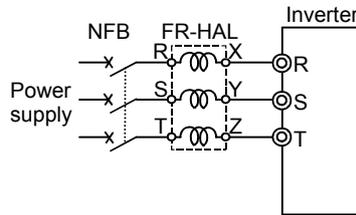
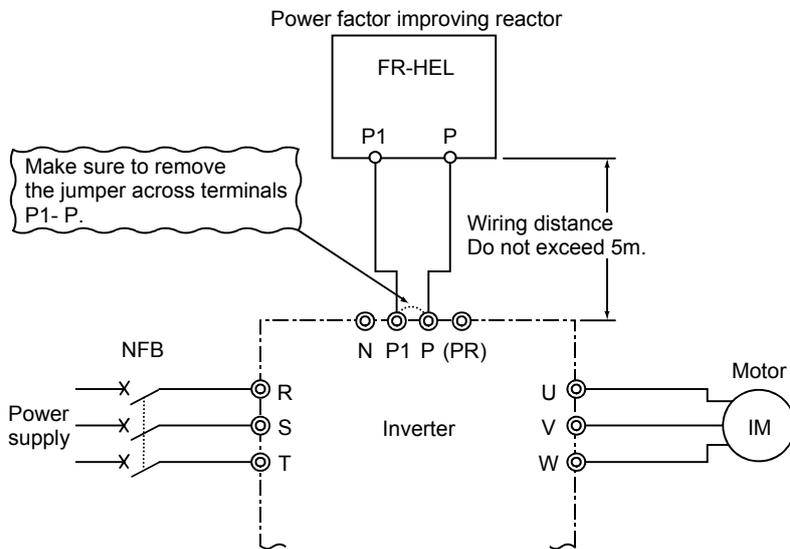


Fig. 2.46 FR-HAL connection example

2) Power factor improving DC reactor FR-HEL(H)

The DC reactor is smaller and lighter than the AC reactor and allows less loss with the same effect.

Power factor improving effect	Power supply power factor 93% (when load is 100%)
Operating environment	• Ambient temperature -10 to +50°C
	• Ambient humidity 90%RH
	• Vibration 5.9m/s ² or less
	• Ambiance No dust and dirt, corrosive gas, flammable gas



*The cable between the reactor and the inverter should be 5m or less and as short as possible. The size of the cable should be the same as or larger than that of the power supply cable.

Fig. 2.47 FR-HEL connection example

Good to know for checking an inverter

By making the input current smaller with a power factor improving reactor, the following advantages are obtained.

- Peripheral devices on the inverter input side can be smaller.
- Harmonic current can be smaller.
- An inverter can be protected from the surge voltage of the power supply side
- The peak current of the converter part at power on can be suppressed.

A power factor improving AC reactor provides the power factor improvement of approximately 88% at the best, whereas a DC reactor provides 93%.

Example

Calculate an input current, motor current and inverter input current respectively for each of the following conditions: a conveyor is operated at 30m/min with a commercial power supply, a conveyor is operated at 30m/min and 15m/min with an inverter.

Given values are: the power supply is 200V60Hz, the motor efficiency $\eta_M = 0.9$, the motor power factor $\cos\phi = 0.88$

(1) Commercial operation (30m/min)

$$P_M = P_{OUT} / \eta_M = 7.5 / 0.9 = 8.33 \text{ [kW]}$$

$$I_M = \frac{P_M}{\sqrt{3} \times E \times \cos\phi} = \frac{8.33 \times 10^3}{\sqrt{3} \times 200 \times 0.88} = 27.3 \text{ [A]}$$

(2) Inverter operation (30m/min)

$$P_M = P_{OUT} / \eta_{M'} = 7.5 / 0.85 = 8.82 \text{ [kW]} \quad (\eta_{M'} = 0.85)$$

$$P_{INV} = P_M / \eta_{INV} = 8.82 / 0.95 = 9.29 \text{ [kW]} \quad (\eta_{INV} = 0.95)$$

$$I_M = \frac{P_M}{\sqrt{3} \times E \times \cos\phi} = \frac{8.82 \times 10^3}{\sqrt{3} \times 200 \times 0.88} = 28.9 \text{ [A]}$$

$$I_{INV} = \frac{P_{INV}}{\sqrt{3} \times E \times \text{Inverter power factor}} = \frac{9.29 \times 10^3}{\sqrt{3} \times 200 \times \text{Inverter power factor}}$$

When inverter power factor is 0.93 : $I_{INV} = 28.8 \text{ (A)}$

When inverter power factor is 0.7: $I_{INV} = 38.3 \text{ (A)}$

(3) Inverter operation (15m/min)..... $P_{OUT} = 7.5 \text{ [kW]} = 15/30 = 3.75 \text{ [kW]}$

$$P_M = P_{OUT} / \eta_{M'} = 3.75 / 0.8 = 4.69 \text{ [kW]} \quad (\eta_{M'} = 0.8)$$

$$P_{INV} = P_M / \eta_{INV} = 4.69 / 0.9 = 5.21 \text{ [kW]} \quad (\eta_{INV} = 0.9)$$

$$I_M = \frac{P_M}{\sqrt{3} \times E \times \cos\phi} = \frac{4.69 \times 10^3}{\sqrt{3} \times 200 \times 0.85} = 31.8 \text{ [A]} \quad (\cos\phi = 0.85)$$

(E=100V if V/f is constant)

$$I_{INV} = \frac{P_{INV}}{\sqrt{3} \times E \times \text{Inverter power factor}} = \frac{5.21 \times 10^3}{\sqrt{3} \times 200 \times 0.7} = 21.5 \text{ [A]}$$

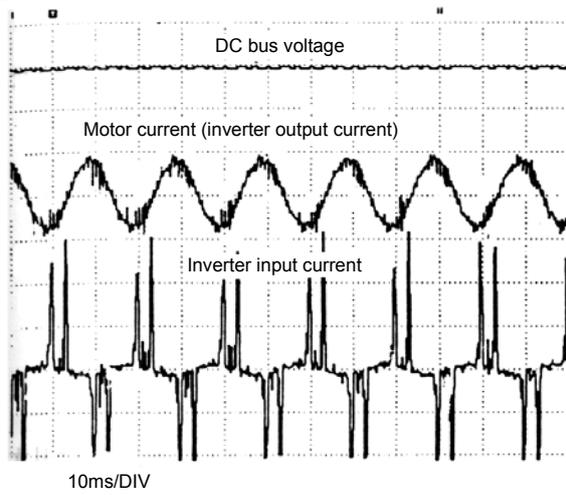


Fig. 2.48 Measurement example of I/O current waveform (50Hz)

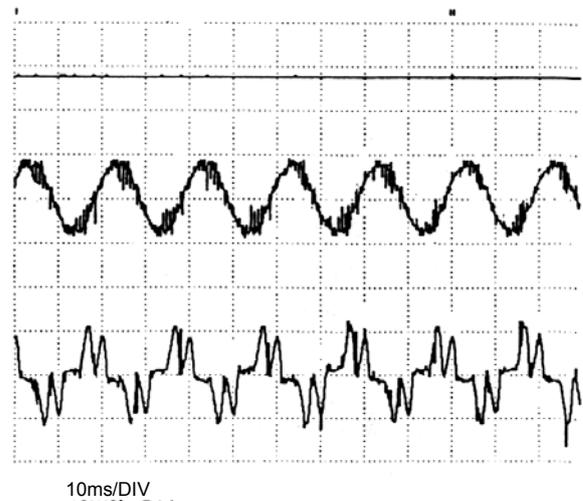


Fig. 2.49 Measurement example of I/O current waveform (with a power factor improving reactor of 50Hz)

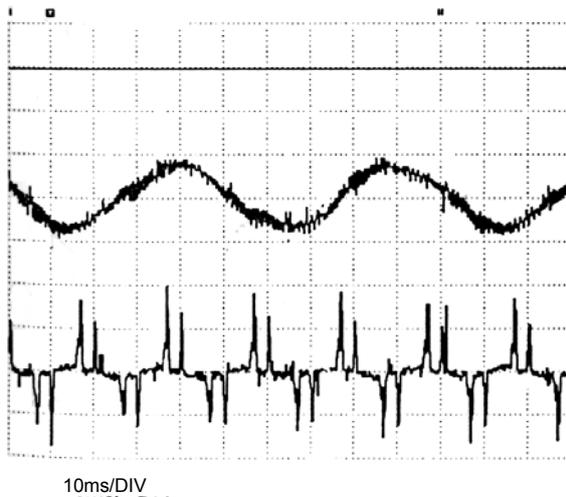


Fig. 2.50 Measurement example of I/O current waveform (20Hz)

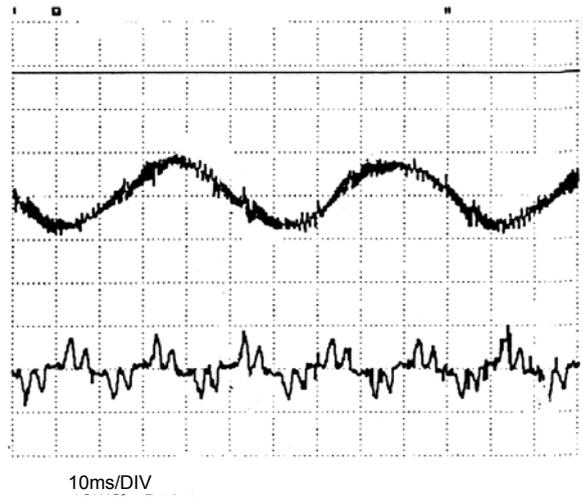


Fig. 2.51 Measurement example of I/O current waveform (with a power factor improving reactor of 20Hz)

3. CAPACITY SELECTION AND OPERATION METHOD FOR MOTOR AND INVERTER

This chapter describes points and measures when an inverter is selected according to the capacity, number and operation status of a motor to be driven.

Since the detailed explanation on the actual capacity selection is given in technical notes, this chapter casts a general notion of capacity selection.

Points for understanding!

1. Most suitable combination of motor and inverter capacities
2. Capacity selection for driving multiple motors
3. Difference between acceleration and deceleration

3.1 Capacity Selection

When an inverter is considered to be the power supply of a motor, the larger capacity inverters are better. The larger capacity inverters can directly start (turn on/off on the inverter output side) motors as if a commercial power supply is used. However, it is not preferable to increase the needless capacity when the economic efficiency and dimensions are taken into account.

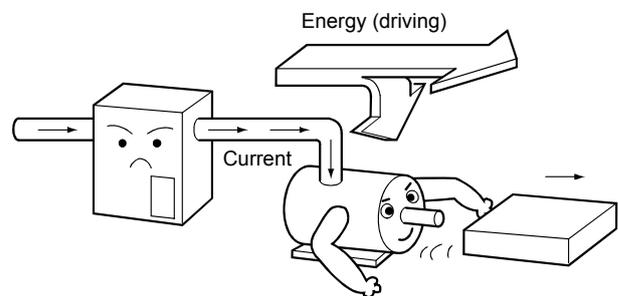
To make a selection for the most suitable capacity which allows the trouble-free operation, clearly understand the following sections.

3.1.1 Capability of inverter

The capability (not function) to drive a motor can be known by understanding the flow of an energy changed according to operation status.

- (1) During acceleration or constant-speed operations

The capability is a peak current which indicates the largest current an inverter can offer when a motor requests. This amount is expressed as a rated output current or an overload current rating.

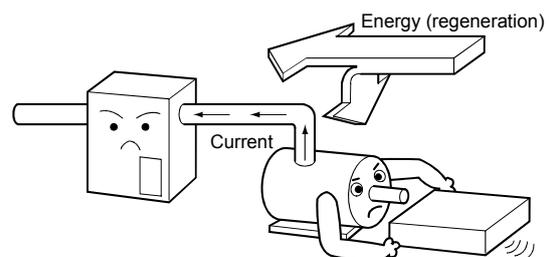


- (2) During deceleration

During deceleration, a motor acts as a generator and the energy flows back into the inverter side contrary to acceleration and constant-speed operations. The capability for disposing of (consuming) this energy is the inverter's capability during deceleration.

The motor consumes part of the energy regenerated from the load side. The remaining energy deducted by the consumed energy is that to be disposed of by the inverter.

To be specific, the inverter suppresses the smoothing capacitor terminal voltage increased by the regenerative energy under the specified value, by consuming the energy or returning it to the power supply side.



3.1.2 Points for capacity selection

The inverter capacity must be selected by not only compatibility with a driven motor but also load characteristics and operation methods/statuses.

(1) Motor capacity

Note that when V/F control is used with an inverter drive, the motor output torque in the low-frequency range is smaller than that when V/F control is used with the commercial power supply. Otherwise, unexpected troubles occur such as disability of the inverter start-up. The same can be said for motor temperature rise. (Refer to Section 1.5 and 1.6.)

(2) Operation method

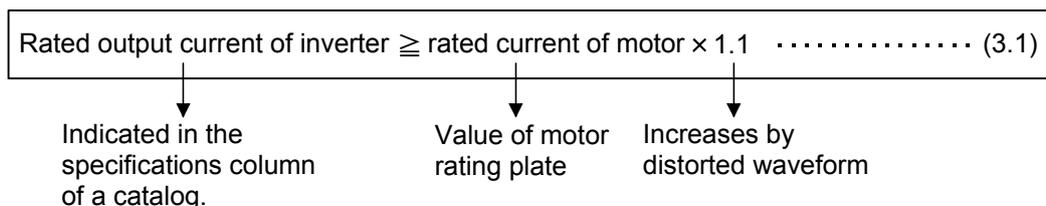
When selecting the inverter capacity by the capacity or number of driven motors, first select the one so that a total of the motor current does not exceed the rated inverter current.

To drive multiple motors with one inverter is a feature of the inverter drive. However, the inverter capacity may become extremely large depending on the operation method, which is not economically efficient. In addition, this kind of drive easily causes capacity selection errors. The V/F control must be selected to drive multiple motors with one inverter since the advanced magnetic flux vector control, etc. are not available for it.

The following lists the general operation methods:

- 1) One motor is driven with one inverter.
- 2) Multiple motors are driven with one inverter.
- 3) Multiple motors are driven by switching with one inverter.
- 4) Motor output shaft is turned on/off with a clutch.

1) When one motor is driven



Note (a) Selecting an inverter corresponding to a motor using the motor capacity "kW" is not a proper method.

Select an inverter so that the condition of formula (3.1) can be satisfied in reference to the rated motor current.

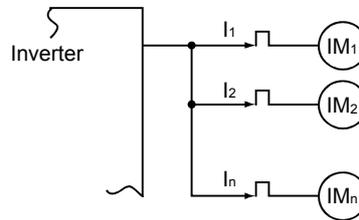
The reason is that when the number of poles increases, the rated current value becomes large for reduced motor efficiency and power factor even if the motor capacities (kW) are not changed.

For the standard motors (2, 4, 6P), selecting an inverter according to "kW" does not cause a specific problem.

(b) The motor with a capacity larger than the inverter is not available.

2) When operating multiple motors in parallel with one inverter

$$\text{Rated output current of inverter} \geq \text{total of rated motor current} \times 1.1 \quad (3.2)$$



Note When multiple motors are operated in parallel, the motors cannot be protected by the built-in electronic thermal relay function. Provide a thermal relay for each motor on the inverter output side. For a continuous drive at low-speed, however, install a temperature detection device on the motors since the motors cannot be protected by the thermal relay function.

(3) Operation pattern

When the acceleration or deceleration time is restricted, the selection of inverter capacity cannot be fully made only by matching the inverter capacity with the motor capacity (selecting with a current).

The capacity must be selected so that the predetermined acceleration/deceleration time can be satisfied. The inverter capacity may increase for the operation which repeats acceleration/deceleration in a short time or for the vertical lift operation. Make sure to fully consider the inverter capacity in advance.

[Example] 1) When rapid acceleration/deceleration or cycle operation is performed (machine tool, cart, etc.)

2) When the vertical lift operation is performed

Memo

Can the inverter with one rank higher inverter capacity used?

- When the inverter capacity is increased, the motor torque (force) becomes larger. _____

The motor generated torque when an inverter is used is less than that when the commercial power supply is used. Depending on the size of the load, the current increases for insufficient torque (force), and the protection function may be activated.

To solve insufficient torque, one of the two methods can generally be taken: increasing the motor capacity (the inverter capacity must also be increased) or increasing only the inverter capacity with the motor capacity left unchanged.

Since the former method costs more and makes motor dimensions larger the latter, the latter is frequently taken.

The increased inverter capacity allows the larger inverter output current, which increases the motor generated torque.

- The rise of the motor temperature cannot be improved even if the inverter capacity is increased.

When the rise of the motor temperature occurs during a continuous operation at low-speed, it cannot be improved even if the inverter capacity is increased.

Since a motor is cooled off with its cooling fan, the cooling capability cannot improved by increasing the inverter capacity.

When the inverter capacity is increased, a measure against the motor overheat must be considered since the motor is forced to operate. In this case, it is important to properly set the inverter electronic thermal according to the motor capacity.

3.2 Selection with Operation Pattern

The basic operation pattern of a motor is start → acceleration → constant speed → deceleration → stop. Each process has points for selection which are overviewed in the following.

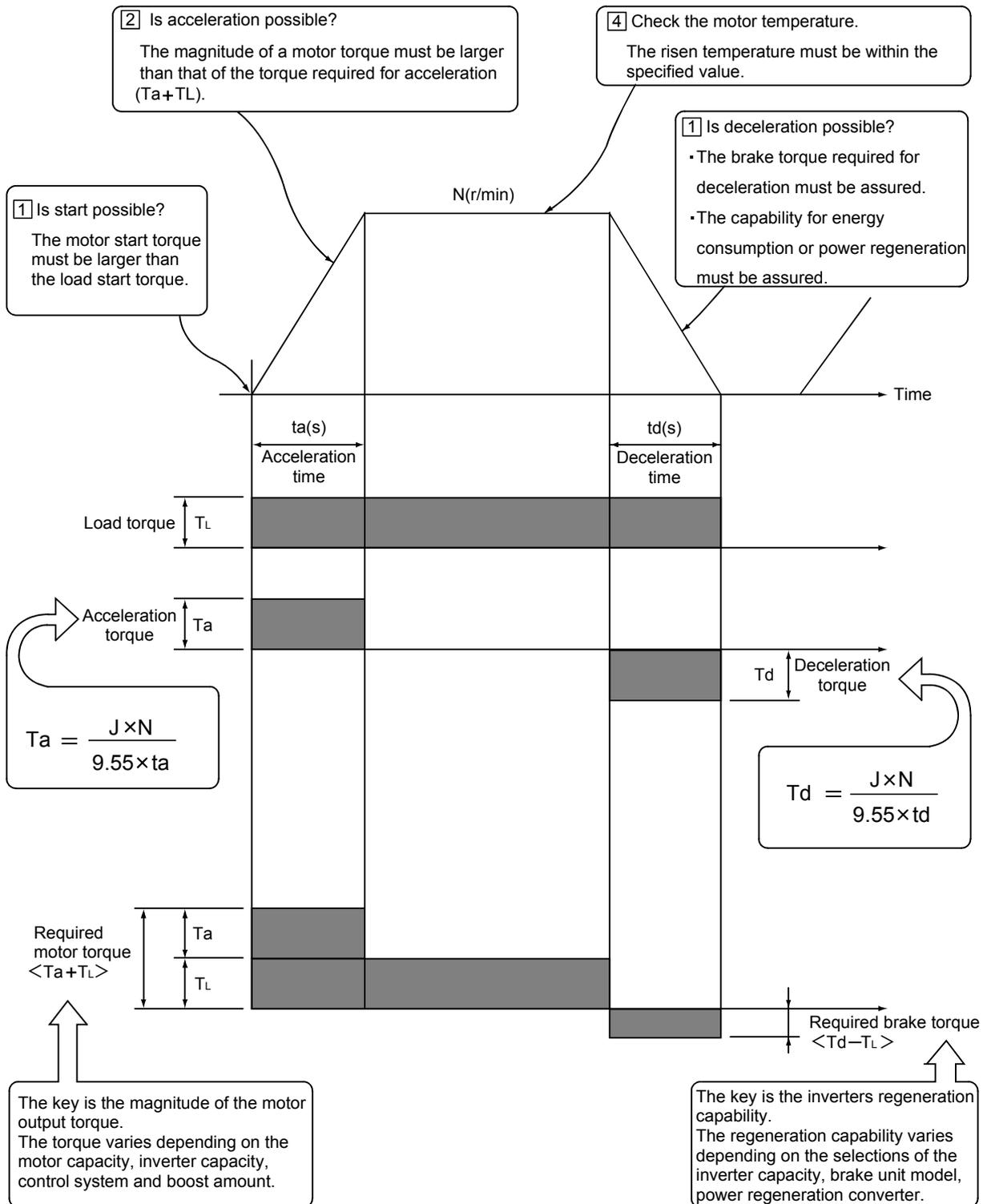


Fig. 3.1 Operation pattern and torque

3.2.1 Start

The motor starts at the intersection of the motor generated torque with the load torque (point A in Fig 3.2). Since the motor is locked while the inverter output frequency is between 0 and point A, the intersection point must be below the maximum start frequency to prevent the inverter from tripping due to the locked rotor current. (Refer to Section 2.6.1.)

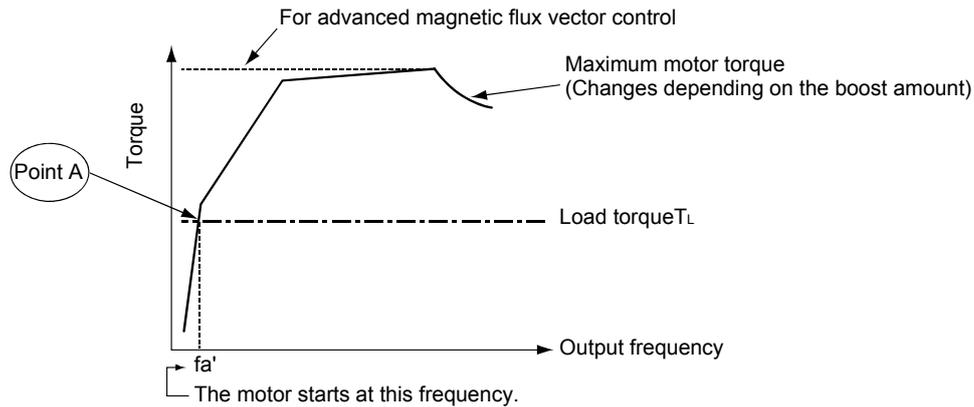


Fig. 3.2 Start of motor

3.2.2 Acceleration

The magnitude of motor output torque must be more than that required for the acceleration ($T_a + T_L$).

There are two acceleration types: a non-linear acceleration which is performed with the operation of the stall prevention (current limit) function and a linear acceleration which is smoothly performed without the operation of the stall prevention (current limit) function. The non-linear acceleration is considered for the general use. Consider the linear acceleration for the fixed position stop operation with an elevator, etc.

Good to know for checking an inverter

To increase the acceleration capability and the start torque

- Select the advanced magnetic flux vector control (FREQR0L-A500, A700 series), the real sensorless vector control (FREQR0L-A700 series) or the general-purpose magnetic flux vector control (FR-E500, A024 series).
- Increase the torque boost adjustment amount.
- Increase the inverter capacity.
- Increase the motor and inverter capacities.

3.2.3 Deceleration

The magnitude of the regenerative brake torque is determined according to the motor and inverter loss. That is to say, the deceleration capability is determined by the inverter loss for an inverter with a built-in brake and by the motor loss for an inverter without a built-in brake. Increasing the capacity for an inverter with a built-in brake is effective to increase the regenerative brake torque. However, doing it for an inverter without a built-in brake is not. Use the BU type brake unit.

While the magnitude of the brake torque has been satisfied, it is necessary to consider the brake resistor's capacity not to overheat during deceleration. The energy regenerated to the inverter at deceleration (W_{INV}) must be fully consumed within the capability of the brake resistor.

When a larger brake capability is required, use a power regeneration common converter (FR-CV) which generates the braking power by returning the regenerative energy (W_{RC}) to the power supply.

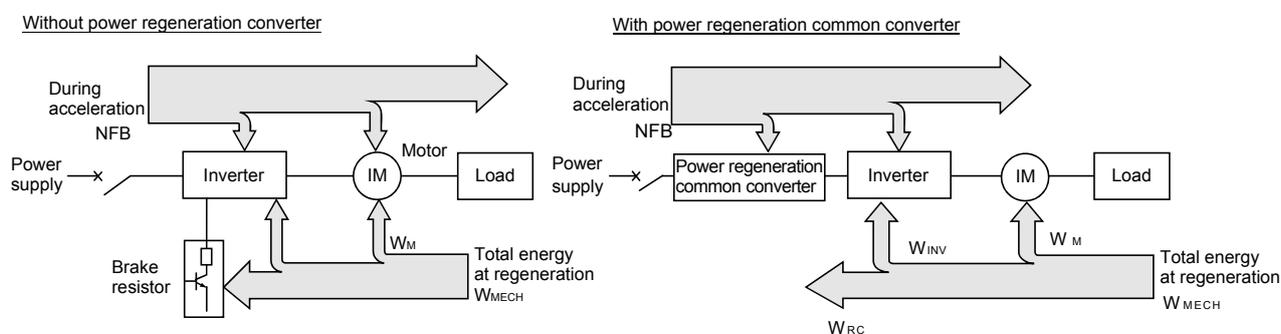


Fig. 3.3 Flow of energy at deceleration

Good to know for checking an inverter

To increase the regenerative brake torque

- Increase the inverter capacity.

This method is effective when the regenerative brake circuit is built in an inverter; however, not effective when it is not.

- Use the power regeneration common converter (optional).
- Use the BU type brake unit (optional).
- When the BU type brake unit has already been used, use the one with a larger capacity or the power regeneration common converter. However, when the capacity of the BU type brake unit is larger than that of the inverter to be combined, the inverter capacity must be increased.

Regenerative brake function

The inverter brakes the motor speed by consuming the regenerated energy. This consuming circuit is a regenerative brake circuit.

The operation is explained taking a built-in type regenerative brake circuit in Fig. 3.4 as an example.

The voltage E of the smoothing capacitor C increases with the regenerative energy.

When the voltage exceeds the specified value, the transistor on the regenerative brake circuit T_{Rd} conducts, and the current I_d flows to the regenerative brake resistor R .

The regenerative brake resistor generates heat with this current, and the regenerative energy is consumed. The energy charged in the capacitor decreases with this operation, and the voltage E drops. When the voltage E drops below the specified value, the transistor on the regenerative brake circuit T_{Rd} stops conducting, and the current of the regenerative circuit is shut off.

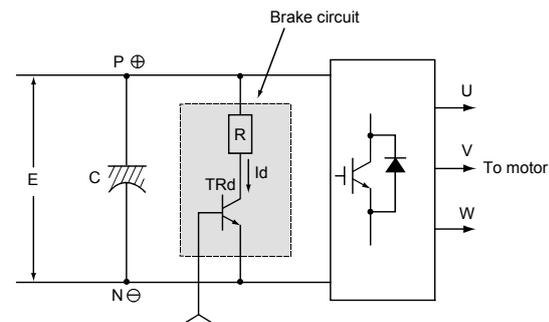


Fig 3.4 Brake circuit

These operations are repeated during deceleration. However, the duty of the regenerative brake circuit decreases or the circuit may not operate when the regenerative energy is small (the torque required for deceleration is small).

The duty of the regenerative brake circuit is set to 2 to 3% according to the heat generation of the circuit. Therefore, the regenerative brake resistor overheats or a fault occurs in the transistor when the duty is needlessly changed.

An optional BU type brake unit is an equivalent of a built-in brake circuit installed outside.

Good to know for checking an inverter

The necessity of the BU type brake unit is defined as follows.

When the DC voltage between P^+ and N^- is measured with a tester, and if the voltage right after deceleration start increases close to the stall prevention operation voltage shown in Section 2.5.3, the brake unit is required. Besides, when the voltage more than the brake operation voltage is maintained, even if the brake unit is built in an inverter, increase the brake unit capacity in case of insufficient brake capability.

- Heat capacity of regenerative brake (temperature rise)

The capability of the regenerative brake unit is determined by the regenerative brake torque described in the previous section and the power consumption. The regenerative brake torque is subject to the regenerative current value flowing in the brake resistor, which is determined by a resistance value (Ω) of the resistor. When the regenerative current flows for a long time, the heat generation exceeds the permissible value of the resistor.

This permissible value is the rated power of the resistor (W). For the high-frequency operation pattern or the continuous regeneration load (an elevator, etc.), consideration of the heat capacity for the regenerative brake is required.

- Power regeneration common converter (FR-CV)

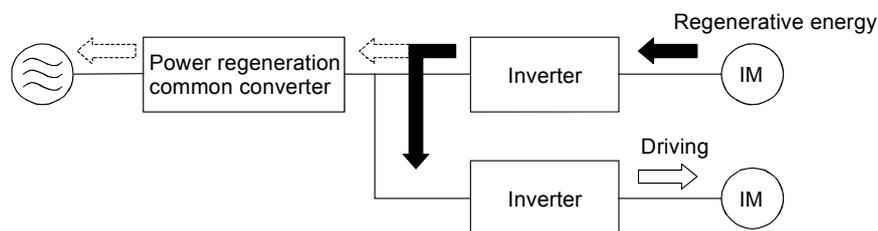
This converter has a compact body and following characteristics.

- 1) Enhances the braking capability.

100% torque continuous regeneration and maximum 150% torque and 60 second regeneration are enabled.

- 2) Reasonable common converter system

Using the regenerative energy for other inverters and returning the remaining energy to the power supply lead to the energy savings.



The remains of the regenerative energy return to the power supply side as shown in dotted lines.

- 3) Easy enclosure design

Adopting a compact body allows an easy in-panel design. Installing a heat sink outside the panel suppresses the rise of in-panel temperature and downsizes the panel.

Good to know for checking an inverter

An elevator generally spends longer time for the regenerative operation. Therefore, the time for one cycle and the load torque at the minus torque for the lifting height (m) (especially machine efficiency) are important factors for capacity selection.

3.2.4 Rise of motor temperature

(1) The motor temperature rise for the continuous operation is different from that for the cycle time operation. This fact requires the consideration of motor heat according to operation methods.

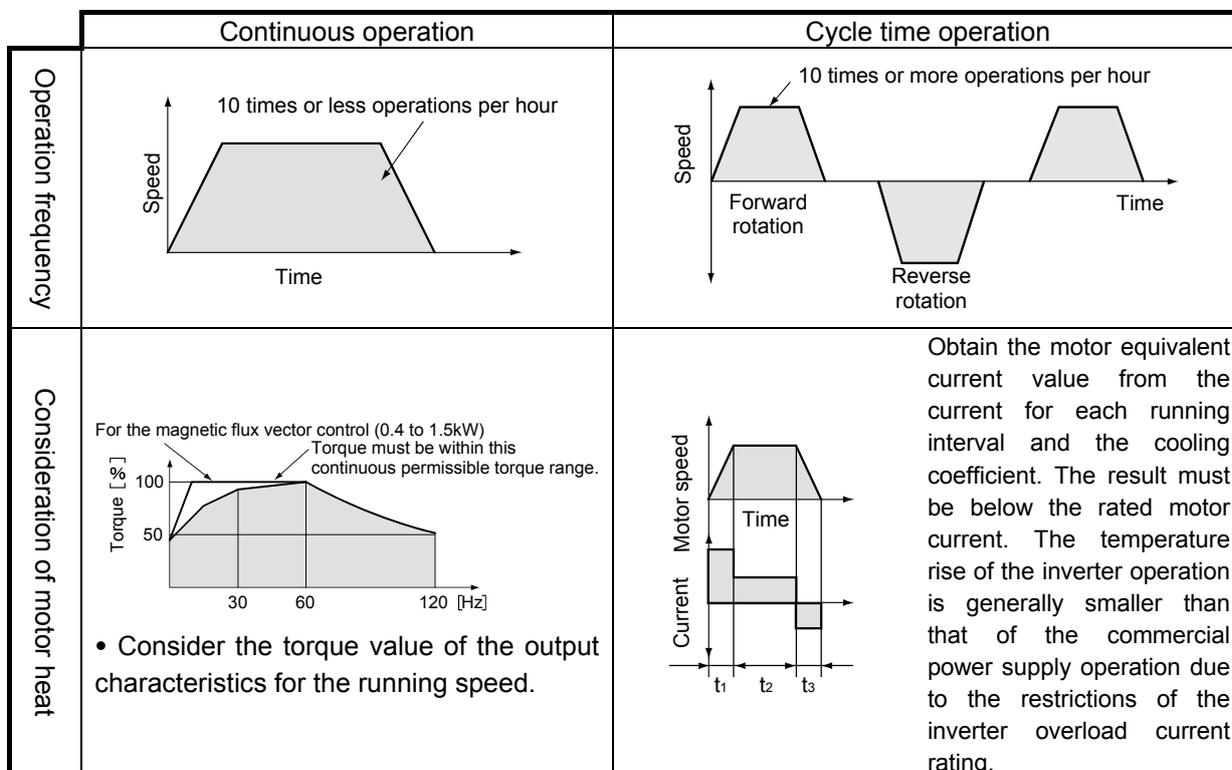


Fig. 3.5 Operation pattern and motor temperature rise

(2) Heat-resistant class of motor

The heat-resistant class indicates the type of insulating materials used for the motor and indirectly expresses the permissible value of motor temperature rise.

Among the standard motors, small capacity motors adopt the insulation type E or B and motors with intermediate capacity or more adopt F. When the ambient temperature is high or when the torque is increased without changing the motor size, a special motor with the upper heat-resistant class is used.

Table 3.1 Heat-resistant class of motor

Heat-resistant class	Maximum permissible temperature [°C]	Coil temperature rise limit [K] (Resistance method)
E	120	75
B	125	80
F	155	105

3.3 Effect of Machine Reduction Ratio

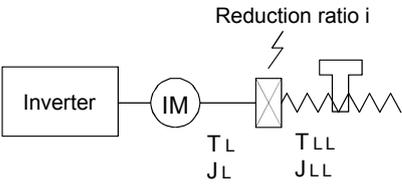
For small capacity motors (7.5kW 4P or less), up to 120Hz are available when the standard motor is used. The reduction ratio on the machine side up to 50Hz has conventionally been determined with reference to the machine speed of 60Hz as a maximum ratio. However, by increasing the reduction ratio to enhance the inverter output frequency (60Hz to maximum 120Hz), the load torque and load inertia moment of the motor shaft are reduced, and therefore the following advantages are developed.

- (1) Starts become easier as the reduction ratio increases.
- (2) Continuous use is enabled at low-speed. (The standard motor will do on the occasion when the inverter dedicated constant torque motor should be selected.)
- (3) A motor can be used in the wide speed deviation range.

Relationship between the reduction ratio i and the motor shaft-equivalent load torque T_L and load inertia moment

$T_L = T_{LL} \times i$
 $J_L = J_{LL} \times i^2$

T_{LL} : Load torque for load shaft
 J_{LL} : Load inertia moment for load shaft



3.4 Capacity Selection Procedure

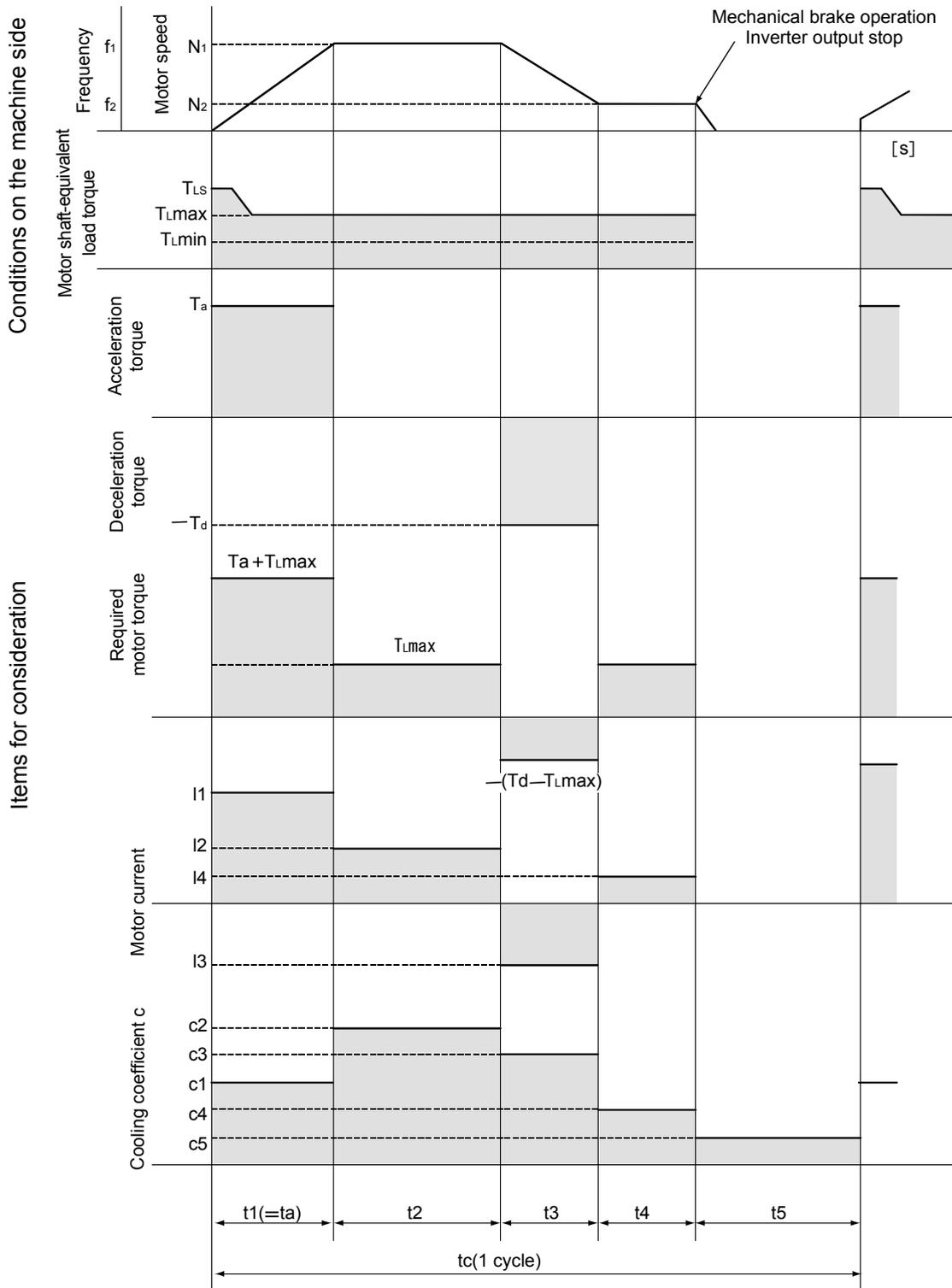


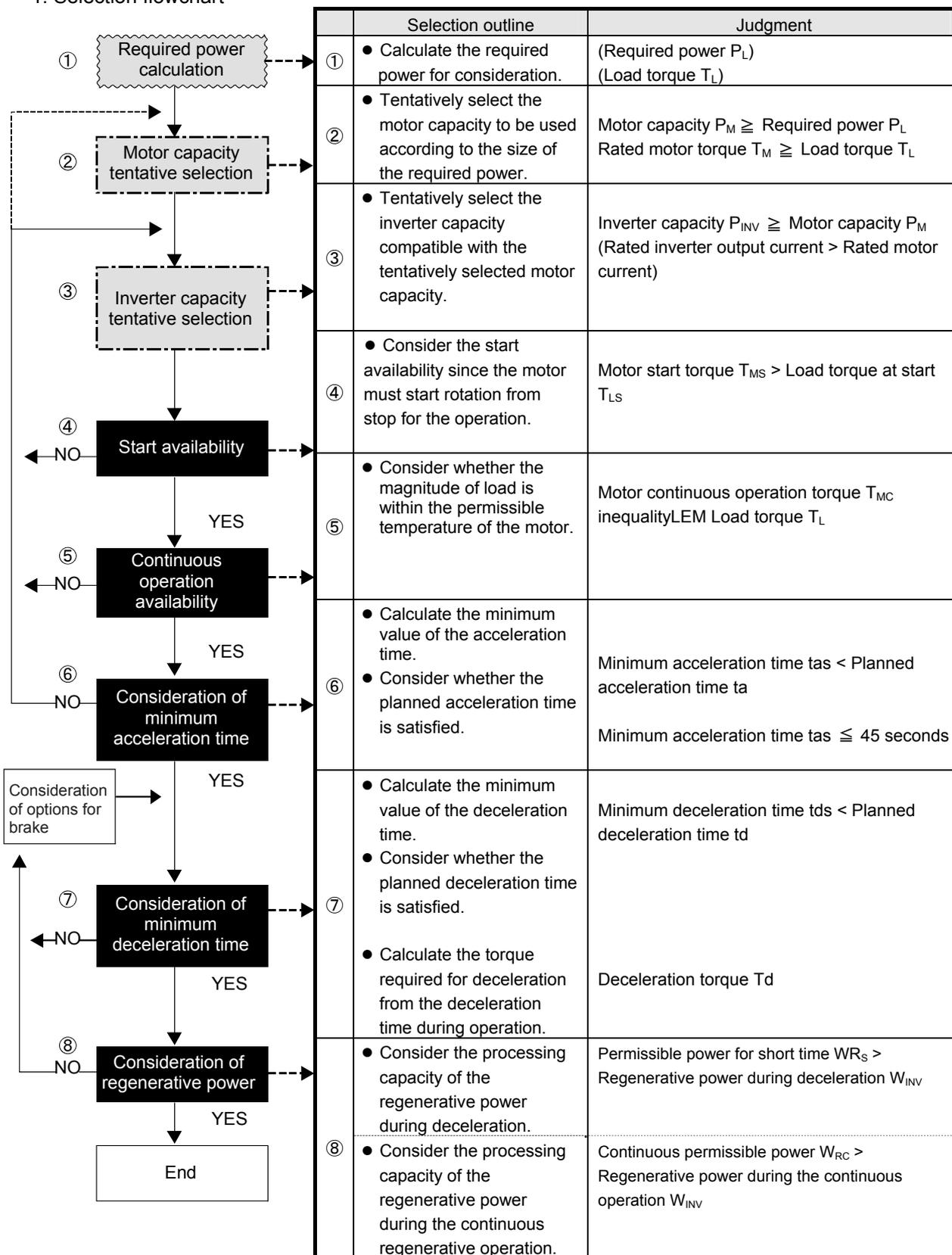
Fig. 3.6 Typical speed patterns and items for consideration

Table 3.2 List of data symbol and unit

	Data	Symbol	Unit
Machine side data	Required power	P_L	kW
	Motor capacity	P_M	kW
	Number of motor poles	P	—
	Motor speed	N	r/min
	Frequency	f	Hz
	Travel speed	V	m/min
	Load mass	W	kg
	Machine efficiency	η	—
	Friction coefficient	μ	—
	Motor shaft-equivalent load torque	T_L	N m
	Motor shaft-equivalent start load torque	T_{LS}	N m
	Motor shaft-equivalent load inertia moment	J_L	kg
	Inertia moment of motor shaft-equivalent mechanical brake	J_B	kg
	Cycle time (1 cycle)	t_c	s
	Time for each running interval	t_n	s
	Acceleration time	t_a	s
	Deceleration time	t_d	s
	Minimum acceleration time	t_{as}	s
	Minimum deceleration time	t_{ds}	s
Acceleration	Acc	m/s^2	
Data used for consideration	Rated motor speed	N_M	r/min
	Rated motor torque	T_M	N m
	Maximum motor start torque	T_{MS}	N m
	Acceleration torque	T_a	N m
	Deceleration torque	T_d	N m
	Load torque ratio	TF	%
	Motor inertia moment	J_M	kg
	Maximum torque coefficient for short time	α_m	—
	Continuous operation torque coefficient	α_c	—
	Maximum start torque coefficient	α_s	—
	Acceleration torque coefficient	α_a	—
	Brake torque coefficient (Generic name)	β	—
	Hot coefficient	δ	—
	Cooling coefficient	C	—
	Motor current	I	%
Motor equivalent current value	I_{MC}	%	
Regenerative power	Regenerative power absorbed by a motor	W_M	W
	Average power regenerated to the inverter	W_{INV}	W
	Average power regenerated from a machine	W_{MECH}	W
	Continuous permissible power of braking unit	W_{RC}	W
	Permissible power for short time per running of the braking unit	W_{RS}	W
Stop accuracy	Stop time	t_b	s
	Coasting distance	S	
	Stop accuracy	$\Delta \varepsilon$	

3.4.1 Consideration procedure for continuous operation

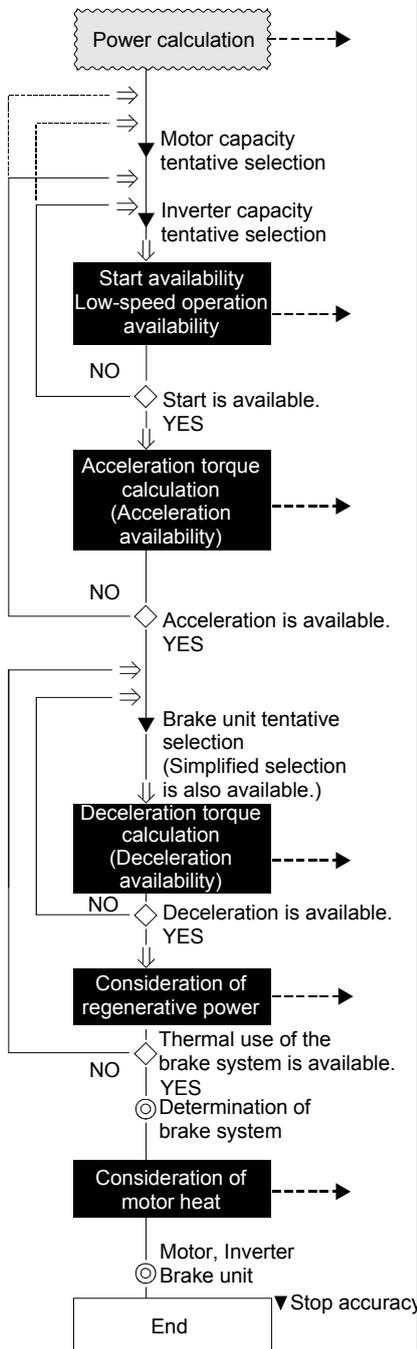
1. Selection flowchart



	Calculation formula, etc.	Reference material/item	Remarks (precautions, etc.)
①	<ul style="list-style-type: none"> Load torque T_L $T_L = 9550 \times PL/N$ [N · m] 	<ul style="list-style-type: none"> Technical Note No.30 (Refer to the appendix.) 	<ul style="list-style-type: none"> Note the insufficient torque since the motor output torque is reduced for the operation at 60Hz or more.
②	<ul style="list-style-type: none"> Rated motor torque T_M $T_M = 9550 \times P_M/N_M$ [N · m] 	<ul style="list-style-type: none"> Motor catalog/Instruction manual Technical Note No.30 Refer to [Table of characteristics] in Chapter 4 Motor/Brake Characteristics. 	<ul style="list-style-type: none"> The permissible motor speed (operating frequency range) differs according to the motor capacity, pole numbers and model.
③	_____	<ul style="list-style-type: none"> Inverter catalog (Standard specifications) 	<ul style="list-style-type: none"> The motor generated torque differs according to the inverter type or the control. (Magnetic flux vector control < V/F control) A built-in brake circuit is present/absent according to the inverter type.
④	<ul style="list-style-type: none"> Motor start torque = Maximum start torque Maximum start torque $T_{MS} = T_M \times \alpha_s \times \delta$ $> T_{LS}$ 	<ul style="list-style-type: none"> Technical Note No.30 Refer to [Data for each torque type] in Chapter 2 Driving Capability Data. α_s: Maximum start torque coefficient δ: Hot coefficient 	<ul style="list-style-type: none"> The start torque of the magnetic flux vector control is larger than that of the V/F control. The start torque can be improved if only the inverter capacity is increased.
⑤	<ul style="list-style-type: none"> Continuous operation torque coefficient α_c $> L$ Load torque ratio $TF = T_L/T_M$ or Continuous operation torque $T_M \times \alpha_c >$ Load torque T_L 	<ul style="list-style-type: none"> Technical Note No.30 Refer to [Continuous torque] in Chapter 2 Driving Capability Data. α_c: Continuous operation torque coefficient 	<ul style="list-style-type: none"> For the magnetic flux vector control, the continuous operation torque range becomes larger according to the motor capacity.
⑥	<ul style="list-style-type: none"> Minimum acceleration time t_{as} $t_{as} = \frac{(J_L + J_M \times N)}{9.55 \times (T_M \times \alpha_a - T_{Lmax})}$ [N · m] 	<ul style="list-style-type: none"> Technical Note No.30 Refer to [Torque type] in Chapter 2 Driving Capability Data. α_a: Acceleration torque coefficient 	<ul style="list-style-type: none"> The acceleration torque of the magnetic flux vector control is larger than that of the V/F control. Recalculate with the linear acceleration torque coefficient when the minimum acceleration time exceeds 45 seconds.
⑦	<ul style="list-style-type: none"> Minimum deceleration time t_{ds} $t_{ds} = \frac{(J_L + J_M \times N)}{9.55 \times (T_M \times \beta + T_{Lmin})}$ [N · m] Deceleration torque T_d 	<ul style="list-style-type: none"> Technical Note No.30 Refer to [Braking capability torque types] in Chapter 3 Driving Capability Data. β: Deceleration torque coefficient 	<ul style="list-style-type: none"> The value of the minimum deceleration time differs according to the presence/absence of a built-in brake resistor. Consider using options for the brake when the minimum deceleration time is larger than that planned.
⑧	<ul style="list-style-type: none"> Regenerative power from a load W_{MECH} Power absorbed by the motor W_M Regenerative power to the inverter $W_{INV} = W_{MECH} - W_M$ [W] 	<ul style="list-style-type: none"> Technical Note No.30 Refer to [Braking capability torque types] in Chapter 3 Driving Capability Data. W_{RS}: Permissible power for short time W_{RC}: Continuous permissible power 	<ul style="list-style-type: none"> The capacity of regenerative power (permissible power) differs according to the inverter type and capacity. The power regeneration converter may be required for continuous regeneration.

3.4.2 Consideration procedure for cycle operation

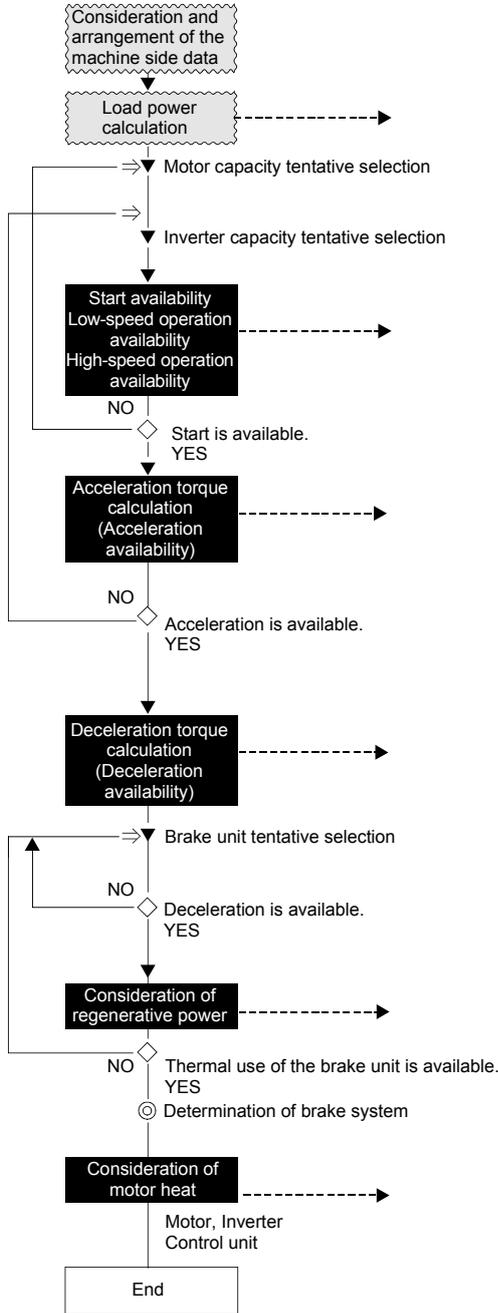
2. Selection flowchart



Selection outline	Judgment
$P_L = \frac{\mu W \times V}{6120 \times \eta} \quad [\text{kW}]$ <p>Also calculate the load torque and inertia moment.</p>	Tentatively selected motor capacity
(1) Select the motor capacity larger than the required power.	$P_M > P_L$
(1) Select the inverter equivalent to the motor capacity.	Tentatively selected inverter capacity $\geq P_M$
(2) Increase the inverter capacity for the acceleration torque increase as necessary.	
<ul style="list-style-type: none"> Check that the motor start torque and the torque at low speed are larger than the load torque. δ : Motor hot coefficient	$T_{MS} > T_L$ $T_M \times \alpha_m \times \delta > T_L$
<ul style="list-style-type: none"> Calculate the relationship between the acceleration speed and the acceleration time Acceleration torque $T_a = \frac{\sum J \times N_{max}}{9.55 \times t_a} \quad [\text{N} \cdot \text{m}]$ <ul style="list-style-type: none"> Calculate the torque required for acceleration α : Linear acceleration torque coefficient	$\alpha a > \frac{T_a + T_{Lmax}}{T_M}$
<ul style="list-style-type: none"> Deceleration torque $T_d = \frac{\sum J \times N_{max}}{9.55 \times t_d} \quad [\text{N} \cdot \text{m}]$ <ul style="list-style-type: none"> Calculate the torque required for deceleration. β_{min} : Brake torque coefficient	$\beta_{min} > \frac{T_d - T_{Lmin}}{T_M}$
(1) Check the permissible power for short time.	$W_{INV} < W_{RS}$
(2) Check the average regenerative power.	$W_{INV} \times t_d / t_c < W_{RC}$
W_{INV} : Power regenerated to the inverter t_d : Deceleration time during 1 cycle t_c : Entire time of 1 cycle	
Check that the equivalent current value does not exceed 100%.	
$I_{MC} = \sqrt{\frac{\sum (I_n^2 \times t_n)}{\sum (C_n \times t_n)}} < 100 \quad [\%]$	
<ul style="list-style-type: none"> Calculate the stop accuracy of the mechanical brake. 	

3.4.3 Consideration procedure for vertical lift operation

3. Selection flowchart



Selection outline
$\text{Required power } P_L = \frac{W \times V}{6120 \times \eta} \quad [\text{kW}]$
(1) Select the motor capacity larger than the required power. (2) Increase the motor capacity for the start torque increase.
(1) Select the inverter equivalent to the motor capacity. (2) Increase the inverter capacity for the acceleration torque increase.
(1) Motor start torque $T_{MS} > \text{Load torque at start } T_{LS}$ (2) Motor torque at low speed $T_M \times \alpha_m \times \delta > \text{Load torque } T_L$ (3) Motor torque at high speed $T_M \times \alpha_m > \text{Load torque } T_L$
Acceleration torque $T_a = \frac{\sum J \times N_{\max}}{9.55 \times t_a} \quad [\text{N} \cdot \text{m}]$ Ta: Acceleration torque ta: Acceleration time [s]
Consider the availability of acceleration. $\frac{T_{a\max}}{T_M} < \alpha_a$ αa: Acceleration torque coefficient
Deceleration torque $T_d = \frac{\sum J \times N}{9.55 \times t_d} \quad [\text{N} \cdot \text{m}]$ Td: Deceleration torque td: Deceleration time [s]
$\frac{T_{d\max}}{T_M} < \beta_{\min}$ β min: Brake torque coefficient (Tentatively select the brake unit according to Data volume of the technical note.)
(1) Check the permissible power for short time. $W_{INV} < W_{RS}$ (2) Check the continuous permissible power. $W_{INV} \times t/t_c < W_{RC}$ W _{INV} : Power regenerated to the inverter t : Time taken for the minus load torque [s] t _c : Entire time of 1 cycle [s]
Motor equivalent current value $I_{MC} = \sqrt{\frac{\sum (I_n^2 \times t_n)}{\sum (C_n \times t_n)}} < 100 \quad [\%]$

[Notes]

An elevator is different from other applications in that there are two modes when the load torque is positive (generally at rise) and negative (minus) (generally at fall) and that the cycle time operation is performed necessarily with the fixed position stop. The following lists the cases when the general-purpose inverter is used for such application.

(1) Vertical lift operation

- Control method

For the following reasons, it is preferable to select any of the advanced magnetic flux vector control, real sensorless vector control, general-purpose magnetic flux vector control or vector control. However, the V/F control may have an advantage in the regenerative torque at low speed.

- An elevator is always accompanied by the overload operation. Therefore, the start torque of 150% or more is required.
- For an elevator with counterweight, the negative load may be generated even at rise according to the load magnitude. The output voltage must be optimally controlled to avoid the overcurrent.

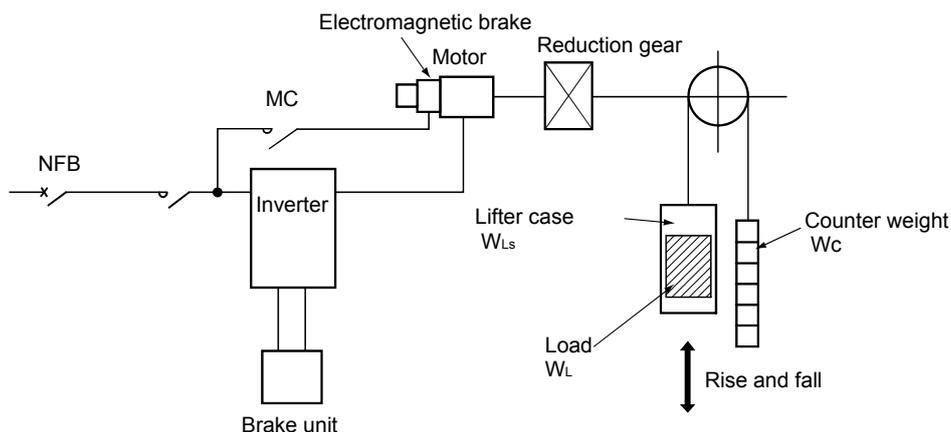


Fig. 3.7 Configuration example of elevator with counterweight

- Mechanical brake opening timing

- Open : For avoiding a drop of the load, open the mechanical brake after the RUN (running) signal of the inverter is turned on with the start signal.
- Close: For avoiding abrasion of the brake lining and overcurrent, fully decelerate, close the mechanical brake and turn on the inverter MRS (output stop) signal.

- Fall operation

The rotation by a load causes the regenerative operation in many cases.

Since the inverter cannot independently absorb the regenerative energy, a braking unit (power regeneration converter, brake unit, etc.) is required.

- Motor selection

If the continuous operation is not performed at low speed, the constant torque motor is not required.

(2) Regenerative operation

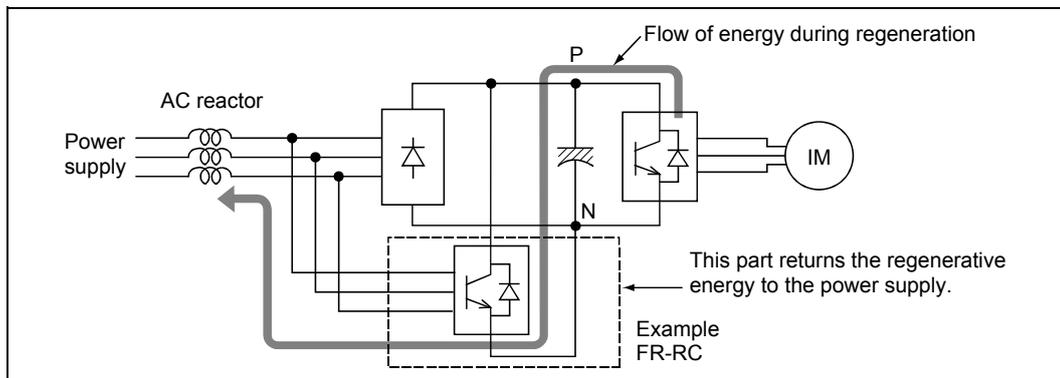


Fig. 3.8 Regenerative operation

When the motor is rotated by an external force (e.g. gravity) such as the fall operation of an elevator, the energy generated by the motor as a generator is stored in the smoothing capacitor, and the voltage of both capacitor ends (between terminals P and N) increases.

This status is called a regenerative operation.

When this regenerative energy is absorbed by following systems, the braking power is generated in the motor.

- | | |
|-------------------------------|---|
| Resistance consumption system | : This system consumes the regenerative energy with heat. Since <u>the initial cost is low</u> , it is suitable for a small capacity inverter. |
| Power regeneration system | : This system returns the regenerative energy to the power supply. Since <u>large braking power</u> can be expected with an energy saving effect, it is suitable for a large capacity inverter. |

It should be fully noted that when the braking unit capacity is insufficient, the voltage of both capacitor ends (between terminals P and N) increases and the inverter falls into OVT (regenerative overvoltage) trip.

Setting Pr.19 (Base frequency voltage) in the inverter according to the power supply voltage prevents the frequent occurrence of the OCT (overcurrent) alarm during regeneration.

(3) Low-speed operation

- Low-speed torque

The inverter drive easily causes the insufficient low-speed torque. Some measure must be taken by adopting the control system (advanced magnetic flux vector control, real sensorless vector control, etc.) according to the specifications of the machine, setting the torque boost properly, etc.

- Motor temperature rise

When the continuous operation is performed at low speed, the motor temperature rise becomes large. Fully consider using a constant torque motor or reviewing the operation pattern.

The appropriate boost setting is also effective to control the temperature rise during low-speed operation.

- Stable operation

High torque at start or at low speed does not exactly mean that smooth operations can be performed at low speed.

To know how slowly smooth operations can be performed, the speed control range is used. For applications to be operated smoothly at ultra low speed, the vector control (speed control range 1:1500) is the most suitable.

<<Example>>

The speed control range 1:200 (real sensorless vector control) means that if the maximum speed is performed at 60Hz, 1/200 of the frequency, i.e. up to 0.3Hz, is the applicable range for a smooth operation.

Good to know for checking an inverter

★The encoder speed feed back operation of FREQROL-A₅₀₀ series, etc. is highly effective for slow load fluctuation. However, it should be noted that the operation may be sometimes unstable due to the control response delay against the uneven rotation by torque ripples at low speed and does not achieve a full improvement.

(4) Inverter and mechanical safety brake

An elevator must be equipped with the mechanical safety brake for holding products for rise and fall. This safety brake is also used for the positioning stop of vertical lifting. An interlock circuit must be installed to prevent the conflict with the deceleration torque from the inverter regenerative brake.

(5) Selecting a fast response inverter

For the elevator's acceleration/deceleration time, a fast response speed such as one to two seconds to reach high speed is required. Among the Mitsubishi general-purpose inverters, the FREQROL-A₇₀₀ series with the real sensorless vector control is the most appropriate for this purpose.

(6) Configuring a fail-safe system for safety

The lifter may naturally drop when the motor torque is lost for the inverter protective circuit activation, power failure, power-off or motor stop. Configure a fail-safe sequence ladder in consideration of this risk. It is also recommended to install the overspeed relay on the machine side in case a motor should stall.

(7) Measures against vibration/impact and cable disconnection

When an inverter is installed to a moving machine such as a crane, measures must be fully taken against vibration, impact and the overrun by power cable disconnection.

Actual selection example for continuous operation (selection example for conveyor operation)

(Load/Operation specifications)

• Power supply voltage/frequency	<input type="text" value="220"/> [V] <input type="text" value="60"/> [Hz]
• Friction coefficient	$\mu = \text{}$ (Friction coefficient at start $\mu_s = \text{}$)
• Machine efficiency	$\eta = \text{}$
• Mass of products conveyed (including a conveyor movable part)	$W (W_T) = \text{}$ [kg] ($W_L=0$)
• Conveyor speed	$V_{\min} = \text{}$ to $V_{\max} = \text{}$ [m/min]
• Motor speed	$N_{\min} = \text{}$ to $N_{\max} = \text{}$ [r/min]
• Output frequency	$f_{\min} = \text{}$ to $f_{\max} = \text{}$ [Hz]
• Load inertia moment	$J_L(J_0) = \text{}$ [kg·m ²] ($J_G, J_R=0$)
• Total of output shaft conversion	
• Planned acceleration/deceleration time	Acceleration time $t_a = \text{}$ [s] Deceleration time $t_d = \text{}$ [s]

Operation pattern

DR
Approx. 0.2m

Conveyor
Without a coupling, with an external reduction gear
Reduction ratio 1/n:1/45

Motor	Inverter
SF-J	FR-S500
R4P	V/F control,
Without brake	Margin coefficient $k_p=1$

Calculation of load power and load torque

(1) Required power PLR

$$\text{Required power PLR} = \frac{\mu \times W \times V_{\max}}{6120 \times \eta} = \frac{0.1 \times 1800 \times 25}{6120 \times 0.85} = \text{} \text{ [kW]}$$

(2) Motor shaft-equivalent torque TLR

$$\text{Motor shaft-equivalent load torque TLR} = \frac{9550 \times \text{PLR}}{N_{\max}} = \frac{9550 \times 0.87}{1800} = \text{}$$

Tentative selection of motor capacity and inverter capacity

(1) Motor capacity tentative selection

• Select a motor of for the required power of 0.87kW. →

$$\text{Rated motor torque } T_M = \frac{9550 \times P_M}{N_M} = \frac{9550 \times 1.5}{1800} = \text{}$$

• Judgment of motor capacity tentative selection

© Judgment condition

• Judgment $T_M = \text{}$ [N·m] \geq $T_{LR} = \text{}$ [N·m] →

(2) Inverter capacity tentative selection

Tentatively select an inverter of the same capacity as the motor.

Consideration of start availability

(1) Motor start torque

• Motor start torque $T_{MS} = T_M \times \alpha_s \times \delta = 7.96 \times 1.15 \times 0.85 = 7.78$ [N·m]

Start torque coefficient α_s : 1.15 Technical Note No. 30 (Driving capability data)
 Hot coefficient δ : 0.85 Technical Note No. 30 (How to use data)

• Load torque at start $T_{LS} = \frac{\mu_s \times 9.8 \times W \times V_{max}}{2\pi \times N_{max} \times \eta} = \frac{0.15 \times 9.8 \times 1800 \times 25}{2\pi \times 1800 \times 0.85} = 6.88$ [N·m]

(2) Judgment of start availability

◎ Judgment condition **Maximum motor start torque $T_{MS} >$ Load torque at start T_{LS}**

• Judgment $T_{MS} = 7.78$ [N·m] $>$ $T_{LS} = 6.88$ [N·m] \rightarrow **OK**

Consideration of continuous operation availability

(1) Continuous operation torque

Consider whether or not the load torque T_{LR} fits in the continuous operation torque in the range of continuous operation (600 to 1800r/min).

① Motor continuous operation torque at 1800r/min (60Hz)

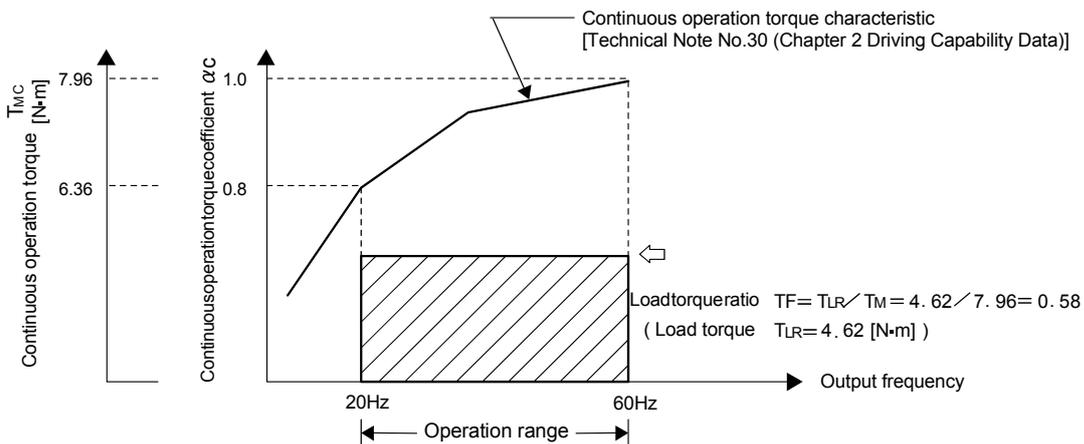
• Motor continuous operation torque $T_{MC} = T_M \times \alpha_c = 7.96 \times 1.0 = 7.96$ [N·m]

Continuous operation torque coefficient α_c : 1.0 (at 60Hz) Technical Note No.30(Driving capability data)

② Motor continuous operation torque at 600r/min (20Hz)

• Motor continuous operation torque $T_{MC} = T_M \times \alpha_c = 7.96 \times 0.8 = 6.36$ [N·m]

Continuous operation torque coefficient α_c : 0.8 (at 20Hz) Technical Note No.30(Driving capability data)



(2) Judgment of continuous operation availability

◎ Judgment condition **Maximum motor start torque $T_{MC} >$ Load torque T_{LR}**

• Judgment $T_{MC} = 6.36$ [N·m] $>$ $T_{LR} = 4.62$ \rightarrow **OK**

Consideration of acceleration availability

(1) Minimum acceleration time t_{as}

$$\bullet \text{ Minimum acceleration time } t_{as} = \frac{(J_L + J_M + J_B) \times N_{max}}{9.55(T_M \times \alpha_a - T_{LRmax})} = \frac{(0.01 + 0.0068 + 0) \times 1800}{9.55(7.96 \times 1.15 - 4.62)} = 0.7 \text{ [s]}$$

Linear acceleration torque coefficient α_a : 0.2	Technical Note No.30 (Driving capability data)
Motor inertia J_M : 0.0068[kg·m ²]	Technical Note No.30 (Motor/Brake characteristics)
Maximum load torque T_{LRmax} : 4.62[N·m]	T_{LR} is used.

(2) Judgment of acceleration availability

◎ Judgment condition Minimum acceleration time t_{as} < Planned acceleration time t_a

• Judgment $t_{as} = 0.7 \text{ [s]} < t_a = 8 \text{ [s]} \rightarrow \text{OK}$

Consideration of deceleration availability

(1) Minimum deceleration time t_{ds}

$$\bullet \text{ Minimum deceleration time } t_{ds} = \frac{(J_L + J_M + J_B) \times N_{max}}{9.55(T_M \times \beta_a - T_{LRmin})} = \frac{(0.01 + 0.0068 + 0) \times 1800}{9.55(7.96 \times 0.2 + 0)} = 2.0 \text{ [s]}$$

Linear acceleration torque coefficient β : 0.2	Technical Note No.30 (Driving capability data)
Motor inertia J_M : 0.0068[kg·m ²]	Technical Note No.30 (Motor/Brake characteristics)
Minimum load torque T_{LRmin} : $T_{LRmin} = 0 \text{ [N·m]}$, the most difficult condition at deceleration, is used.	

(2) Judgment of deceleration availability

◎ Judgment condition Minimum deceleration time t_{as} < Planned deceleration time t_a

• Judgment $t_{ds} = 2.0 \text{ [s]} < t_d = 8 \text{ [s]} \rightarrow \text{OK}$

Regenerative power (when the deceleration time is 8 seconds)

(1) Judgment of regenerative power processing capacity

The regenerative power processing capacity is satisfied since the minimum deceleration time of 2s is shorter than the planned deceleration time of 8s in the capacitor regenerative system.

<Selection result>

● Motor	: SF-JR 1.5kW 4P
● Inverter	: FR-S520E-1.5K V/F control (Torque boost large)
● Brake resistor	: Not required (capacitor regeneration)

Mitsubishi General-Purpose Inverter Model Selection Quick Reference Table

Item	Inverter model						
	FREQROL-S500	FREQROL-E500	FREQROL-A500	FREQROL-A700	FREQROL-F700	FREQROL-V500	
Inverter type	Small size, low price, standard functions	Small size, moderate functions	High performance, advanced functions	High performance, advanced functions	For fan/pump, low noise	High accuracy, advanced functions	
Power supply specifications	3 φ 200/400V 1 φ 100/200V	3 φ 200/400V 1 φ 100/200V	3 φ 200V 3 φ 400V	3 φ 200V 3 φ 400V	3 φ 200V 3 φ 400V	3 φ 200V 3 φ 400V	
Capacity	0.1 to 3.7kW	0.1 to 7.5kW	0.4 to 55kW	0.4 to 500kW	0.75 to 560kW	1.5 to 55kW	
Control method	Selected from V/F control or automatic torque boost	Selected from V/F control or general-purpose magnetic flux vector control	Selected from V/F control or advanced magnetic flux vector control	Selected from V/F control, real sensorless vector control or advanced magnetic flux vector control	Selected from V/F control or optimum excitation control	Vector control	
Low noise	○	○	○	○	○	○	
Reset/output stop	○	○	○	○	○	△ Output stop is optional.	
Multi-speed	15 speeds	15 speeds	15 speeds	15 speeds	15 speeds	15 speeds	
Brake resistor	Built-in	-	○ 7.5K or less	○ 7.5K or less	-	○ 5.5K or less	
	Option	○ FR-S520E 0.4K or more	○ 0.4K or more	○ 7.5K or less	○ 22K or less	-	○ 15K or less
Brake unit connection	○	○	○	○	○	○	
Speed command	0 to 5VDC, 10V 4 to 20mA	0 to 5, 10VDC 4 to 20mA	0 to 5, 10VDC ±5V, ±10V 4 to 20mA	0 to 5, 10VDC ±5V, ±10V 4 to 20mA	0 to 5, 10VDC ±5V, ±10V 4 to 20mA	0 to 5, 10VDC ±10V	
Alarm output	1 contact	1 contact	1 contact	1 contact X 2	1 contact X 2	1 contact	
Output signal	1 type	2 types	5 types	5 types	5 types	3 types	
Automatic restart after instantaneous power failure	○	○	○	○	○	○	
Low-speed torque	○ 5Hz 150%	◎ 1Hz 150% 3Hz 200%	◎ 0.5Hz 150%	◎ 0.3Hz 200% (3.7K or less)	△ 3Hz 120%	◎ 0r/min 100% Continuous	
Stall prevention	○	○	○	○	○	○ (V/F control)	
Fast-response current limit	○	○	○	○	○	○	
0.75kW installation area ratio %	31	31	100	100	100	-	
0.75kW standard price ratio %	55	61	100	100	95	-	
EC Directive	EMC Directive	△ (Dedicated noise filter available)	△ (Dedicated noise filter available)	△ (Dedicated noise filter available)	○ (Noise filter built-in)	○ (Noise filter built-in)	△ (Dedicated noise filter available)
	Low Voltage Directive	○	○	○	○	○	○
UL standards	○	○	○	○	○	○	
cUL standards	○	○	○	○	○	○	
Point for selection	Small size and standard.	When a certain level of functions such as the multi-speed operation or motor operation with brake is required.	When the high start torque or trip-less is required. When operation conditions are not defined. Compatible with most applications.	When the high start torque or trip-less is required. When operation conditions are not defined. Compatible with most applications.	When low noise is required for fan or pump use	When the high torque, high accuracy and fast response are required.	
Major applications	Conveyance machine Pulley Starter	General industrial machine Variable speed Conveyance machine Pulley Starter Conveyor driving	Conveyance machine Machine tool General industrial machine Elevator	Conveyance machine Machine tool General industrial machine Elevator	Air conditioning	Elevator Winding machine Conveyance machine	

3.5 Operation Method

3.5.1 Types of operation methods

A main characteristic of the inverter is the operation with various signals. Operation methods of an inverter (start, stop and variable speed) are roughly classified as follows.

The explanation is given using the inverter FREQROL-A700 series as an example.

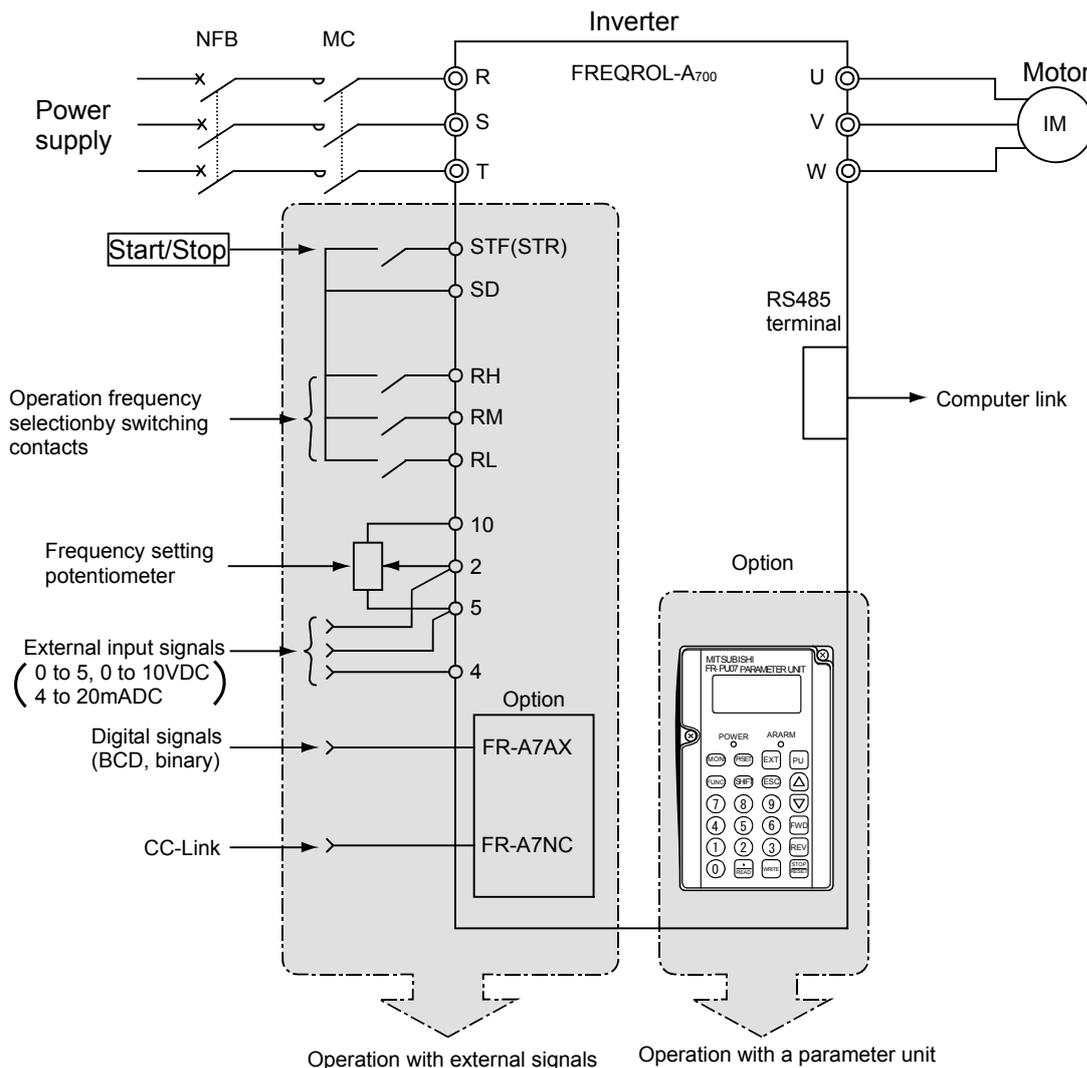
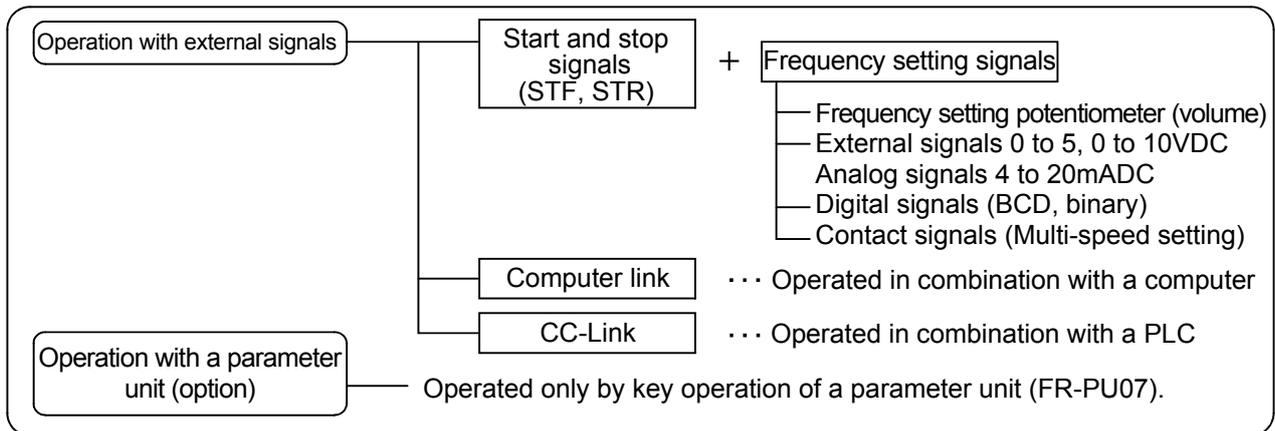
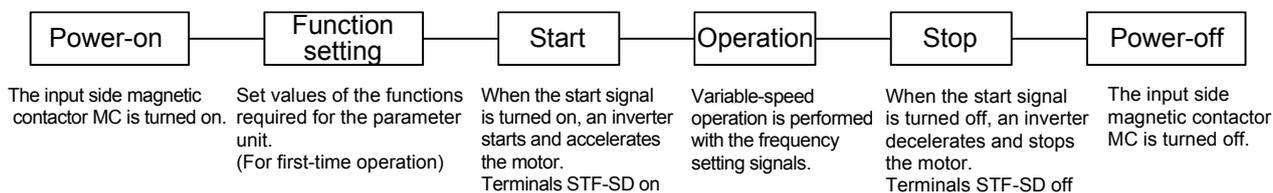


Fig. 3.9 Operation method of inverter

3.5.2 Operation procedure outline

The general procedure for "Operation with external signals" is as follows.



3.5.3 Concept of function setting

Multiple functions are provided with FREQROL-A₇₀₀ series and a certain value is factory-set for those functions. Therefore, operations can be performed without setting functions. Set only the necessary functions according to the operation specifications.

(1) To operate with factory setting values

Function setting is not required.

(2) Functions commonly set

Functions to be used differ according to the operation specifications. The following functions are the major "functions commonly set".

- Acceleration [Function number 7]
- Deceleration [Function number 8]
- Electronic thermal O/L relay [Function number 9]

Function	Parameter No.	Name	Screen display	Setting range	Minimum setting unit	Factory setting
Basic function	0	Torque boost (handle)	Trq.Bst1	0 to 30%	0.1%	0%/4%/3%/2%/1% (Note 1)
	1	Maximum frequency	Max. F	0 to 120Hz	0.01Hz	120/60Hz (Note 2)
	2	Minimum frequency	Min. F	0 to 120Hz	"	0Hz
	3	Base frequency	VFBase F	0 to 400Hz	"	60Hz
	4	Multi-speed setting (high speed)	PresetS1	0 to 400Hz	"	60Hz
	5	Multi-speed setting (middle speed)	Preset2F	0 to 400Hz	"	30Hz
	6	Multi-speed setting (low speed)	Preset3F	0 to 400Hz	"	10Hz
	7	Acceleration time	Acc.T1	0 to 3600 seconds/ 0 to 360 seconds	0.1 second/ 0.05 second	5 seconds/15 seconds (Note 3)
	8	Deceleration time	Dec.T1	0 to 3600 seconds/ 0 to 360 seconds	0.1 second/ 0.05 second	5 seconds/15 seconds (Note 3)
	9	Electronic thermal O/L relay	SetTHM	0 to 500A	0.01A	Rated output current
	10	DC injection brake operation frequency	DCBr.F	0 to 120Hz, 9999	0.01Hz	3Hz
	11	DC injection brake operation time	DCBr.T	0 to 10 seconds, 8888	0.1 second	0.5 seconds
	12	DC injection brake operation voltage	DCBr.V	0 to 30%	0.1%	4%/2%/1% (Note4)
	13	Starting frequency	Start F	0.01 to 60Hz	0.01Hz	0.5Hz
14	Applied load selection	Load VF	0 to 5	1	0	

(Note 1) The setting value depends on the inverter capacity and 6% is for 0.4K or 0.75K, 4% for 1.5K to 3.7K, 3% for 5.5K or 7.5K, 2% for 11K to 55K and 1% for 75K or more.

(Note 2) The setting value depends on the inverter capacity and 120Hz is for 55K or less and 60Hz for 75K or more.

(Note 3) The setting value depends on the inverter capacity and 5seconds is for 7.5K or less and 15 seconds for 11K or more.

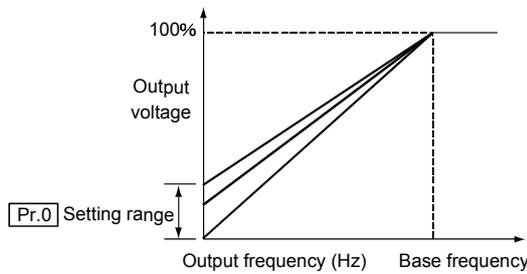
(Note 4) The setting value depends on the inverter capacity and 4% is for 7.5K or less, 2% for 11 to 55K and 1% for 75K or more.

(3) Parameter number and definition

(Note) Pr. is an abbreviation of parameter.

Pr. 0 Torque boost (manual) setting

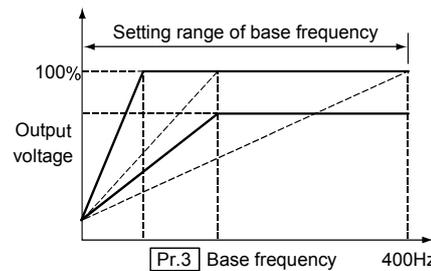
- The motor torque in the low frequency range can be adjusted to the load.



Pr. 3 Base frequency setting

Pr. 3 Base frequency

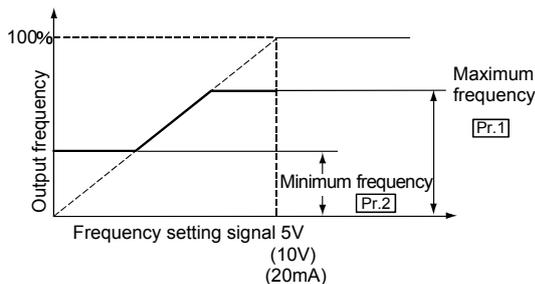
- The base frequency (reference frequency at the rated motor torque) can be set as desired within the range of 0 to 400Hz according to the rated motor torque.



Pr. 1 **Pr. 2** Maximum/minimum frequency settings

Pr. 1 Maximum frequency **Pr. 2** Minimum frequency

- The upper and lower limits of the output frequency can be clamped.



(Note) When setting the frequency of 120Hz or more, make setting in Pr.18.

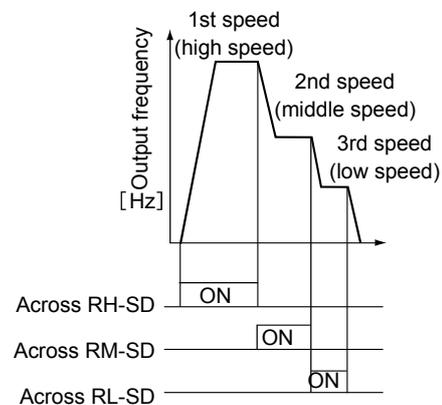
Pr. 4 **Pr. 5** **Pr. 6** Multi-speed setting

Pr. 4 Multi-speed setting (high speed)

Pr. 5 Multi-speed setting (middle speed)

Pr. 6 Multi-speed setting (low speed)

- Each speed (terminal RH, RM or RL-SD) can be selected by merely switching external contact signals.
- Each speed (frequency) can be set to any value within the range of 0 to 400Hz while the inverter is running. Setting can also be made with the \blacktriangle \blacktriangledown keys.



(Note) 1. The multi-speed settings override the main speeds (across terminals 2-5, 4-5).

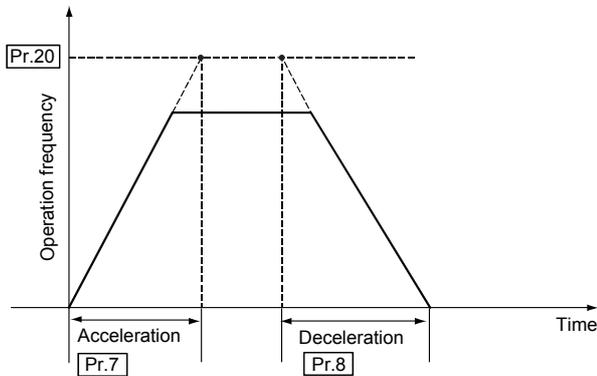
2. The multi-speed setting is available in the PU or

external operation mode.

Pr. 7 Pr. 8 Acceleration/deceleration time setting

- Pr. 7** Acceleration time
- Pr. 8** Deceleration time
- Pr. 20** Acceleration/deceleration reference frequency
- Pr. 21** Acceleration/deceleration time increments

- For the acceleration time Pr.7, set the time taken to reach the setting value in the reference frequency Pr.20 from 0Hz. For the deceleration time Pr.8, set the time taken to reach 0Hz from the Pr.20 value.
 - Use the acceleration/deceleration time increments Pr.21 to set the setting range and minimum setting increments.
- Setting value 0: 0 to 3600 seconds (minimum setting increment: 0.1 second)
 Setting value 1: 0 to 360 seconds (minimum setting value: 0.01 second)



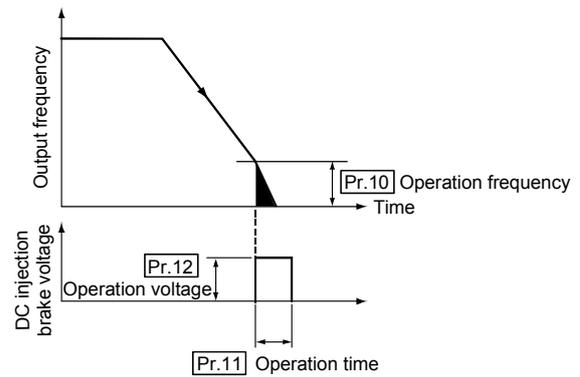
Pr. 9 Electronic thermal O/L relay setting

- The current value (A) to protect the motor from overheat can be set as it is. Normally set the rated motor current value at 50Hz so that the motor can be in the optimum thermal condition. This feature provides the optimum protective characteristics, including reduced motor cooling capability, at low speed.
- Setting 0A makes the motor protective function invalid. (The output transistor protection of the inverter functions.)
- When using the Mitsubishi constant-torque motor, set any of 1, 13 to 18, 50, 53 or 54 in Pr.71 (Applied motor), select the 100% continuous torque characteristic at low speed, and then set the rated motor current in Pr.9 (Electronic thermal O/L relay).
- The factory setting value is set to [Rated output current of inverter]. However, 0.4K and 0.75K are set to 85% of the inverter rated current.

Pr. 10 Pr. 11 Pr. 12 DC injection brake adjustment

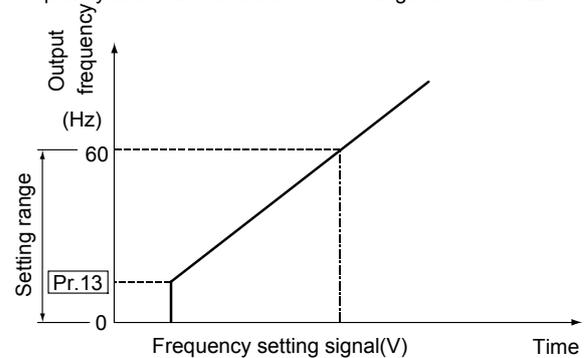
- Pr. 10** DC injection brake operation frequency
- Pr. 11** DC injection brake operation time
- Pr. 12** DC injection brake voltage

- By setting the DC injection brake torque (voltage) at a stop, the operation time and the operation starting frequency, the stopping accuracy of a positioning operation, etc. can be adjusted according to the load.



Pr. 13 Starting frequency setting

- Frequency at a start can be set in the range of 0 to 60Hz.

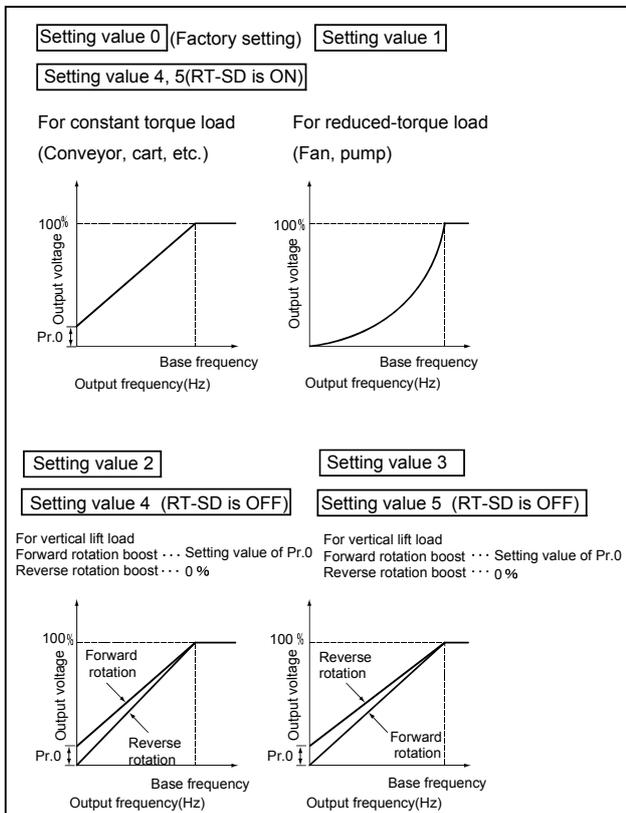


Pr. 14 Applied load selection

- The optimum output characteristic (V/F characteristic) for applications and load characteristics can be selected.

Pr.14 setting value	Output characteristics		
0	Constant torque load		
1	Reduced-torque load		
2	For constant torque elevators	Reverse rotation boost 0%	
3		Forward rotation boost 0%	
4	Signal across terminals RT-SD.	ON	Constant torque load (same as when Pr.14=0)
		OFF	Reverse rotation boost for constant torque elevators 0% (same as when Pr.14=2)
5	Signal across terminals RT-SD.	ON	Constant torque load (same as when Pr.14=0)
		OFF	Forward rotation boost for constant torque elevators 0% (same as when Pr.14=3)

(Note) This parameter setting is ignored when Pr.80 or Pr.81 has been set to select the advanced magnetic flux vector control or the real sensorless vector control.



3.5.4 Starting/Stopping methods

If a motor is not properly started/stopped, the inverter may not operate properly or may be damaged in the worst case.

	Correct	Incorrect	Incorrect
Method	The inverter is started and stopped with the terminals (STF, STR).	The inverter is started and stopped with the input side magnetic contactor (MC1).	The inverter is started and stopped with the output side magnetic contactor (MC2).
Operation procedure	<p>The diagram shows three stages: 1. Power-on (MC1 ON) with a switch diagram for MC1 (R, S, T). 2. Start signal ON (Across STF-SD ON) with a switch diagram for STF and SD. 3. Start signal OFF (Across STF-SD OFF) with a switch diagram for STF and SD.</p>	<p>The diagram shows three stages: 1. Power-on (MC1 ON) with a switch diagram for MC1 (R, S, T). 2. Start signal is kept ON with a switch diagram for STF and SD. 3. Power-off (MC1 OFF) with a switch diagram for MC1 (R, S, T).</p>	<p>The diagram shows four stages: 1. Power-on (MC1 ON) with a switch diagram for MC1 (R, S, T). 2. Start signal ON (Across STF-SD ON) with a switch diagram for STF and SD. 3. MC2 OFF with a switch diagram for MC2 (U, V, W) and motor (IM). 4. MC2 ON with a switch diagram for MC2 (U, V, W) and motor (IM).</p>
Motor speed/inverter output	<p>The graph shows Motor speed (N) and Output frequency (f) vs time (t). The speed profile is a trapezoid. STF is ON during acceleration and deceleration. MC1 is ON throughout the entire process.</p>	<p>The graph shows Motor speed (N) and Output frequency (f) vs time (t). After deceleration, there is a 'Coasting to stop' phase where speed decreases naturally. STF is ON during acceleration and deceleration. MC1 is ON during acceleration and deceleration but OFF during coasting.</p>	<p>The graph shows Motor speed (N) and Output frequency (f) vs time (t). After deceleration, there is a 'Coasting to stop' phase. STF is ON during acceleration and deceleration. MC2 is ON during acceleration and deceleration but OFF during coasting. An 'Inverter trip' event is shown during the coasting phase.</p>
Remarks	The inverter starts when the terminals STF-SD are turned on and decelerates to stop when they are turned off.	Frequently turning on and off the MC1 may damage the inverter.	When the MC2 is turned on, the overcurrent protection is activated and the inverter trips.

Fig.3.10 Starting/Stopping methods

3.5.5 Start/stop with the input side magnetic contactor MC

- (1) An inverter is not designed on the assumption that it is started/stopped with the input side magnetic contactor (MC1).
- (2) When the AC power supply is turned on by the input side magnetic contactor (MC1), a large inrush current flows to the large-capacity smoothing capacitor in the inverter. To suppress this current, a short-time rating control resistor is installed at the place shown in Fig. 3.11. In addition, a relay or magnetic contactor (MC3) is installed to short both ends of the resistor when charging the capacitor is completed.
- (3) When an inverter is frequently turned on/off using the input side MC, the repeated inrush current causes overheating of the control resistor and eventually breakage. If the relay or input side magnetic contactor (MC1) shorting the resistor is turned on in this state, a large inrush current flows into the smoothing capacitor through the converter elements (diodes) for charging. This uncontrolled inrush current damages the converter elements.

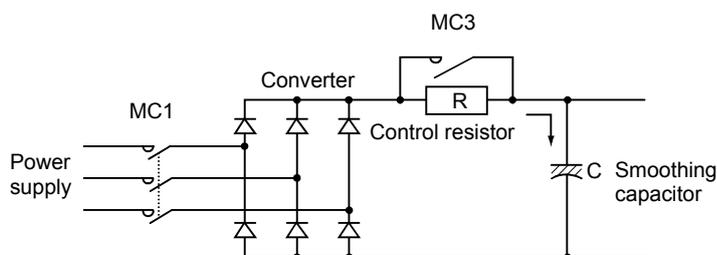


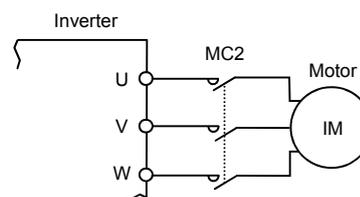
Fig. 3.11 Converter circuit

- (4) Such operation must be avoided since not only the lives of the converter elements but of the smoothing capacitor, the relay for shorting a control resistor and the magnetic contactor (MC3) are shortened.
- (5) When a motor is stopped by turning off the input side magnetic contactor (MC1), the regenerative brake proper to the inverter control is not operated. The motor coasts to stop.
When an instantaneous power failure or a power failure occurs, the motor also coasts to stop.

Good to know for checking an inverter

For a machine which requires the motor (including the inverter) be shut off from the power supply at every operation end to prevent hazardous conditions, it is recommended to use the output side magnetic contactor (MC2) installed between the inverter and the motor for shutting off the motor from the power supply.

(Note) Turn on the output side magnetic contactor (MC2) in the status of the inverter stop (output stop).
(Turn off the MC2 after turning on the terminals MRS-SD.)



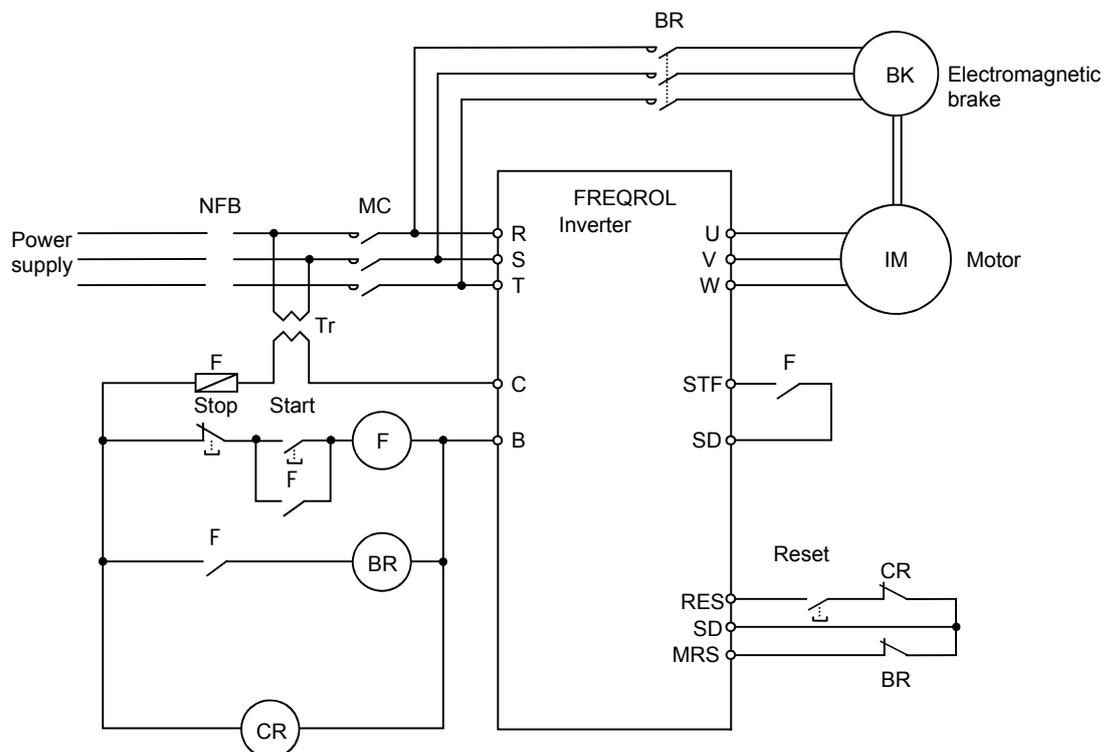
3.5.6 Inverter start during motor coasting

The inverter cannot be started during motor coasting. The following explains the reasons and precautions.

- (1) A residual voltage is generated in the motor when it coasts to stop. If the voltage is applied to the motor from the inverter in that status, the phases of the motor residual voltage (sine wave) and inverter output voltage (PWM) do not match and the overcurrent occurs.
(Reference: The overcurrent is also generated when switching from λ to Δ is performed in the λ - Δ starting system on the commercial-power supply operation.)
- (2) The inverter always outputs the starting frequency (variable according to 0.5Hz parameter) at start. If the motor is coasting at this time, the regenerative overcurrent occurs due to the rapid braking operation to decelerate the motor to the synchronous speed of the starting frequency.
A regenerative overvoltage trip may occur.
- (3) Generally, an interlock, coating interlock timer, is provided with the sequence to prevent the inverter from being started during motor coasting.
- (4) To continue an operation without stopping the motor in the case of an instantaneous power failure, etc., the automatic restart after instantaneous power failure function is effective if selected.

3.5.7 Using method of motor with electromagnetic brake

The following shows the precautions and circuit example when the motor with brake is operated with an inverter.



For details, refer to Fig. 3.19.

Fig. 3.12 Circuit example of motor with brake

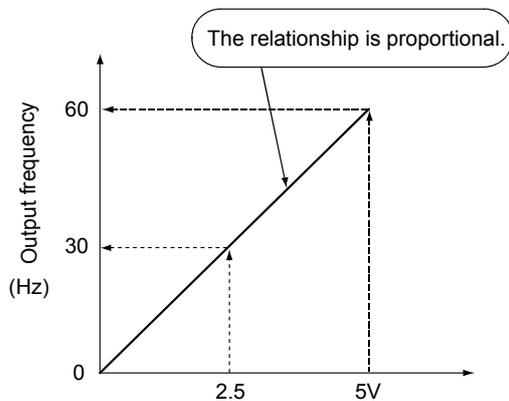
- (1) Provide the power supply for brake from the input side of the inverter.
- (2) To stop a motor with electromagnetic brake, turn off the inverter output by turning on the inverter output stop terminals MRS-SD. Otherwise, an overcurrent (OC3) may occur when the locked current flows to the motor at braking.
- (3) When a motor with brake is used, rattle may be heard according to the type of the brake during continuous operation at the low speed (30Hz or less). The motor can be used without trouble if used for the low-speed operation in a short time such as the positioning stop.
- (4) When an inverter is used with the 400V system power distribution, the operation circuit is controlled by stepping down to 400V/100V or 400V/200V via a step-down transformer Tr.

3.5.8 Frequency setting (select) signals and output frequency

The output frequency can be varied using the following methods.

- Continuously change the frequency setting signal (e.g. 0 to 5VDC, 4 to 20mA).
(Hold down the ▲ or ▼ key to operate with the parameter unit.)
- Change the frequency step-by-step by switching the multiple frequency setting potentiometers or by switching the multi-speed selection terminals (RH, RM and RL).
(Directly enter the frequency when the parameter unit is used to control.)

- (1) When the frequency setting signal is continuously varied



* If the frequency setting signal is started earlier than the acceleration/deceleration time setting value (t_a), the acceleration/deceleration time does not become shorter than t_a .

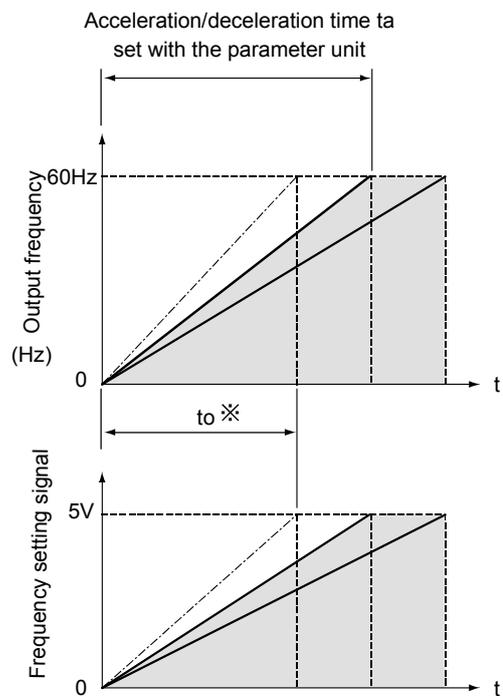


Fig. 3.13 Variable time of frequency setting signal

(2) When switching the multi-speed selection signals

- When switched simultaneously
- When switched at some interval

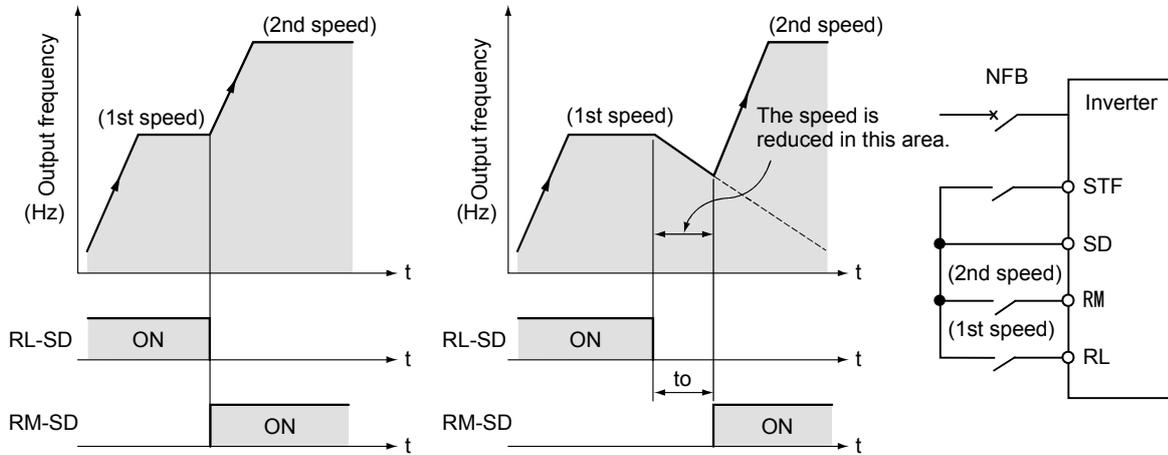
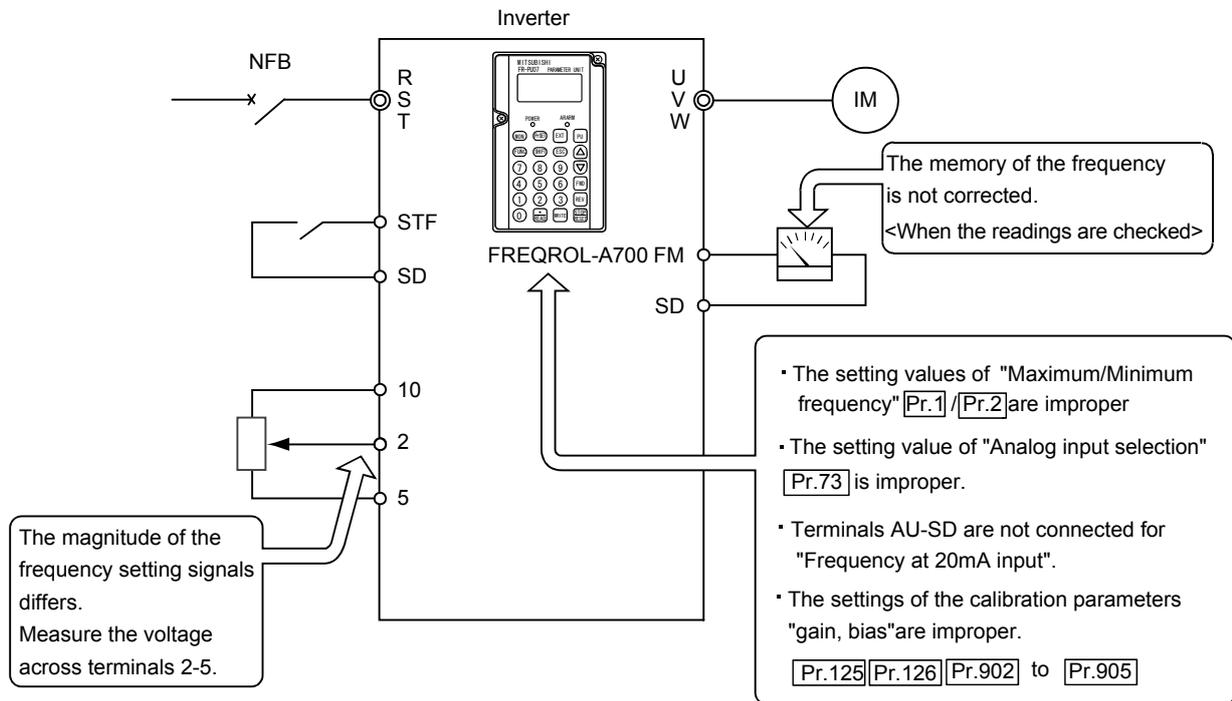


Fig. 3.14 Change of output frequency at switching

Good to know for checking an inverter

When the motor speed does not reach the setting value, the causes may be as follows.



Good to know for checking an inverter

When the motor remains stopped with the start signal turned on

(1) Check the main circuit.

- 1) Check that the power is supplied.
- 2) Check that the R or S phase of the power supply is not opened.
- 3) Check that the motor is securely connected to the inverter.

(2) Check the input signal.

- 1) Check that the frequency setting signal is being input or not set to the zero level.
- 2) Check that the start signals of both forward and reverse rotation are not input.
- 3) Check that the "Reset" or "Output stop" signal is not input.
- 4) Check that the terminals AU-SD at 4 to 20mA input is turned on.

(3) Check the function setting values.

- 1) Check that "Reverse rotation prevention" is not set. [Pr.78](#)
- 2) Check that "Operation mode" is not set to the PU operation.
- 3) Check that each operation function is not set to 0 when used.
"Multi-speed setting" [Pr.4~6, 24~27](#)
"JOG frequency" [Pr.15](#)
- 4) Check that "Starting frequency" is not larger than the operation frequency. [Pr.13](#)
- 5) Check that the "Bias" setting is proper. [Pr.902, 904](#)

(4) Others

- Check that the alarm lamp is not lit.

3.5.9 Other operation methods

(1) Three-wire type (terminal STF, STR, STOP)

The three-wire type connection is shown in Fig. 3.16.

1) Short the terminals STOP-SD to enable the start self-holding function.

In this case, the forward/reverse rotation signal functions only as a start signal.

2) If the start signal terminals STF (STR)-SD are once shorted and then opened, the start signal is kept on, and either of the terminals which is shorted earlier is enabled to start the inverter.

3) The inverter is decelerated to stop by opening the signals STOP-SD once. For the frequency setting signal and the operation of DC injection brake at stop, refer to Section 2.7.2. Fig. 3.16 shows the three-wire type connection.

4) When the terminals JOG-SD are shorted, the signal of terminal STOP is disabled and the JOG operation has a priority.

5) Short the output stop terminals MRS-SD to deactivate the self-holding function.

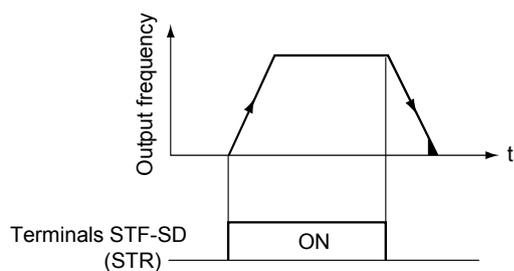
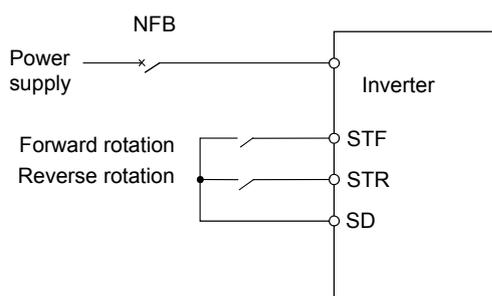


Fig. 3.15 Two-wire type connection example

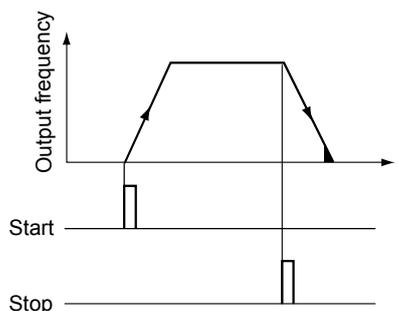
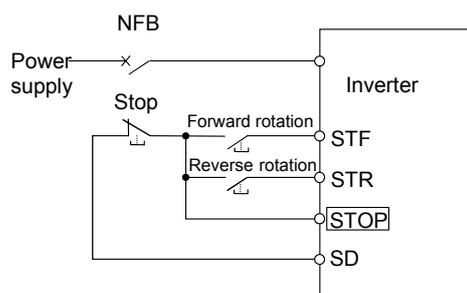


Fig. 3.16 Three-wire type connection example

(2) When one motor is run by one inverter

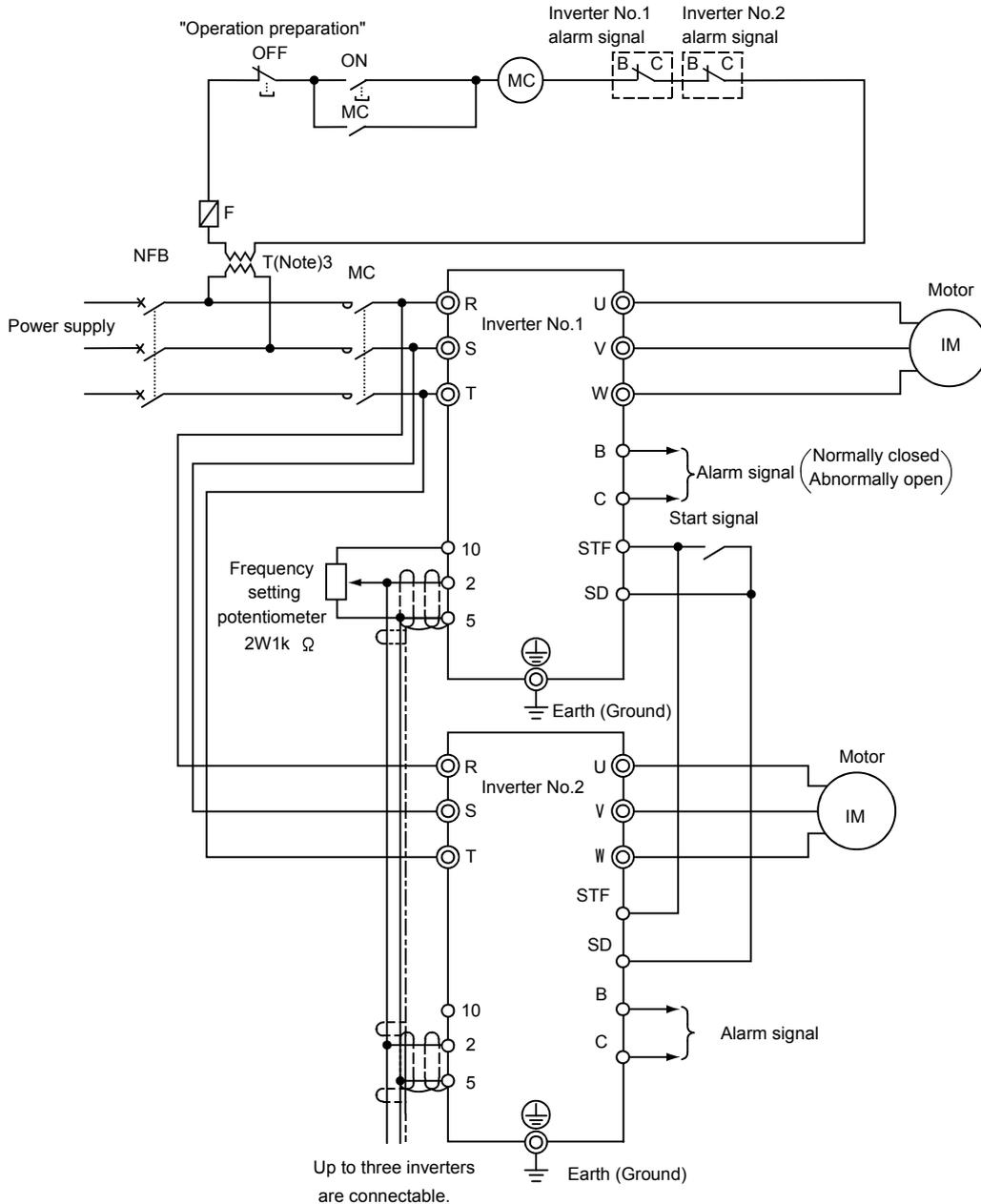
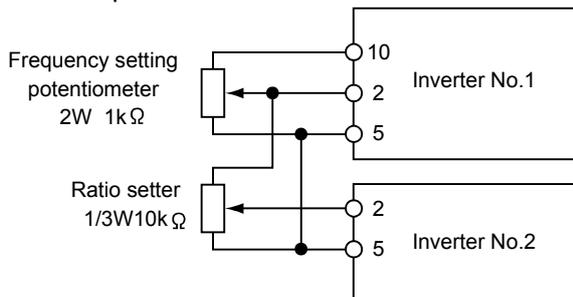


Fig. 3.17 When one motor is run by one inverter

For ratio operation



The ratio setting can be skipped by setting the gain/bias of the parameter unit calibration functions.

Fig. 3.18 For ratio operation

- (Note) 1. Using the parameter unit calibration functions, the output frequency of three inverters corresponding to a common command voltage value from the frequency setting potentiometer can be adjusted to match.
2. When more than two motors are mechanically connected, the load may be applied to one motor and an overload may occur.
3. When the power supply is 400V class, install a control transformer.

(3) Motor with brake

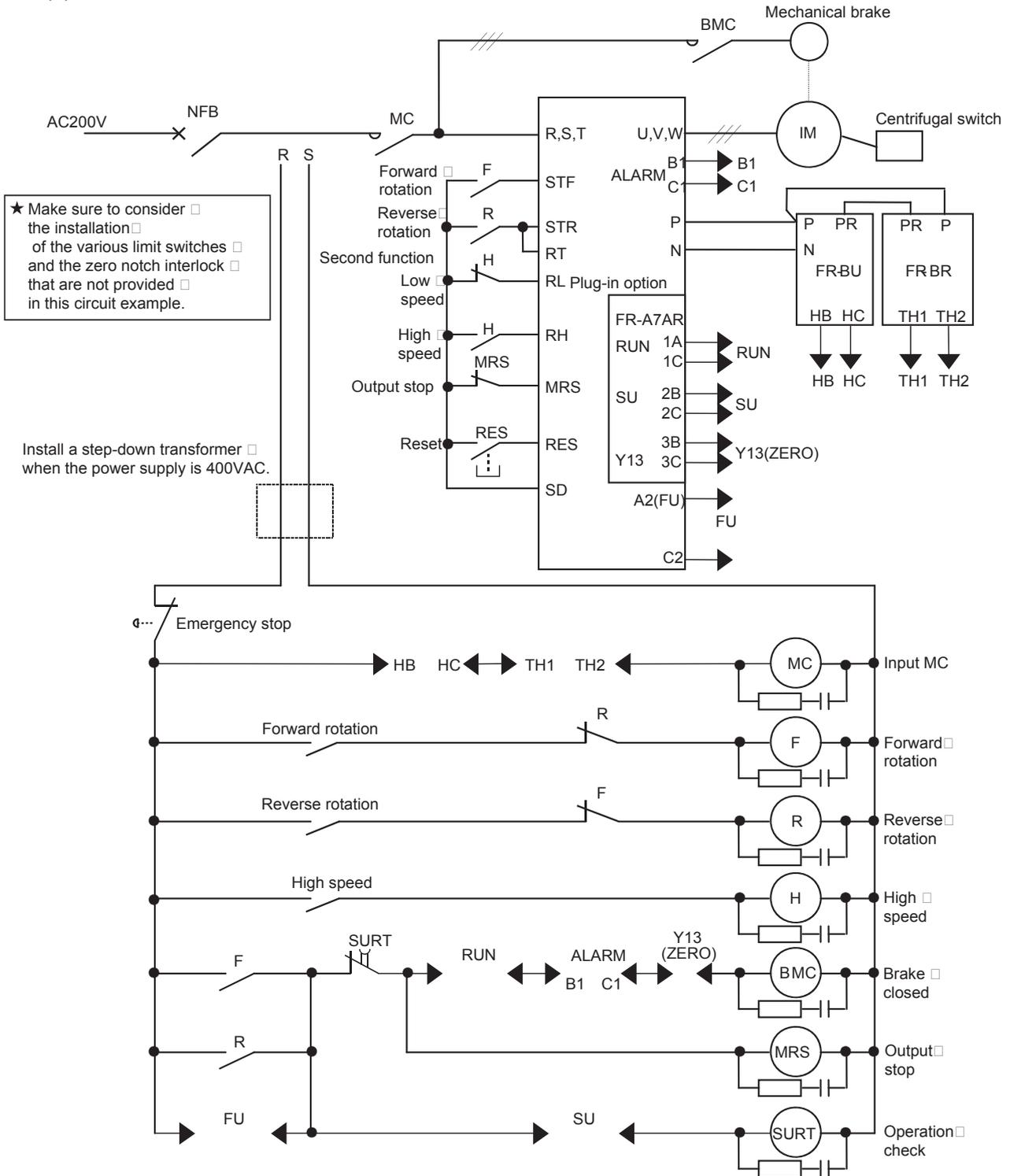


Fig. 3.19 Motor with brake

4. POWER SUPPLY OF INVERTER (HARMONICS AND INSTANTANEOUS POWER FAILURE)

This chapter describes how the power source and its system to which an inverter is connected are affected by the harmonics generated by the inverter. Then, it examines what measures should be actually taken against the harmonics with judging the effect to peripheral devices with the harmonic amount generated by inverters.

This chapter also describes how the fluctuation of the power supply (instantaneous power failure, voltage drop, etc.) affects an inverter. It is important to understand how an inverter and motor work.

POINTS for understanding!

1. Difference between harmonics and noise
2. Influx path and magnitude of the harmonic current
3. Harmonic suppression measure guideline and the measures
4. Harmonic permissible values of peripheral devices (capacitor and generator)
5. Movement of an inverter and motor at the instantaneous power failure (including the instantaneous voltage drop)

4.1 Harmonics

The harmonics are defined as a fundamental wave (generally, power supply frequency) with an integral multiple frequency. One fundamental wave combined with multiple harmonics is called a distortion (Refer to Fig. 4.2).

Distorted waves generally include the harmonics of high frequency band (kHz to MHz order). The frequency band handled as the harmonics of a power distribution system is 40th to 50th (until 3kHz), and it should be regarded as a different problem from a high frequency band with a random aspect. For example, the radio disturbance or noise (refer to Chapter 5) caused by a personal computer should be treated as a local problem of hardware. Therefore, its influences and measures are different from those of the harmonics generated from an electrical circuit network. This point must be made clear.

$$i = i_0 + \sum_{n=1}^{\infty} i_n \cdot \sin(2\pi fnt + \psi_n) \quad (4.1)$$

$n = 1, 2, 3, \dots$

$f =$ Fundamental frequency

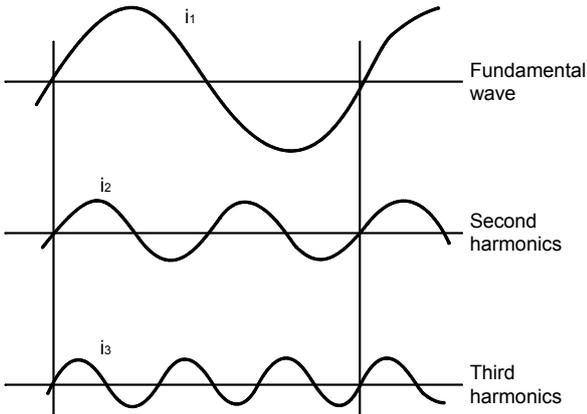


Fig. 4.1 Fundamental wave and harmonics

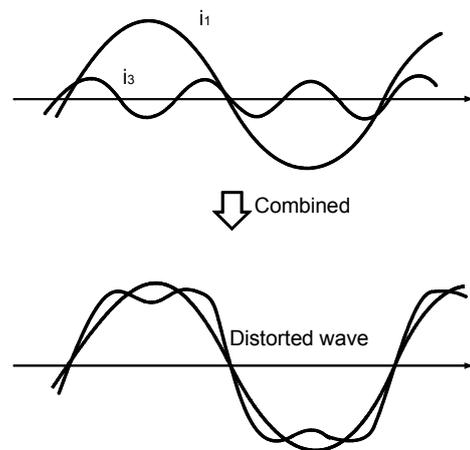


Fig 4.2 Distorted wave

Table 4.1 Difference between harmonics and noise

Item	Harmonics	Noise
Frequency	Normally 40th to 50th or less, 3kHz or less	High frequency (Several tens of kHz to MHz order)
Source	Converter part	Inverter part
Cause	Communication of rectifying circuits	Switching of capacitors
Environment	To wire paths, power impedance	Across spaces, distance, laying paths
Quantitative understanding	Logical computation is possible	Occurs randomly, quantitative understanding is difficult.
Generated amount	Approximately proportional to load capacity	According to current fluctuation rate (larger with faster switching)
Immunity of affected device	Specified in standards for each device.	Differs according to maker's device specifications.
Examples of safeguard	Install a reactor (L).	Increase the distance(ℓ).

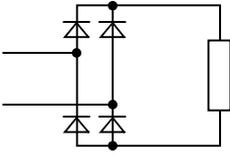
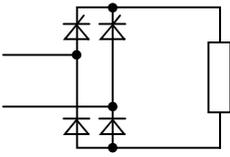
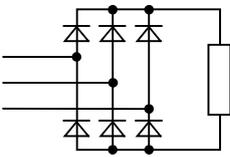
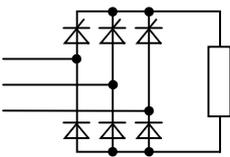
4.2 Rectifying Circuit and Characteristics of Generated Harmonics

The sources of the generated harmonics are a rectifier, AC power regulator, etc. The converter in a general-purpose inverter consists of rectifying circuits, which generate many harmonics.

There are various rectifying circuits depending on the main circuit pattern as shown in Table 4.2. For the most general-purpose inverters, three-phase bridge is adopted.

The theoretical harmonic occurrence order (n) is $n = PK \pm 1$ (P = number of pulses, $K=1, 2, 3\dots$). Three-phase bridge type general-purpose inverters generate 5th, 7th, 11th, 13th...harmonics. The magnitude of harmonics (harmonic contents) is $1/n$, which means that the generated amount becomes smaller as the harmonic order becomes larger. One-phase power input inverters generate the harmonics with the order of $4K \pm 1$ (3rd, 5th, 7th, 9th...).

Table 4.2 Rectifying circuit types and harmonics

Circuit name	Basic circuit	Harmonic order	Harmonic contents	Main devices
1-phase bridge		$n = 4K \pm 1$ $K = 1, 2, \dots$	$Kn \times 1/n$	AC electric train
1-phase hybrid bridge		$n = 2K \pm 1$ $K = 1, 2, \dots$	$Kn \times 1/n$	—
3-phase bridge		$n = 6K \pm 1$ $K = 1, 2, \dots$	$Kn \times 1/n$	Inverter DC electric train Substation Electrochemistry Other general use
3-phase hybrid bridge		$n = 3K \pm 1$ $K = 1, 2, \dots$	$Kn \times 1/n$	—

Kn : Coefficient determined by an angle of control delay, angle of communication overlap, etc.

4.3 Shunt of Harmonic Current

When the harmonics are considered in the power distribution system, the power source of the harmonics is not the commercial power supply but the harmonic occurrence source (converter for general-use inverters). The commercial power supply (low and high-voltage power transformers) becomes a part of the load for the harmonics. Accordingly, the harmonic equivalent circuit of the power distribution system diagram shown as an example in Fig. 4.3 will be the one shown in Fig. 4.4. The harmonic current generated by the inverter I_n ($I_n = I_2 + I_3 + I_4 + \dots$ if n is an order) shunts in proportion to $1/Z$, which is the inverse proportion of the impedance of the power transformer ($\dot{Z}_L = R_L + jnX_L$) and the devices that is connected in parallel with the transformer (motor B and capacitor in the example of Fig. 4.3), that is to say, the impedances of the motor B ($\dot{Z}_M = R_M + jnX_M$) and capacitor ($\dot{Z}_C = jnX_C - jX_C/n$).

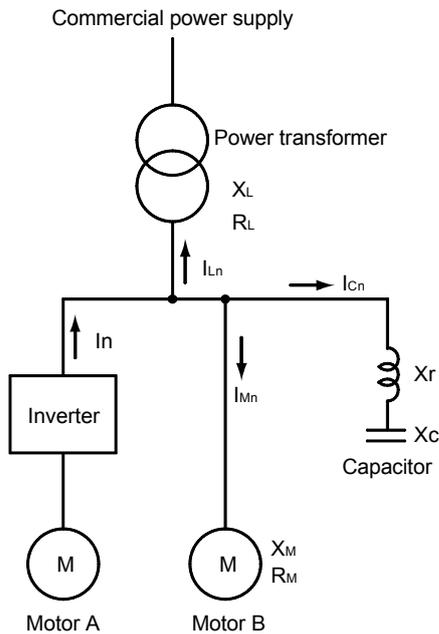


Fig. 4.3 Power distribution system diagram (No.1)

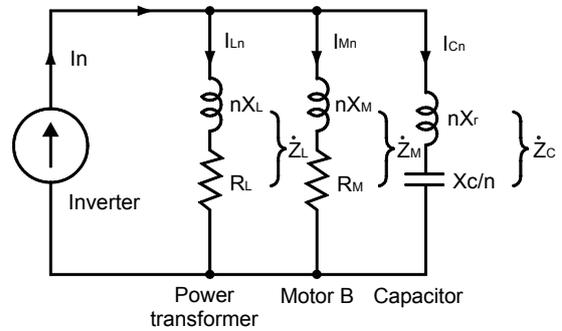


Fig. 4.4 Harmonic equivalent circuit (No.1)

Fig. 4.5 shows an example of a power distribution system diagram including a high-tension circuit. In this example, loads on the low-tension side (motors, etc.) are abbreviated since the harmonics generated in the inverter mostly flow into the power transformer for the enormous load impedance (\dot{Z}_M) in comparison with the power transformer impedance (\dot{Z}_L). The harmonic current on the high-tension side I_n is the total harmonic current value of the low-tension inverter divided by the transformation ratio.

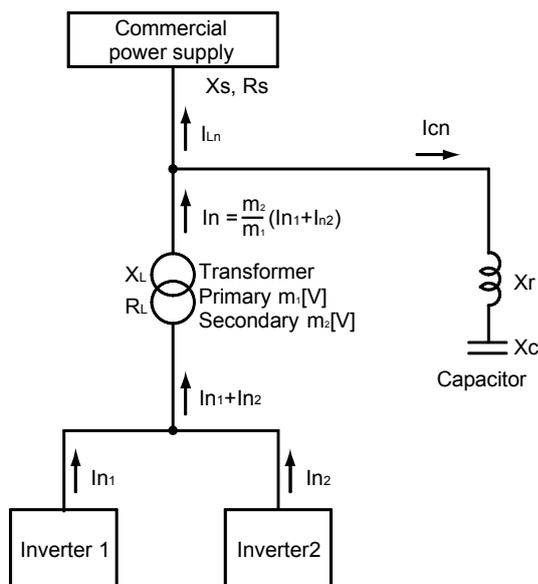


Fig. 4.5 Power distribution system diagram (No.2)

$$I_{Ln} = I_n \times \frac{\dot{Z}_c}{\dot{Z}_s + \dot{Z}_c}$$

$$I_{cn} = I_n \times \frac{\dot{Z}_s}{\dot{Z}_s + \dot{Z}_c}$$

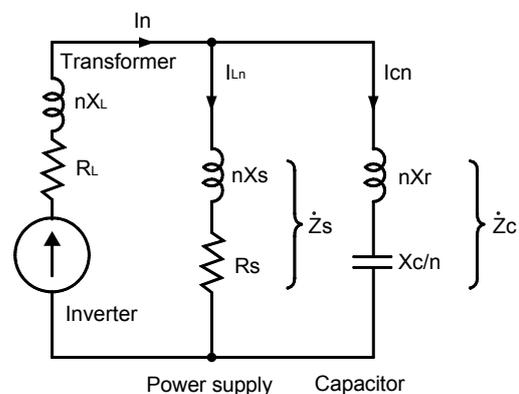


Fig. 4.6 Harmonic equivalent circuit (No.2)

Good to know for checking an inverter

▪ Impedance \dot{Z} of inductive loads (motors, transformers, etc.)

$$\dot{Z} = R + j\omega X = R + j2\pi f X \quad (f = nf_0 \quad f_0 : \text{Fundamental frequency})$$

$$= R + j2\pi f_0 n X = R + n (j2\pi f_0 X)$$

▪ Impedance \dot{Z} of capacitive loads (capacitors)

$$\dot{Z} = -j \frac{1}{\omega C} = -j \frac{1}{2\pi f C} = -j \frac{1}{2\pi f_0 n C} = \frac{1}{n} \left(-j \frac{1}{2\pi f_0 C} \right)$$

- The current tends to flow to the smaller impedance, and a capacitive impedance element (power factor correction capacitor) may magnify the harmonics.

When the harmonics are considered as a problem, the following can be said from the above:

- 1) The impedance on the power supply side \dot{Z}_s is represented by the short-circuit capacity on the power supply system and is not less affected by other factors as the power capacity is larger.
- 2) The inductive loads can be neglected since they have higher impedance than the harmonics.
- 3) What should be considered is only capacitive loads such as a power factor correction capacitor.

Good to know for checking an inverter

- (a) If a power factor improving reactor is installed, the harmonic components decrease with the effect equivalent to the larger impedance of the inverter power supply side. The impedance of a reactor is well over that of a power transformer. The gap due to the capacity of power transformers is reduced to almost zero.
- (b) The harmonic components without a power factor improving reactor installed highly depend on the capacity of the power transformer (including a line impedance).
- (c) When the inverter output frequency or motor load factor is low, the harmonic contents against the inverter input current become higher. However, the absolute value of the harmonic current does not become higher than at full load since the input current itself is small. For the reduced-torque loads such as a fan and pump, calculate the harmonic current under the conditions of the maximum setting frequency, 50Hz or 60Hz.

4.4 Harmonic Suppression Guideline

Harmonic currents flow from the inverter to a power receiving point via a power transformer. The harmonic suppression guideline was established to protect other consumers from these outgoing harmonics.

The three-phase 200V input specifications 3.7kW or less are previously covered by "Harmonic suppression guideline for household appliances and general-purpose products" and other models are covered by "Harmonic suppression guideline for consumers who receive high voltage or special high voltage". However, the general-purpose inverter has been excluded from the target products covered by "Harmonic suppression guideline for household appliances and general-purpose products" in January 2004 and then the guideline was abolished on September 6, 2004.

All capacity models of general-purpose inverter used by specific consumers are now covered by "Harmonic suppression guideline for consumers who receive high voltage or special high voltage" (hereinafter referred to as "Guideline for specific consumers").

4.4.1 Harmonic suppression guideline for consumers who receive high voltage or special high voltage

The maximum amount of generated harmonics must be suppressed under the following values per 1kW contract power.

Table 4.3 Maximum values of outgoing harmonic currents per 1kW contract power (Unit: mA/kW)

Received power voltage	5th	7th	11th	13th	17th	19th	23rd	Over 23rd
6.6kV	3.5	2.5	1.6	1.3	1.0	0.9	0.76	0.70
22	1.8	1.3	0.82	0.69	0.53	0.47	0.39	0.36
33	1.2	0.86	0.55	0.46	0.35	0.32	0.26	0.24
66	0.59	0.42	0.27	0.23	0.17	0.16	0.13	0.12
77	0.50	0.36	0.23	0.19	0.15	0.13	0.11	0.10
110	0.35	0.25	0.16	0.13	0.10	0.09	0.07	0.07
154	0.25	0.18	0.11	0.09	0.07	0.06	0.05	0.05
220	0.17	0.12	0.08	0.06	0.05	0.04	0.03	0.03
275	0.14	0.10	0.06	0.05	0.04	0.03	0.03	0.02

The harmonic contents for each circuit type are shown in the following table.

Table 4.4 Harmonic contents

(Unit: %)

Circuit type	5	7	11	13	17	19	23	25
3-phase bridge								
▪ 6-pulse converter	17.5	11.0	4.5	3.0	1.5	1.25	0.75	0.75
▪ 12-pulse converter	2.0	1.5	4.5	3.0	0.2	0.15	0.75	0.75
▪ 24-pulse converter	2.0	1.5	1.0	0.75	0.2	0.15	0.75	0.75
3-phase bridge (capacitor smoothing)								
▪ Without reactor	65	41	8.5	7.7	4.3	3.1	2.6	1.8
▪ With reactor (AC side)	38	14.5	7.4	3.4	3.2	1.9	1.7	1.3
▪ With reactor (DC side)	30	13	8.4	5.0	4.7	3.2	3.0	2.2
▪ With reactors (AC, DC sides)	28	9.1	7.2	4.1	3.2	2.4	1.6	1.4
1-phase bridge (capacitor smoothing)								
▪ Without reactor	50	24	5.1	4.0	1.5	1.4	—	—
▪ With reactor (AC side)	6.0	3.9	1.6	1.2	0.6	0.1	—	—

1) Calculation method of outgoing harmonic current

(a) Calculate the rated capacity [kVA].

The rated capacity is used for calculation of 6-pulse equivalent capacity to determine the application of "Harmonic suppression guideline for consumers who receive high voltage or special high voltage". Adjust the rated capacity [kVA] and the fundamental wave current [A] according to the motor capacity regardless of the installation of a reactor.

- It should be noted that the rated capacity above is used to determine the application of the harmonic suppression guideline and is different from the power supply capacity (power transformer, etc.) required for actual inverter drive.

For the power supply capacity, 1.3 to 1.6 times as large as the above rated capacity (correct values are described in a catalog of the inverter).

(b) Calculate the 6-pulse equivalent capacity using the conversion coefficient K_i .

- 6-pulse equivalent capacity
= Rated capacity ×
conversion coefficient K_i [kVA]

The conversion coefficient K_i is:

Circuit type	K_i
Without reactor	3.4
With AC reactor	1.8
With DC reactor	1.8
With AC/DC reactors	1.4

Table 4.6 Conversion coefficient K_i

capacity

Motor capacity [kW]	Fundamental wave current [A]		Rated capacity [kVA]	
	200V	400V	200V	400V
0.4	1.61	0.81	0.57	
0.75	2.74	1.37	0.97	
1.5	5.50	2.75	1.95	
2.2	7.93	3.96	2.81	
3.7	13.0	6.5	4.61	
5.5	19.1	9.55	6.77	
7.5	25.6	12.8	9.07	
11	36.9	18.5	13.1	
15	49.8	24.9	17.6	
18.5	61.4	30.7	21.8	
22	73.1	36.6	25.9	
30	98.0	49.0	34.7	
37	121	60.4	42.8	
45	147	73.5	52.1	
55	180	89.9	63.7	
75	245	123	87.2	
90	293	147	104	
110	357	179	127	
132	—	216	—	153
160	—	258	—	183
200	—	323	—	229
220	—	355	—	252
250	—	403	—	286
280	—	450	—	319

Table 4.5 Fundamental wave current and rated

(c) Convert to the rated current of the received power voltage.

- Rated current value converted to the received power voltage = fundamental wave current × (200V or 400V/received power voltage) [A]

For the fundamental wave current, the value in Table 4.5 must be used.

(d) Calculate the outgoing harmonic current of each order from the harmonic contents.

- Outgoing harmonic current = rated current value converted to the received power voltage × operation ratio × harmonic contents [A]

2) Calculation example

When a 30kW/400V motor is driven without a reactor by the inverter FR-A740-30K

- The fundamental wave current of the motor is 49.0A.from Table 4.5.
- The rated capacity is 34.7 [kVA].from Table 4.5.
- 6-pulse equivalent capacity = rated capacity × conversion coefficient Ki (Table 4.6) = 34.7 × 3.4 = 118 [kVA] Calculate the outgoing harmonic current by the following procedure.
- Rated current value converted to the received power voltage = fundamental wave current × (400V/received power voltage) = 49.0 × 400/6600 = 2.97 [A]
- Outgoing harmonic current = rated current value converted to the received power voltage × operation ratio × harmonic contents (Table 4.4) makes the following table.

Assume that the operation ratio is 50%. For example, if the order is 5th, $2.97 \times 0.5 \times 0.65 = 965\text{mA}$

Order	5th	7th	11th	13th	17th	19th	23rd	25th
Outgoing current [mA]	965	609	126	114	64	46	39	27
Maximum value of outgoing current [mA/kW]	3.5	2.5	1.6	1.3	1.0	0.9	0.76	0.70

Guideline setting value ←

Therefore, if the contract power is $965/3.5 = 275\text{kW}$ or less, a harmonic suppression measure must be taken.

(1) Measures against harmonics

To suppress the harmonics on the inverter, the following measures can be taken.

- High power factor converter: The high power factor converter reshapes an input current waveform into a sine wave and greatly decreases the generated harmonics from a combined inverter.
- AC reactor : Installing an AC reactor on the inverter power supply side suppresses the harmonics with the larger impedance.
- DC reactor : Installing the DC reactor on the inverter DC circuit suppresses the harmonics with the larger impedance.
- With AC/DC reactors : Installing an AC reactor on the power supply side and a DC reactor on the DC circuit suppresses the harmonics with the larger impedance.

(d) Calculation example

(1) When FR-HAL-H30K (AC reactor) is connected to the power supply according to the motor capacity under the condition of the item 2), the rated capacity is:

34.7 [kVA] from Table 4.5

- 6-pulse equivalent capacity = rated capacity × conversion coefficient K_i (Table 4.6) = $34.7 \times 1.8 = 62.5$ [kVA] Calculate the outgoing harmonic current by the following procedure.
- Rated current value converted to the received power voltage = fundamental wave current × (400V/received power voltage) = $49.0 \times 400/6600 = 2.97$ [A]
- Outgoing harmonic current = rated current value converted to the received power voltage × operation ratio × harmonic contents (Table 4.4) makes the following table.

Assume that the operation ratio is 50%. For example, if the order is 5th, $2.97 \times 0.5 \times 0.38 = 564$ mA

Order	5th	7th	11th	13th	17th	19th	23rd	25th
Outgoing current [mA]	564	215	110	50	48	28	25	19
Maximum value of outgoing current [mA/kW]	3.5	2.5	1.6	1.3	1.0	0.9	0.76	0.70

←
Guideline
setting
value

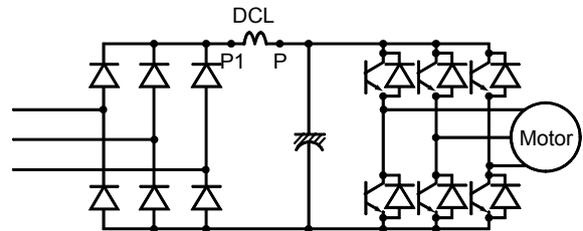
Therefore, if the contract power is $564/3.5 = 161$ kW or less, a harmonic suppression measure must be taken.

(This is only for the 5th.)

C) DC reactor

Installing the DC reactor on the inverter DC circuit suppresses the harmonics with the large impedance.

• Connection example of DCL



(a) Features

- The AC reactor can be used as a power factor improving reactor when using an inverter since it improves the input power factor to approximately 0.93.
- The DC reactor is advantageous for the little influence from the insufficient torque of a motor since it is connected to the DC circuit so that the voltage drop occurs only for the DC resistance (1% or less).
- The DC reactor is smaller and lighter than the AC reactor and has the better power factor improving effect.

(a) Features

Combining the AC and DC reactors decreases the harmonic contents as shown in Table 4.4 and heightens the effects on harmonic suppression.

(b) Selection method

Select an AC reactor and a DC reactor respectively according to the motor capacity.

Refer to the items B) and C) for the details.

(c) Precautions

- A relatively large voltage drop (approx. 6%) occurs on the power supply side, and it may cause the insufficient torque of a motor.
- When installing AC/DC reactors does not clear the guideline, another measure without reactors must be taken .

(d) Calculation example

(1) When FR-HAL-H30K is connected for an AC reactor and FR-HEL-H30K is connected for a DC reactor under the conditions of the item 3)

- The rated capacity is 34.7 [kVA].from Table 4.5.
- 6-pulse equivalent capacity = rated capacity × conversion coefficient $K_i = 34.7 \times 1.4 = 48.6$ [kVA] Since this value is less than 50 [kVA] (received power voltage: 6600V), it is not applied to the guideline and the measures against the harmonic suppression are not required.

(3) Outline of the measures against harmonics

The following table outlines the principle and characteristics of the methods to control and absorb the harmonics.

No.	Item	Definition	Effects, etc.
1)	Reactor for inverter (FR-HAL, HEL)	Installing an AC reactor on the power supply side of an inverter or a DC reactor on its DC side or both to suppress the harmonic currents with a large circuit impedance.	The harmonic current is suppressed to approximately half.
2)	High power factor converter (FR-HC)	The converter circuit is switched to convert an input current waveform into a sine wave, suppressing the harmonic current substantially. Connect to the inverter on the DC side.	The harmonic current can be suppressed to almost zero.
3)	Installation of power factor improving capacitor	The power factor improving capacitor has small impedance against the harmonics. When used with a series reactor, the power factor improving capacitor has an effect of absorbing harmonic currents. Install on the high or low voltage side.	Installing on the low voltage side has more absorbing effect.
4)	Transformer multi-phase operation	When two or more transformers are connected with a phase angle difference of 30° as in Y-Δ, Δ-Δ combination, an effect corresponding to 12 pulses, reducing low-degree harmonic current can be obtained since the peak current is suppressed for the difference of timings.	Even when the capacity combination is different from Y-Δ or Δ-Δ, the effect equivalent to 12 pulses can be expected, suppressing approximately half of the harmonic current.
5)	AC filter	The AC filter has the same effects as the power factor improving capacitor. A capacitor and a series reactor are used together to reduce impedances at specific frequencies (orders), producing a great effect of absorbing harmonic currents.	Substantial effect on suppression. (The guideline can be cleared.)
6)	Active filter	This filter detects the current of a circuit generating a harmonic current and generates a harmonic current equivalent to a difference between that current and a fundamental wave current to suppress a harmonic current at a detection point.	Substantial effect on suppression. (The guideline can be cleared.) The power factor improving effect can also be expected since the filter compensates the entire waveform.

★ The above procedures are:

- More advantageous in suppression effect in the order of 6) → 5) → 4) → 3) → 2) → 1).
- More advantageous in cost performance in the order of 1) → 2) → 3) → 4) → 5) → 6).

For consumers other than specific consumers

For consumers to whom "Harmonic suppression guideline for consumers who receive high voltage or special high voltage" is not applied, Japan Electrical Manufacturer's Association established JEM-TR226 "Harmonic suppression guideline of the general-purpose inverter (input current of 20A or less) for consumers other than specific consumers" as technical information using the conventional guidelines as a reference for promoting the comprehensive harmonic suppression.

This guideline is established for consumers to take all possible measures against the harmonics for the inverter itself the same as before.

For compliance to "Harmonic suppression guideline of the general-purpose inverter (input current of 20A or less) for consumers other than specific consumers"

Available models

Input power supply	Applied motor capacity	Measure
1-phase 100V	0.75kW or less	Connect the AC reactor or DC reactor recommended in a catalog or an instruction manual.
1-phase 200V	2.2kW or less	
3-phase 200V	3.7kW or less	

4.5 Influences of Harmonics to Peripheral Devices and Measures

4.5.1 Power factor correction capacitor

A capacitor prompts the heat deterioration of inductives and insulators and causes a burnout or breakdown of them in the long run when the harmonics overlapped to the fundamental wave current causes the temperature rise for the increase of losses and the overheat for the increase of the current effective value.

For the power factor correction capacitor, the capacity for overvoltage and overcurrent is specified by JIS Standards. For the high voltage power factor correction capacitor, JIS-C4902 specifies 130% or less of the rated current. For the low voltage power factor correction capacitor, JIS-C4901 specifies so. When the permissible values are exceeded, the capacity must be changed or installing or changing a series reactor must be examined.

The harmonic current flowing into a capacitor can be calculated from the following formula. (Refer to Formula (4.6).)

$$I_{cn} = I_n \times \frac{\dot{Z}_s}{\dot{Z}_s + \dot{Z}_c} = I_n \times \frac{R_s + jnX_s}{R_s + jnX_s + jnX_r - jX_c/n}$$

$$\approx I_n \times \frac{nX_s}{n(X_s + X_r) - X_c/n} \dots \dots \dots (4.2)$$

If the capacitor fundamental wave current is I_{c1} , the capacitor effective current I_c is:

$$I_c = \sqrt{I_{c1}^2 + \sum_{n=2}^{\infty} I_{cn}^2} \dots \dots \dots (4.3)$$

The judgment conditions are:

For the low voltage power factor correction capacitor $I_{c1} \cdot 1.3 > I_c \dots \dots \dots (4.4)$
 For the high voltage power factor correction capacitor $I_{c1} \cdot 1.3 > I_c \dots \dots \dots (4.5)$

Good to know for checking an inverter

- The possible measures for suppressing the harmonic current to a capacitor as follows.
- (a) Install a power reactor improving DC reactor on the DC side of the inverter or a power factor improving AC reactor on the primary side to suppress the generated harmonic amount.
 - (b) Use a capacitor with a series reactor. A capacitor with a series reactor is available with 6%, 8% or 13% of reactance. Avoid the series resonance for the selection.
 - (c) Receive the power from a large capacity power supply to decrease the harmonic impedance of the power supply.

4.5.2 Private generator

When the n-th harmonic current flows into a private generator, the rotating magnetic field n times as much as that of the fundamental wave is generated. The rotating magnetic field links the positive phase sequence harmonics when the speed is n-1 times the speed of a rotor and it links the negative phase sequence harmonics when the speed is n+1 times the speed of a rotor. This causes an inductive current in the damper winding or field winding, which may result in the output loss, life shortening, or breakdown.

These influences from the harmonics can be calculated as an equivalent negative phase sequence current on the assumption that the loss by the harmonic current equals the loss by the negative phase sequence current.

Various standards specify the negative phase sequence permissible value of a generator. JEM1354 specifies it as 15% or less.

$$\text{Equivalent negative phase sequence current} = \sqrt{\sum \left(\frac{1}{2} \sqrt{\frac{n}{n-1} + \frac{n}{n+1}} \right)^2} \dots \dots \dots (4.6)$$

Good to know for checking an inverter

- The possible measures for suppressing the harmonics to a generator are as follows.
- (a) Install a power reactor improving AC reactor on the primary side of the inverter or a power factor improving DC reactor on the DC side to suppress the generated harmonic amount.
 - (b) Order a generator with a large negative phase sequence current permissible value. (Consulting a manufacturer is recommended since a large-capacity generator is designed according to ordered specifications.)
 - (c) Restrict the inverter load used for the generator.

4.6. Influence of an instantaneous power failure to the inverter

When a power failure occurs, the power voltage from the control circuit used to control an inverter stops. To prevent the control malfunction, the instantaneous power failure protection is activated to stop the inverter output and maintain the output stop status. This protective operation differs according to the length of the instantaneous power failure. The explanation is given below using FREQROL-A700 series as an example.

4.6.1 Inverter operations according to the instantaneous power failure

(1) When an instantaneous power failure is within 15ms

The protective function is not activated and the operation continues normally.

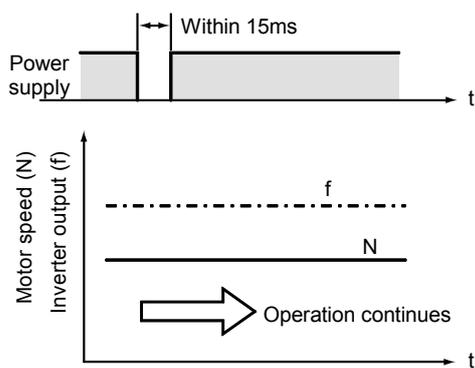


Fig. 4.7 Instantaneous power failure within 15ms

(2) When an instantaneous power failure is longer than 15ms and shorter than 100ms

The protective function is activated and the inverter output stops. (The motor coasts to stop.)

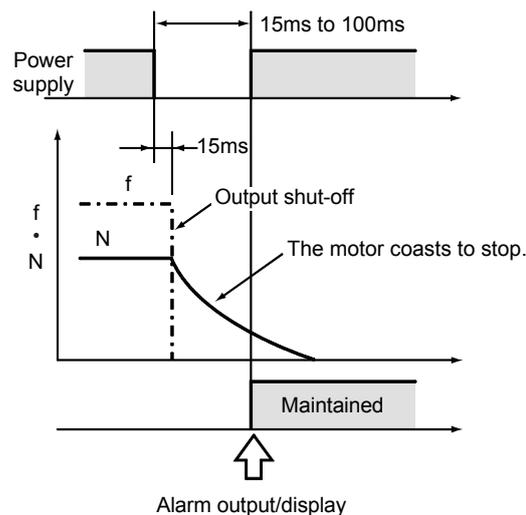


Fig. 4.8 Instantaneous power failure longer than 15ms and shorter than 100ms

(3) Instantaneous power failure longer than 100ms The inverter is automatically reset by the power restoration and becomes ready for resuming an operation.

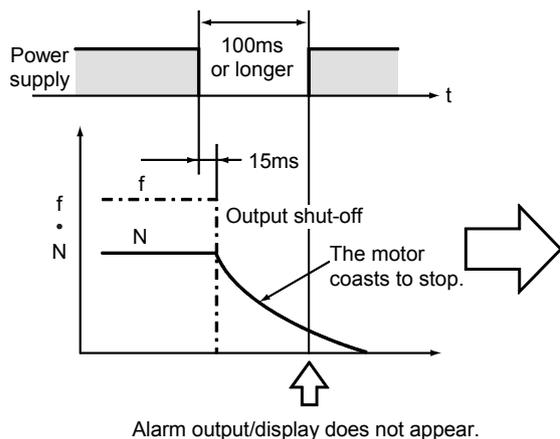


Fig. 4.9 Instantaneous power failure longer than 100ms

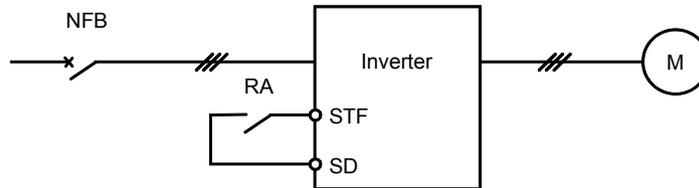
[Point to notice]

When the start signal (STF, STR) is on, the inverter restarts with the power restoration. If a motor is coasting at this time, the overvoltage or overcurrent protection is activated and a trip occurs. To restart the inverter with the power restoration, use the instantaneous power failure restart function.

(This function is available for FREQROL-A₇₀₀ series as standard. However, the restart function is not factory-set. Set "0" in Pr. 57.) See Section 4.6.3 for details on the automatic restart after instantaneous power failure function

4.6.2 Inverter peripheral circuit and inverter operation at instantaneous power failure

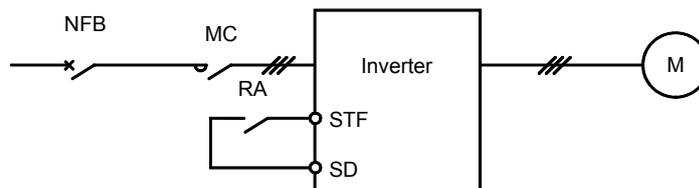
(1) When magnetic contactors are not installed in the primary or secondary side of the inverter



When an instantaneous power failure is short and the relay RA does not trip (the start signal STF is still ON), the inverter operates as shown in Section 4.6.1.

When an inverter stops the output due to an instantaneous power failure and the motor coasts, the automatic restart after instantaneous power failure operation must be used or the start signal must be turned off by inverter output stop.

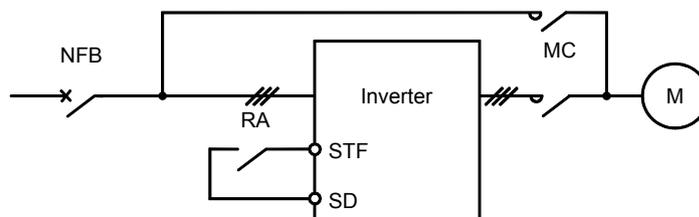
(2) When a magnetic contactor (MC) is installed in the primary side of the inverter



When an instantaneous power failure is short and both magnetic contactor MC and relay RA do not trip, the same as in (1) is applied.

When only the magnetic contactor MC trips, the motor coasts to stop. The MC must be switched on after the coasting to a stop of the motor (a free run interlock timer is required) to restart the inverter after the power is restored.

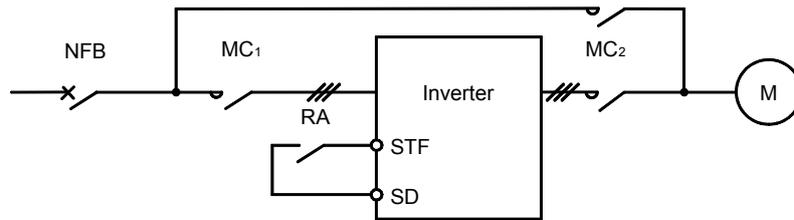
(3) When a magnetic contactor (MC) is installed in the secondary side of the inverter



When an instantaneous power failure is short and both magnetic contactor MC and relay RA do not trip, the same as in (1) is applied.

When only the magnetic contactor MC trips, the motor coasts to stop. The inverter may continue the output depending on the instantaneous power failure time. Otherwise, only the inverter restarts after the inverter initial reset by power restoration. Therefore, switching on the MC directly starts the motor with the ongoing inverter output frequency, and the inverter may trip due to the overcurrent.

(4) When magnetic contactors (MC) are installed in both primary and secondary sides of the inverter



The same as in (2) and (3) is applied.

Good to know for checking an inverter

- (a) Even if an instantaneous power failure occurs at the receiving end, a (perfect) instantaneous power failure does not always occur at the low voltage side, i.e., the inverter input terminals (R, S and T). Most cases are instantaneous voltage drops.
- (b) The inverter has the instantaneous power failure protection function and the undervoltage protection function. The undervoltage protection function is activated when the voltage in the inverter DC circuit below a certain level continues for a certain period. When an instantaneous power failure occurs at the power supply, the protection function is activated for some inverters depending on the load output (kW). If the load output is small, inverters may continue the operation.
- (c) Once a magnetic contactor or relay is switched on, it may not trip with an instantaneous voltage drop. Generally, it trips at the voltage of 30 to 50% or less of the coil rating.

4.6.3 Automatic restart after instantaneous power failure control

(1) Commercial power supply switchover, automatic restart after instantaneous power failure function

Note These functions are effective when the number of motor connected to an inverter is one.

They do not work when multiple motors are used.

- Commercial power supply switchover.....To switch from the commercial operation to the inverter operation, the inverter can be started without a motor stopped but with coasting.
- Automatic restart after instantaneous power failure.. When an instantaneous power failure occurs, a motor does not need to be stopped to continue the operation after the power restoration.

(2) Operations of the automatic restart after instantaneous power failure function

(a) When the power supply to a motor is switched off, the motor coasts.

(b) When the DC voltage is applied to the coasting motor from the inverter, the DC current flows in the motor. (Refer to A) in Fig. 4.10.)

This DC current includes the ripple at the frequency proportional to the motor speed.

(c) The CPU takes in the signal from a current detector to count the frequency for the ripple and determines the motor speed.

(d) The inverter outputs the signal with the frequency according to the motor speed. (Refer to B) in Fig. 4.10.) Then, the inverter operation is restarted, controlling the start current of the motor by gradually increasing the output voltage.

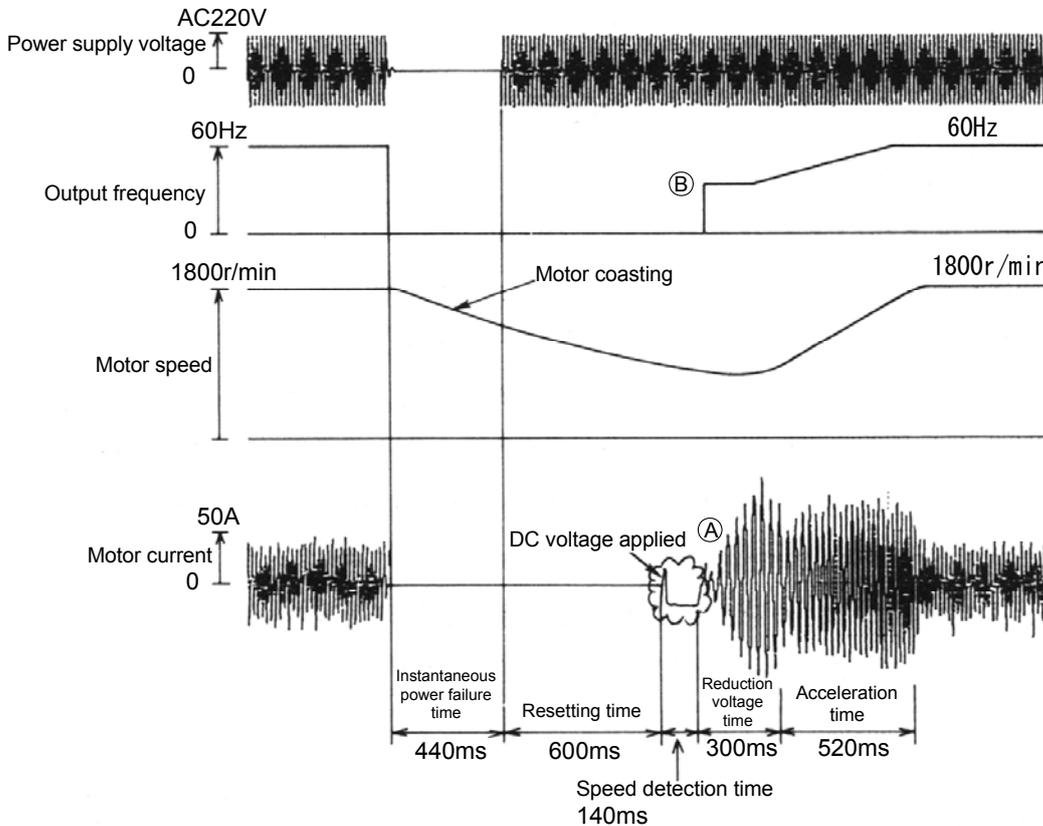


Fig. 4.10 Example of automatic restart after instantaneous power failure operation

When the automatic restart after instantaneous power failure function is equipped (Example: FREQROL-A₇₀₀ series)

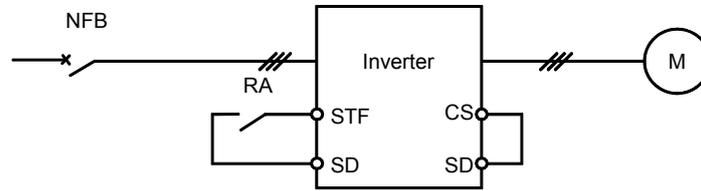


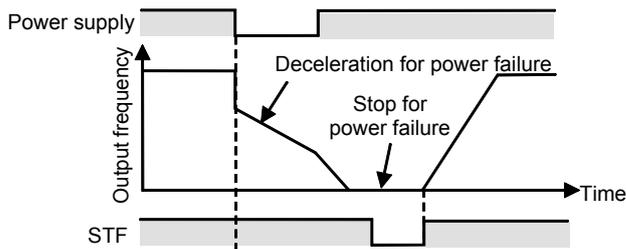
Fig. 4.11 Wiring of automatic restart after instantaneous power failure function

Short between CS-SD to use the automatic restart after instantaneous power failure function.

Functions for good to know

Power-failure deceleration stop function

When an instantaneous power failure occurs, a motor usually coasts. However, the power-failure deceleration stop function decelerates a motor to stop using the residual bus voltage. If the power is restored during the deceleration for power failure, a mode can be selected to accelerate the motor again.

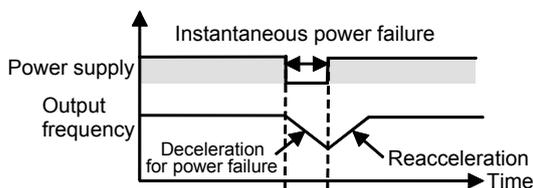


Instantaneous power-failure operation continuation function

This function makes the operation continue using the regenerative energy generated by deceleration after detecting an instantaneous power failure. After the power is restored, it accelerates the motor to the command frequency and continues the operation.

The inverter will trip if enough regenerative energy is not given from the motor due to the small load inertia.

In this case, use the automatic restart after instantaneous power failure function.



5 NOISE

Along with the spread of electrical devices, the troubles caused by noise tend to increase.

Since the inverter generates the noise from the operation principle, it may affect the adjacent devices.

The degree of the effect varies according to the inverter control system, noise capacity of external device, laying condition of wiring, installation distance, grounding method, etc. When installing the devices described below near the inverter, it is recommended to take the following measures according to the condition.

[Devices to be taken the measures against noise]

Sensors (proximity switch, etc.), video cameras (ITV, image scanner, etc.), wireless radios (including an AM radio), acoustic devices (microphone, video, audio, etc.), CRT display and medical equipments

[Devices better to be taken the measures against noise]

Measuring equipments and internal telephones

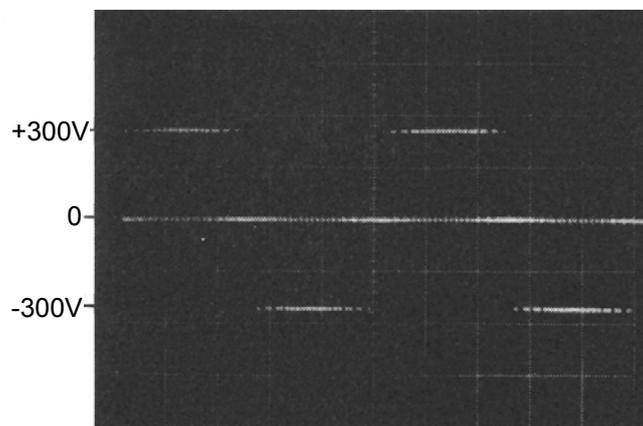
5.1 Principle of Noise Generation

As described in Chapter 2, the output voltage waveform is controlled by switching the DC voltage at high speed in the inverter.

The magnified output waveform is as shown in Fig. 2.17 of Chapter 2.

Since the steep rise and drop include lots of high frequency components, these components are the noise source.

The noise generated here and the harmonics mentioned in Chapter 4 are sometimes confused since both of them affect other electrical equipment. Generally, however, the harmonics commonly refer to waves with a frequency between 40th and 50th (2.4 to 3kHz) whereas noise commonly refers to waves with a frequency of tens of kilohertz or higher.



**Fig. 5.1 Example of inverter output voltage waveform
(When using the power supply of 200V class)**

5.2 Noise Types and Propagation Paths

Inverter-generated noises are largely classified into those radiated by the cables connected to the inverter and inverter main circuits (I/O), those electromagnetically and electrostatically induced to the signal cables of the peripheral devices close to the main circuit power supply, and those transmitted through the power supply cables.

The types of noise are shown in Fig. 5.2 and the paths of noise in Fig. 5.3.

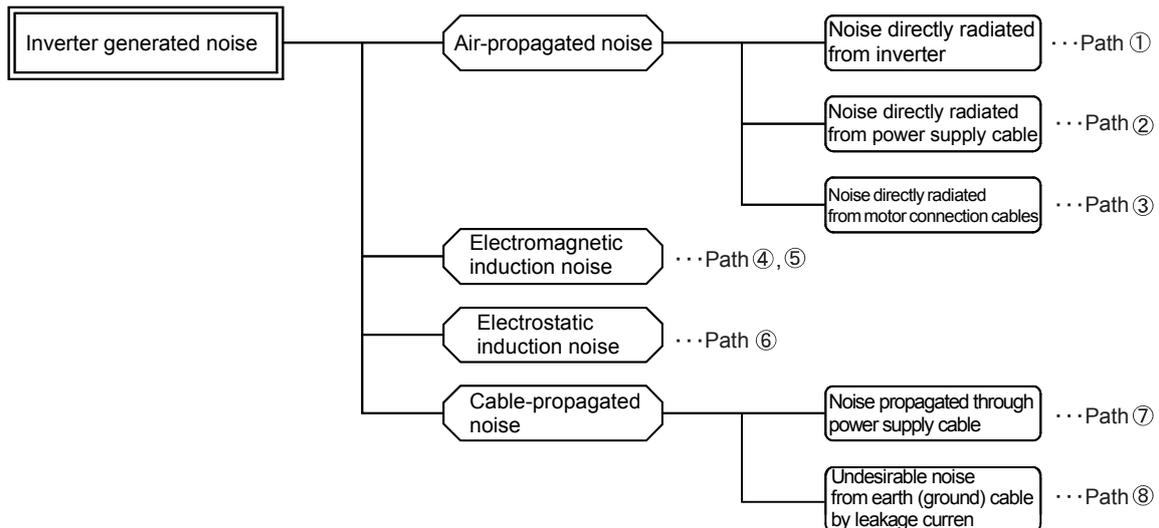


Fig. 5.2 Types of noise

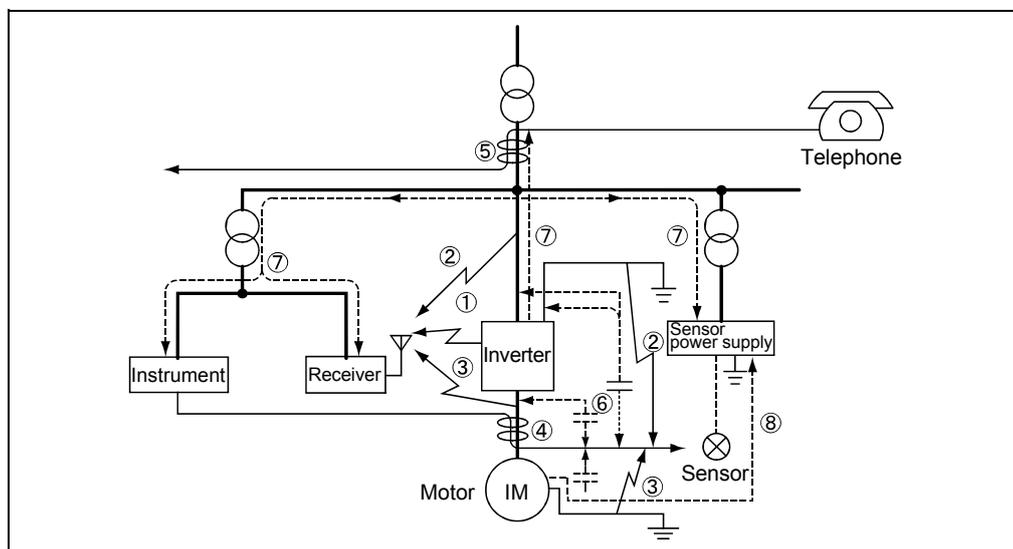


Fig. 5.3 Paths of noise

These noises tend to gain the lower noise level as the noise frequency band is higher. Generally, the noise level is low enough not to be problematic in frequencies of 30MHz or higher.

Consequently, though the noise does not affect a TV or FM radio used in the frequency of 30MHz or higher so much excluding some part, it affects the radios of the low frequency band (0.5 to 10MHz) such as an AM radio.

As mentioned above, it is reasonable to consider the measures with attention to the noise frequency band.

(1) Air-propagated noise (Paths 1) to 3))

This noise is generated in an inverter and radiated to the air. The paths of this noise can be classified into the three types shown in Fig. 5.4.

- 1) Radiated from inverter 2) Radiated from input cable 3) Radiated from motor connection cables

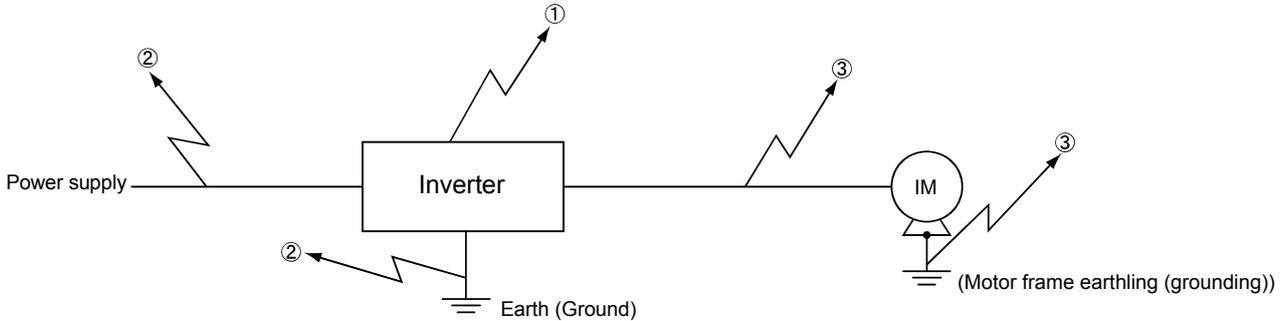


Fig. 5.4 Air-propagated noise

(2) Electromagnetic induction noise (Paths 4) and 5))

This noise is generated and transmitted when power cables or signal cables of peripheral devices cross a magnetic field generated by the current that is input to or output from an inverter. (Refer to Fig. 5.5.)

When the both cables are adjacent and parallel or the size of the loop created by each cable is large, the noise to be induced is also larger.

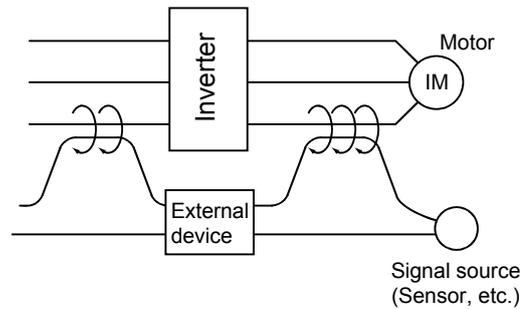


Fig. 5.5 Electromagnetic induction noise

(3) Electrostatic induction noise (Path 6))

This noise is generated and transmitted when an electric field generated by the inverter I/O cable is combined with signal cables through the electrostatic capacitances.

(Refer to Fig. 5.6.)

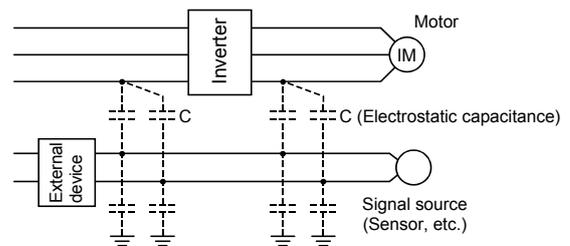


Fig. 5.6 Electrostatic induction noise

(4) Cable-propagated noise (Path 7))

This noise is a high-frequency noise that is generated inside the inverter and transmitted to peripheral devices through cables on the power supply side.

(Refer to Fig. 5.7.)

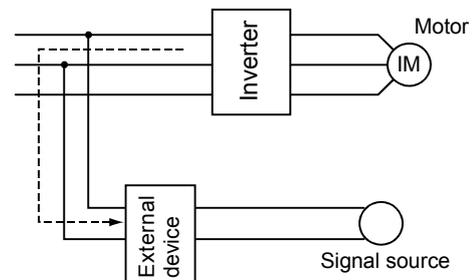


Fig. 5.7 Cable-propagated noise

To measure the magnitude of these noises, there are two methods, measuring the electric field intensity in the air or measuring the noise voltage in the power supply terminal part. (Refer to Fig. 5.8 Example of noise measurement.) The air-propagated noise is measured by the former, and the cable-propagated noise by the latter. Since there is no method to measure the electromagnetic induction noise and the electrostatic induction noise with accuracy, the noises are generally identified according to the data measured by the two mentioned above.

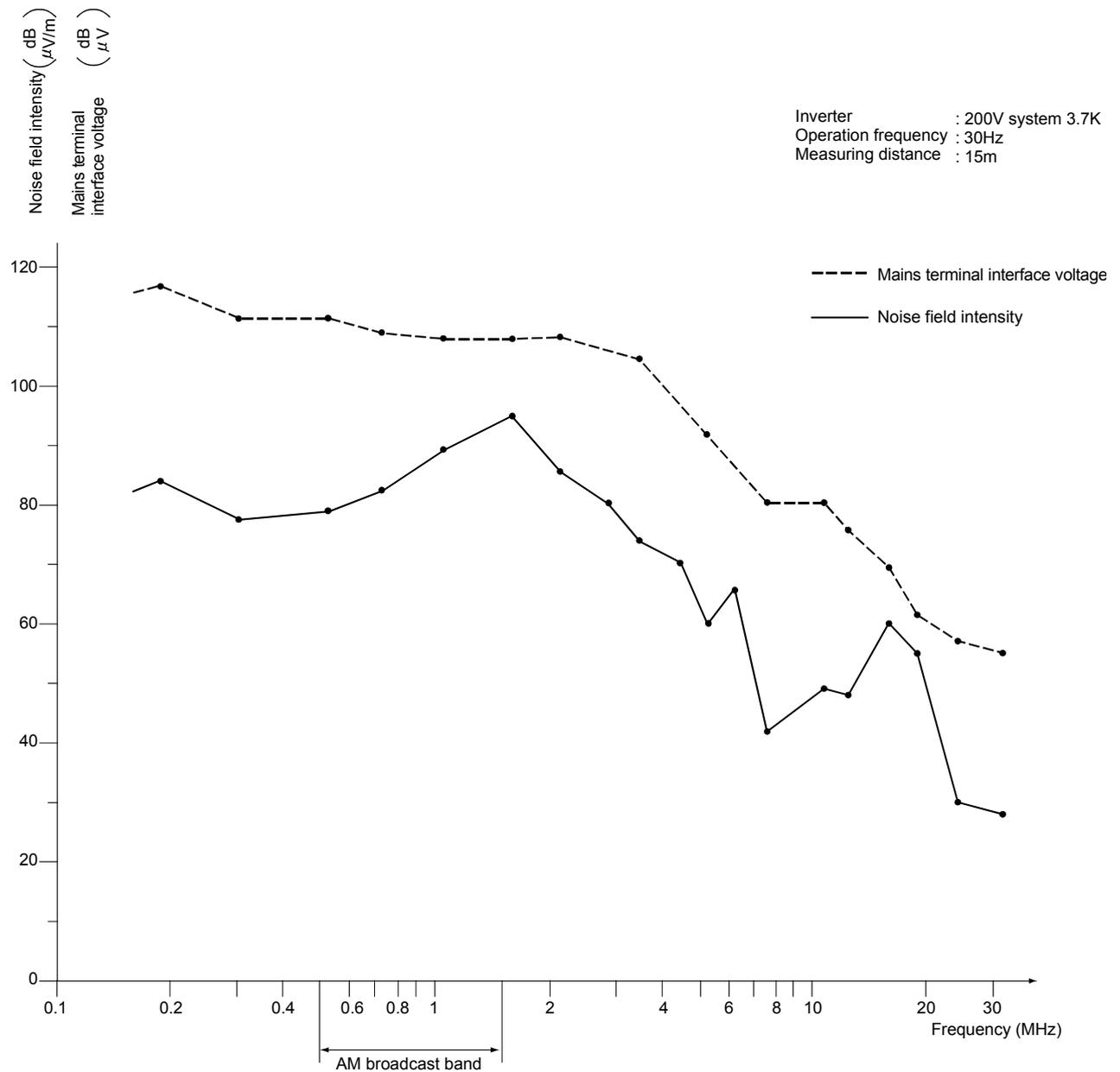


Fig. 5.8 Example of noise measurement

5.3 Measures against Noise

5.3.1 Concept of the measures against noise

Although there are many noise propagation paths as described in Section 5.2, noise sources can broadly be classified into the following three types as shown in Fig. 5.2 and 5.3:

- 1) Propagation, induction or radiation from an input power supply cable
- 2) Induction or radiation from motor connection cables
- 3) Radiation from an inverter

These noises tend to gain the lower noise level as the noise frequency band is higher. Generally, the noise level is not to be problematic in frequencies of 10MHz or higher. (Refer to Fig. 5.8.)

Consequently, though the noise does not affect a TV or FM radio used in the frequency of 70MHz or higher, it affects the radios of the low frequency band such as an AM radio. As mentioned above, it is reasonable to consider the measures with attention to the noise frequency band.

(1) Reducing noises transmitted to the power supply cable

It is effective to install a filter between an inverter and the power supply cable.

As a filter, the following types are available.

How to use and the effect are described.

1) Radio noise filter FR-BIF (200V class), FR-BIF-H (400V class)

This filter must be distinguished between for 200V and for 400V, but common for all capacities.

As shown in Fig. 5.9, it is connected to the power input terminals of the inverter. If the connection cables between the filter and the inverter are long, this part becomes a noise radiation antenna and the effect cannot be exerted enough. Therefore, connect the filter connection cables including the ground cable directly to the terminals of the inverter and make the cables as short as possible.

Also, if the distance from the ground terminal of the inverter to the earth is too long, the ground cable becomes an antenna and the enough effect may not be obtained. Therefore, the ground cable must be also made as short as possible.

This filter has a larger effect at a few MHz or lower and is effective to reduce the noise to an AM radio.

In addition, this filter has a built-in capacitor. Connecting it to the inverter output side causes damage, and therefore it is necessary to pay attention to make a correct connection.

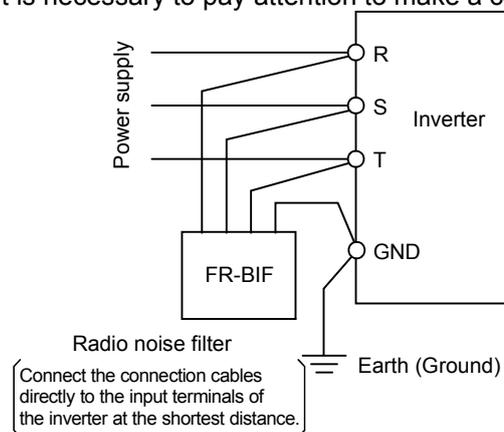


Fig. 5.9 Installation of radio noise filter FR-BIF

2) Line noise filter FR-BSF01, FR-BLF

Since this filter consists of only core, it can be used for all models regardless of the power supply voltage or capacity.

As shown in Fig. 5.10, wind 3-phase wires in the same direction and insert them to the power input side of the inverter. The larger the winding number, the more effect can be obtained. Therefore, wind the wires four or more turns, as many as possible.

However, if the wire is thick and cannot be wound four or more turns, prepare 2 or more filters and make the total winding number four or more turns.

The two types are chosen and used depending on the wire size to be used.

This filter has a larger effect at several 100 kHz or more. Also, this filter can be used on the inverter output side.

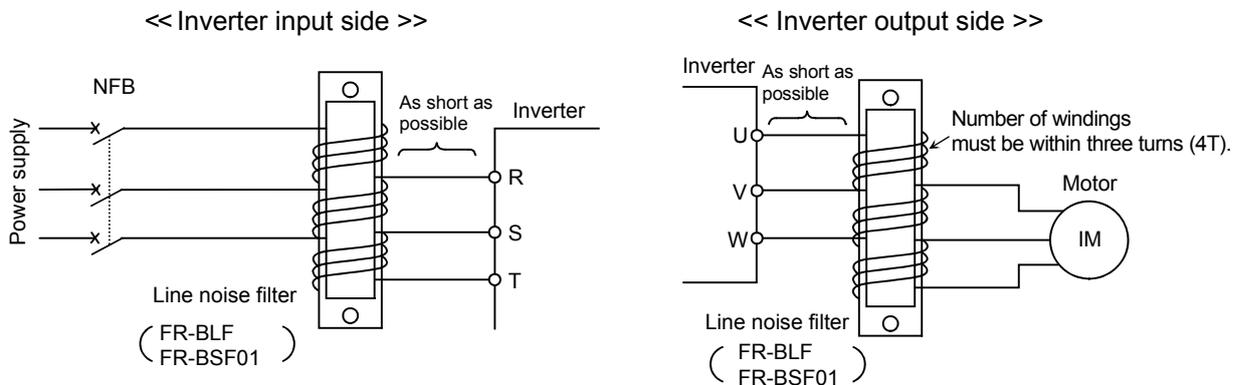


Fig. 5.10 Installation of line noise filter FR-BSF01 and FR-BLF

3) Combination of FR-BIF(-H) and FR-BLF/FR-BSF01

As described above, FR-BIF is relatively effective to the noise of the low frequency, and FR-BLF to that of the high frequency. Therefore, combining the both filters brings a better result.

In this case, make a connection as shown in Fig. 5.11.

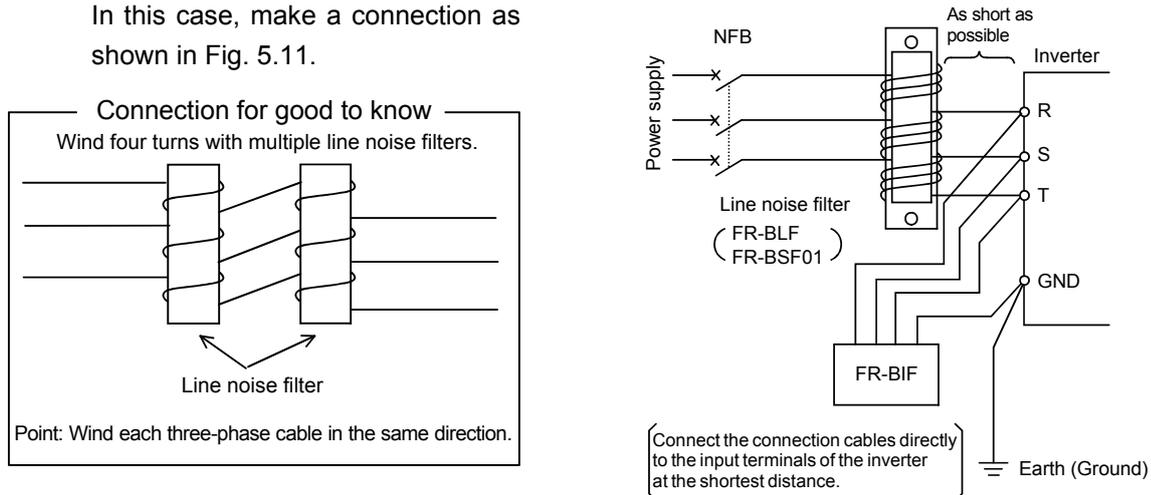


Fig. 5.11 Combination of FR-BIF and FR-BLF/FR-BSF01

Good to know

For 55kW or less of the FREQROL-A700 and F700 series, functions equivalent to the line noise filter and radio noise filter on the input side are provided.

4) Noise cutting transformer

The noise cutting transformer is a transformer for which the magnetic and electrostatic coupling of the primary and secondary coils are extremely reduced, and it has a great reducing effect against not only the noise emission but also the noise entrance.

(Refer to Table. 5.1.)

Since there is no need to be earthed in principle, it is an ideal noise reducing method which exhibits the effect when a good grounding cannot be made or when a ground wire is lengthened. However, a transformer with a capacity necessary for the main circuit is required, three of single-phase transformer must be used for the three-phase power supply, and therefore it takes up space and is to be expensive. In addition, the internal impedance is large, and it is necessary to pay attention to the large voltage drop.

Table. 5.1 Noise reducing example of noise cutting transformer

Measuring frequency [Hz]	5K	7.5K	10K	25K	50K	75K	100K	250K	500K	750K	1M	2.5M	5M	7.5M	10M	25M	50M	75M	100M
Reducing ratio -[dB]	100 or less							85 or less	74 or less	77 or less	72 or less	54 or less	45 or less	37 or less	32 or less	22 or less	28 or less	42 or less	46 or less

(Note) Attenuation ratio = $20 \log_{10} \frac{\text{Voltage after attenuation}}{\text{Voltage before attenuation}}$ [dB]

(2) Reducing noises radiated from cables between an inverter and a motor

Installing the previously described FR-BLF or FR-BSF01 line noise filter to the output side of the inverter is a method to reduce the radiated noises. Generally, a metal pipe is used as shown in Fig. 5.12. Here, grounding the motor must be performed on the inverter side with one of the four-core cables, and as the thickness of a pipe, using a pipe of 2mm or more produce a better effect. Also, running the cable in a pit of the concrete instead of a metal pipe or placing the cable in a room surrounded by the concrete can produce a similar effect.

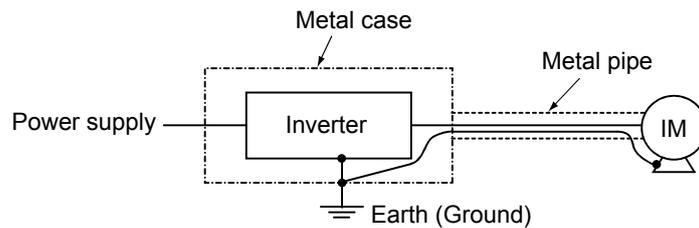


Fig. 5.12 Piping process of motor connection cables

(3) Reducing noises radiated from an inverter

Generally, noises radiated from an inverter are relatively small and less problematic. However, when an inverter is installed close to the previously described devices easily affected by noises, it is required to place the inverter in a metal case and install a noise filter on the power supply side. Also, for the output side, connect a metal pipe to the case.

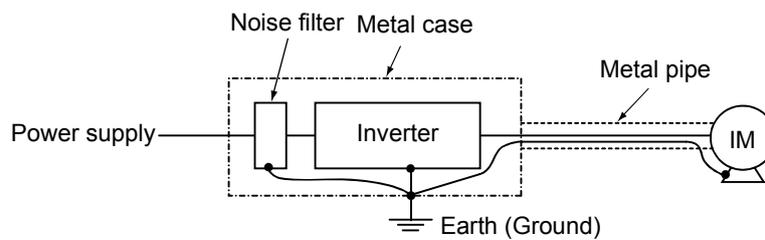


Fig. 5.13 Reducing noises radiated from an inverter

5.3.2 Particular measure cases

(1) Corrective action and effect

For each item of the measure example (refer to the next page.), the effect levels (estimated values) to be expected are as shown below. Refer to them for the priority determination when actually taking the measure.

Definition of symbols
 ◎: Substantially effective
 ○: Effective
 △: Slightly effective
 -: No effective

Table. 5.2 Effect of measures against noise

Location	Symbol	Corrective action	Noise propagation method						
			Air-propagated noise			Electromagnetic induction noise	Electrostatic induction noise	Cable-propagated noise	
			Inverter radiation	Power supply cable radiation	Motor cable radiation			Power supply cable	Undesirable path of earth (ground) cable
Inverter	A	Reduce the carrier frequency (Pr.72). (For FR-A series)	◎	◎	◎	◎	◎	◎	◎
	B	Increase the input S/W filter constant (Pr.74). (For FR-A series)	△	△	△	○	△	-	-
Input side	C	Install the radio noise filter FR-BIF(-H).	-	◎	-	-	-	◎	-
	D	Install the line noise filter FR-BSF01 or FR-BLF.	-	◎	-	-	-	◎	△
	E	Wire the power supply cable with a metal pipe or shield cable	-	◎	-	-	-	◎	-
	F	Install an insulated transformer or noise cutting transformer.	-	△	-	-	-	◎	-
	G	Separate the power supply system.	-	-	-	-	-	◎	◎
Output side	H	Install the line noise filter FR-BSF01 or FR-BLF.	-	-	◎	△	△	-	◎
	I	Wire the output cable with a metal pipe or shield cable	-	-	◎	○	○	-	-
	J	Use 4-core cable for motor power cable and use one cable as earth (ground) cable.	-	-	△	△	△	-	◎
External device	K	Use a twisted pair shielded cable for the sensor signal.	○	○	○	◎	◎	-	-
	L	Connect a shield to the common cable of the sensor signal.	-	-	-	◎	◎	-	◎
	M	Do not ground the power supply unit for sensor directly to the enclosure, etc.	-	-	-	-	-	△	◎
	N	Ground the power supply unit for sensor with a capacitor.	-	-	-	-	-	△	○
	O	Use a shielded cable for the signal input and connect a shield to the common (input terminal) SD.	△	△	△	○	◎	-	△
	P	Use a twisted pair shielded cable for the speed input and connect a shield to the terminal 5.	○	○	○	◎	◎	-	△
	Q	Insert a commercially available ferrite core to the speed input cable (on the output side of the external device).	△	△	△	○	-	-	-
	R	Reduce the impedance in the output circuit of the external device.	△	△	△	○	-	-	-
	S	Separate the external device from the inverter and power line by 30cm or more.	◎	◎	◎	◎	◎	-	-
	T	Do not wire the cables in parallel with each other and do not bundle them.	△	△	△	◎	◎	-	-
	U	Install a closure plate.	○	△	△	△	△	-	-
V	Suspend from the earth.	△	○	○	△	△	-	-	
W	Insert a commercially available ferrite core on the input side of the external device.	-	-	-	-	-	○	△	

Measure example

The following shows the methods in which an effect can be expected as the measures against noise of the inverter.

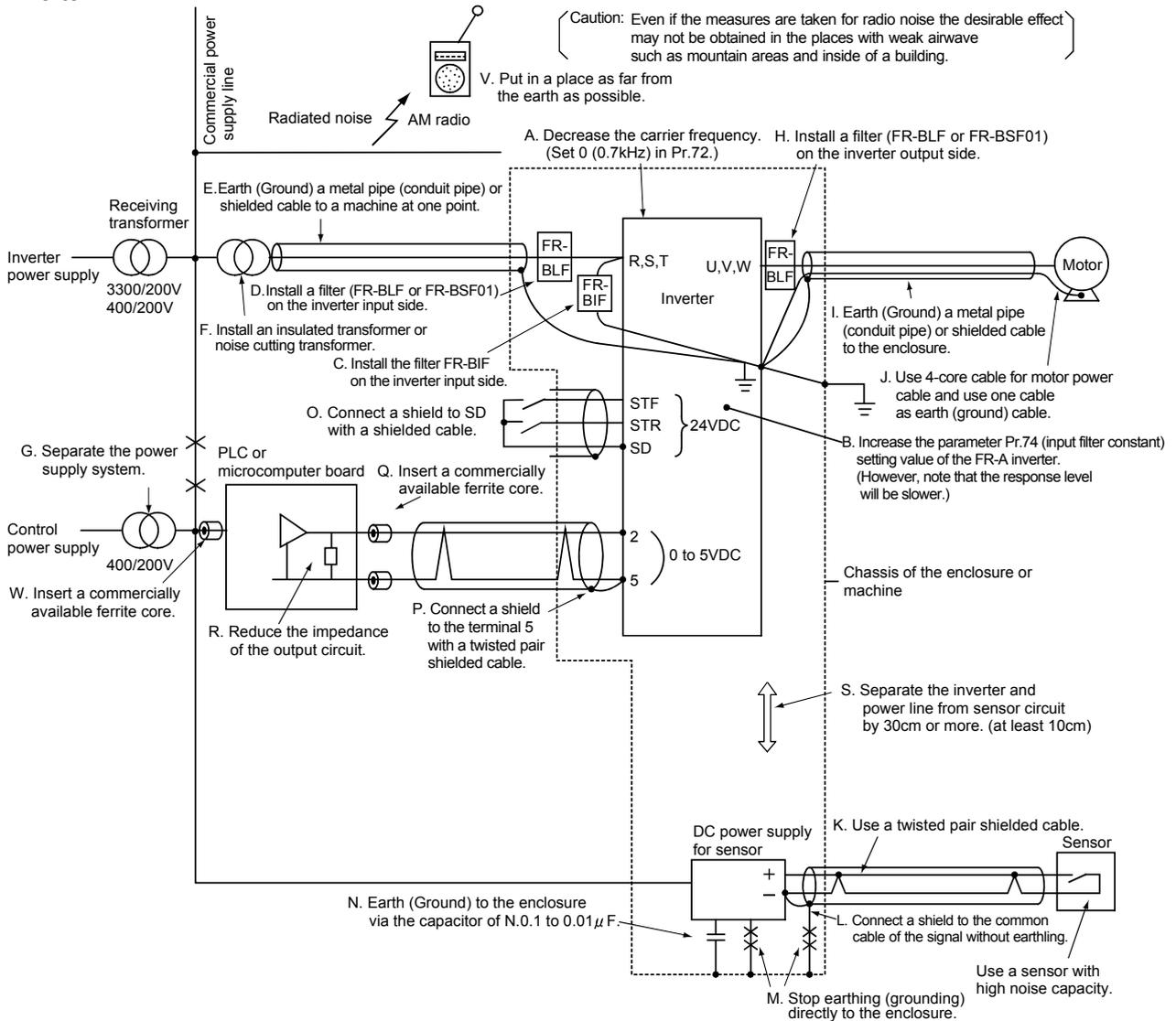
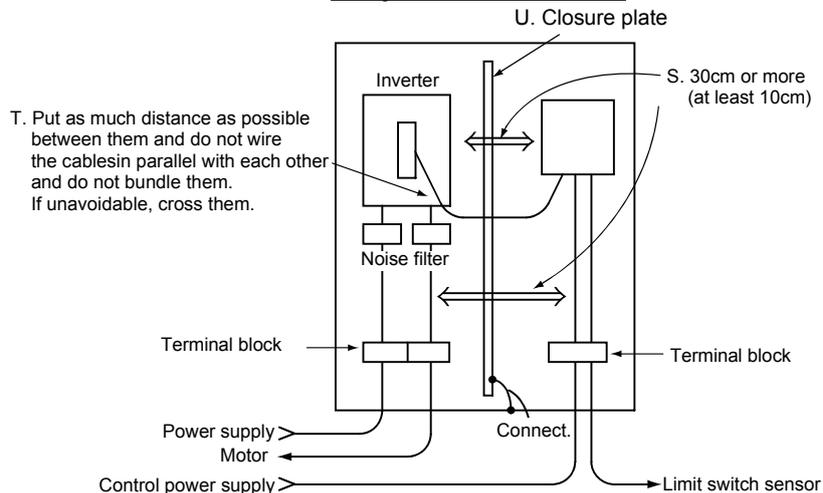


Fig. 5.15 Examples of measures against noise of the inverter

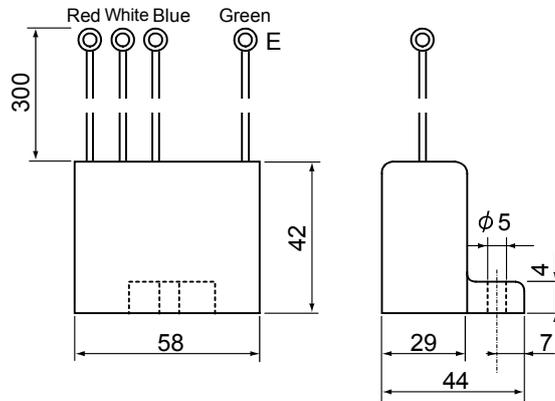
Wiring method in the enclosure



5.3.3 Noise filter

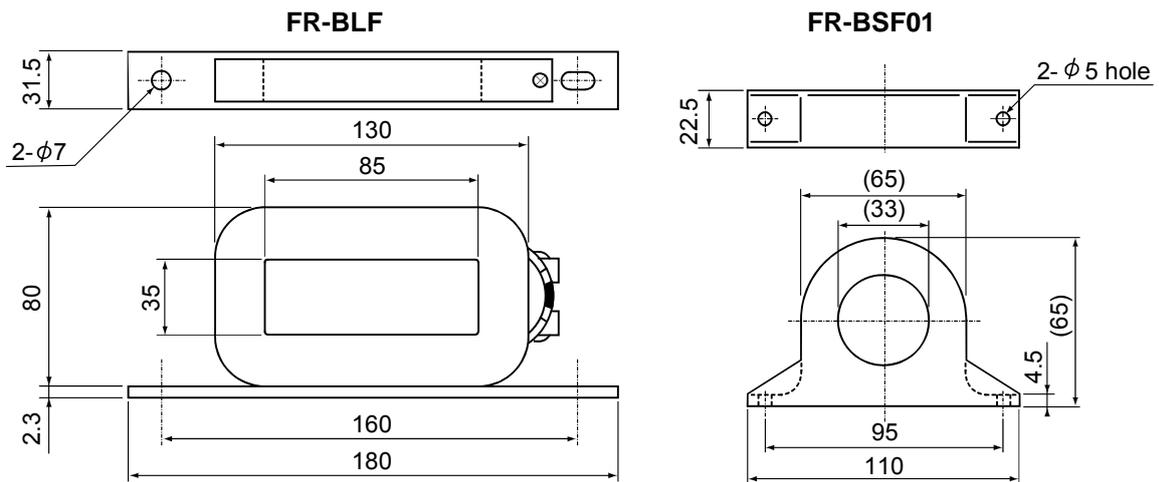
(1) Outline drawing of the noise filter (Unit: mm)

(a) FR-BIF and FR-BIF-H



The same outline is applied for FR-BIF (200V class) and FR-BIF-H (400V class).

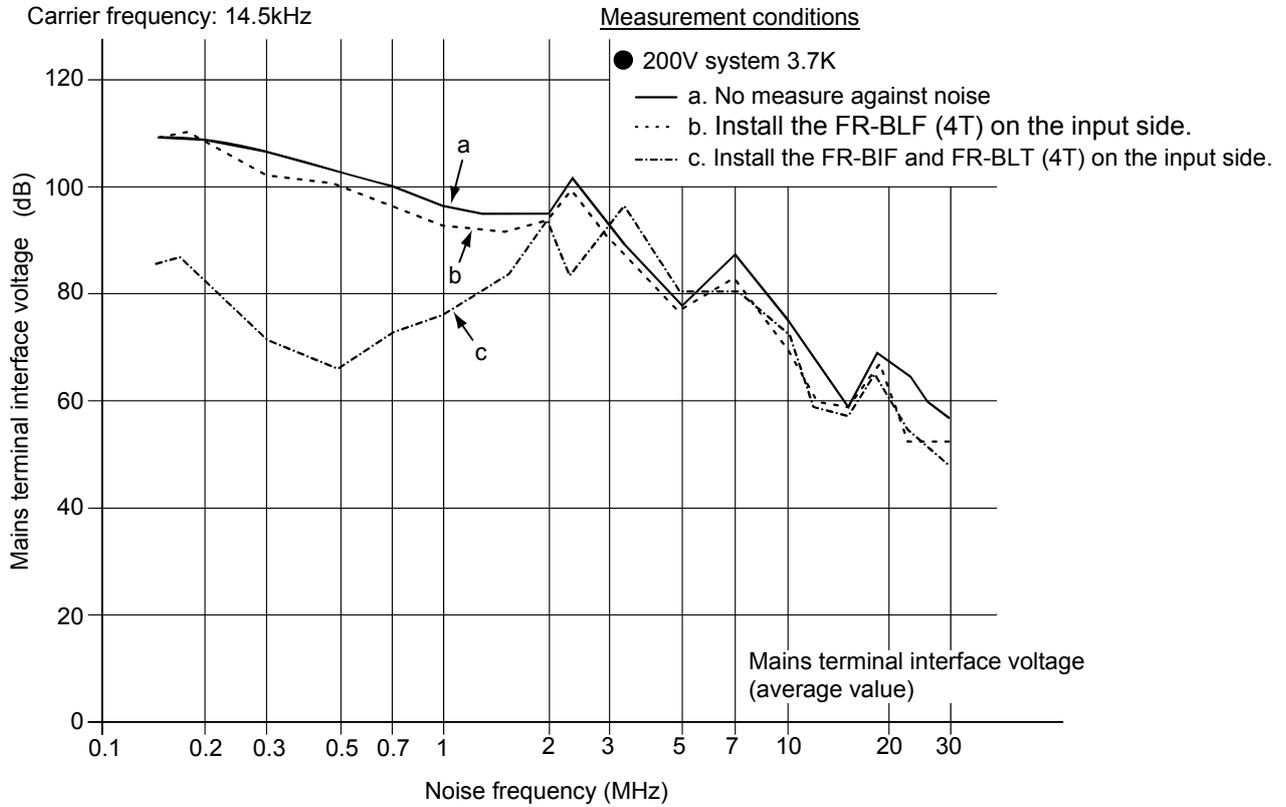
(b) FR-BLF and FR-BSF01



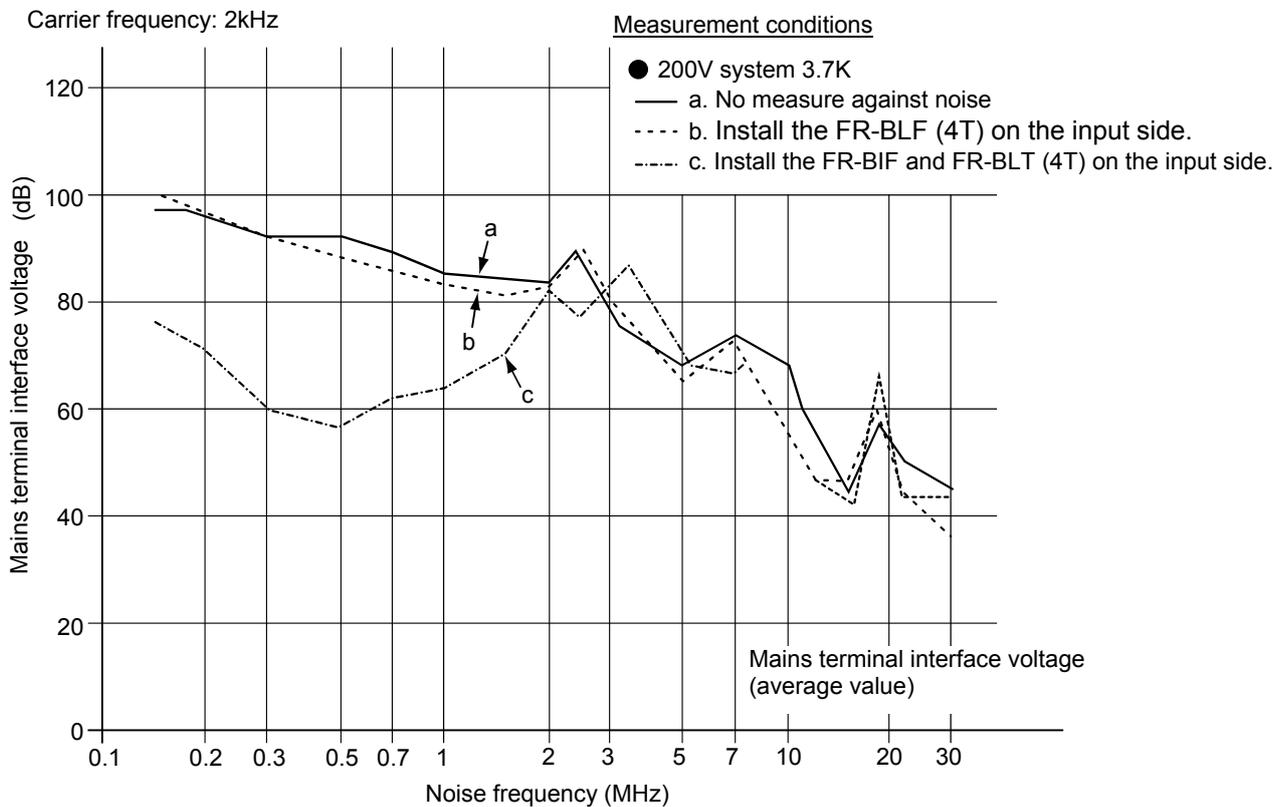
(2) Noise reducing effect examples

(a) FR-BIF and FR-BIF

Carrier frequency: 14.5kHz



Carrier frequency: 2kHz



5.4 Leakage Current

In I/O cables and motors of an inverter, the electrostatic capacitances exist. The leakage current flows through them.

The amount of the leakage current differs depending on the electrostatic capacitances, carrier frequency, etc. Accordingly, the low-noise type inverters generate the larger leakage current, and therefore take measures in the following methods.

5.4.1 Leakage current between grounds

The leak current may flow into not only the inverter's own system but also other system through the earth cable. The leakage breaker or leakage relay may operate unnecessarily due to this leakage current.

(1) Measures

- Decrease the carrier frequency (Pr. 72) of the inverter. Note that doing so causes a louder motor noise.
- For leakage breakers for the inverter's own line and other line, select the ones designed for harmonic and surge suppression to take measures with low noise (with the carrier frequency kept high).

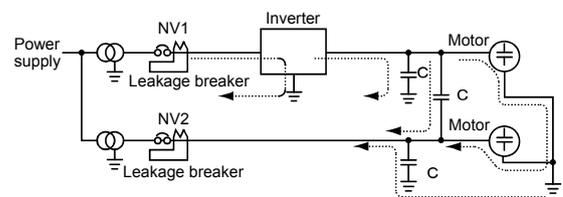


Fig. 5.17 Undesirable current path of leakage current

* Refer to Section 7.5 for the selecting method of a leakage breaker.

(2) Data example of leakage current between grounds

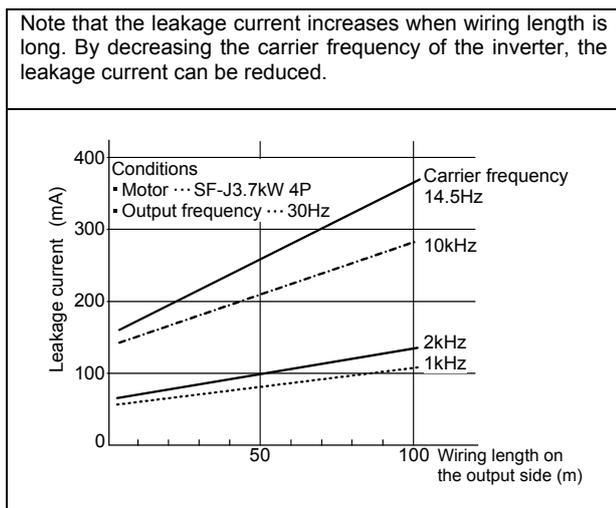


Fig. 5.18 Difference of the leakage current between grounds by the carrier frequency and the wiring length

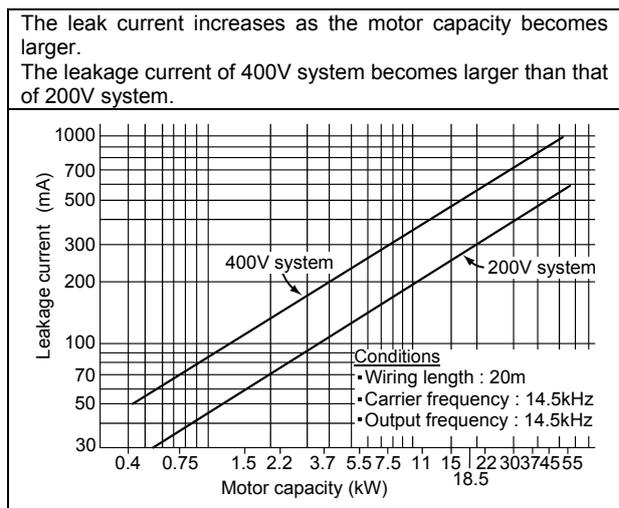


Fig. 5.19 Difference of the leak current between grounds by the motor capacity

5.4.2 Leakage current between cables

The external thermal relay may operate unnecessarily due to the harmonics of the leakage current flowing in electrostatic capacitances between the inverter output cables. When the wiring length is long (50m or more) for the 400V series small-capacity model (especially 7.5kW or less), the external thermal relay is likely to operate unnecessarily because the ratio of the leakage current to the rated motor current increases.

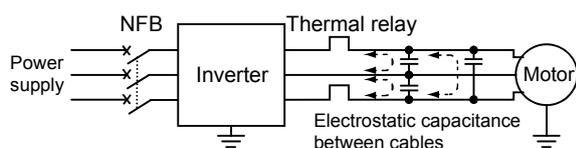


Fig. 5.20 Paths of leakage current between cables

Table 5.3 Data example of leakage current between cables (200V series)

Motor capacity (kW)	Rated motor current (A)	Leakage current (mA)	
		Wiring length 50m	Wiring length 100m
0.4	1.8	310	500
0.75	3.2	340	530
1.5	5.8	370	560
2.2	8.1	400	590
3.7	12.8	440	630
5.5	19.4	490	680
7.5	25.6	535	725

- Motor: SF-J 4P
- Used cable: 2mm² 4-core Cab-tire cable
- Carrier frequency: 14.5kHz
- ★ For the 400V series, the leakage current is approximately 2 times.

(1) Measures

- Use the electronic thermal of the inverter.
- Decrease the carrier frequency. Note that doing so causes a louder motor noise.

To ensure that the motor is protected against leakage current between cables, it is recommended to use a temperature sensor to directly detect motor temperature.

5.5 Earth (Ground)

Generally, an electrical apparatus has an earth (ground) terminal, which must be connected to the ground before use.

An electrical circuit is usually insulated by an insulating material and encased. However, it is impossible to manufacture an insulating material that can shut off a leakage current completely, and actually, a slight current flow into the case.

The purpose of earthing (grounding) the case of an electrical apparatus is to prevent operator from getting an electric shock from this leakage current when touching it.

To avoid the influence of external noises, this earthing (grounding) is important to audio equipment, sensors, computers and other machines that handle low-level signals or operate very fast.

As above, there are two types of the earthing (grounding), which have completely different characters. Applying them together for earthing (grounding) causes troubles as a matter of course. Therefore, it is necessary to differentiate between a dirty earthing (grounding) for electric shock prevention and a clean earthing (grounding) for noise prevention.

In addition, when the inverter is used, the output voltage becomes not a sine wave but a steep waveform as shown in Fig. 2.17 of Chapter 2, and therefore the charging/discharging current to the electrostatic capacitances existing in the insulation part flows as leakage current.

Moreover, the same charging/discharging leakage current flows to the motor to which the output voltage of this inverter is applied, and it becomes a larger current value with more high frequency components compared to that in the operation with the commercial power supply as shown in Fig. 5.22. The higher the inverter carrier frequency is, the stronger this tendency develops.

5.5.1 Earthing (grounding) methods and earthing (grounding) work

As described previously, earthing (grounding) is roughly classified into an electrical shock prevention type and a noise-affected malfunction prevention type.

Therefore, these two types should be discriminated clearly, and the following work must be done to prevent the leakage current having the high frequency components from entering the malfunction prevention type earthing (grounding):

(a) Where possible, use independent earthing (grounding) for the inverter. (Refer to Fig. 5.21.)

If independent earthing (grounding) (same figure (a)) is impossible, use joint earthing (grounding) (same figure (b)) where the inverter is connected with the other equipment at an earthing (grounding) point.

Joint earthing (grounding) as in (c) of the same figure must be avoided as the inverter is connected with the other equipment by a common earth (ground) cable.

Especially, joint earthing (grounding) with a high-power equipment such as a motor and transformer must be avoided.

Also a leakage current including many high frequency components flows in the earth (ground) cables of the inverter and inverter-driven motor. Therefore, they must use the independent earthing (grounding) method and be separated from the earthing (grounding) of equipment sensitive to the aforementioned noises.

In a tall building, it will be a good policy to use the noise malfunction prevention type earthing (grounding) with steel frames and carry out electric shock prevention type earthing (grounding) in the independent earthing (grounding) method.

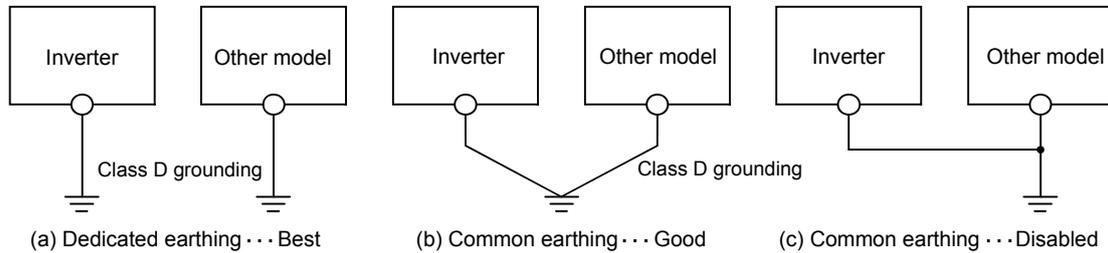


Fig. 5.21 Earthing (grounding) methods

- (b) Use Class D grounding (grounding resistance 100Ω or less) for the 200V class inverter and Class C grounding (grounding resistance 10Ω or less) for the 400V class on the earthing (grounding) work.
- (c) Use the thickest possible earth (ground) cable. The earth (ground) cable should be of not less than the size indicated in the instruction manual.
- (d) An earthing (grounding) point should be as close to the inverter as possible, and make an earth cable as short as possible.
- (e) Run the earth (ground) cable as far away as possible from the I/O wiring of equipment sensitive to noises and run them in parallel in the minimum distance.
- (f) Use one wire in a 4-core cable with the earth (ground) terminal of the motor and earth (ground) it on the inverter side.

If the earthing (grounding) of the inverter and the motor driven with the inverter is connected together with the earthing (grounding) of an audio, sensor, computer, etc., the generated leakage current becomes a noise source and makes a bad effect.

To solve this problem, earthing (grounding) work must be performed using separately a dirty earthing (grounding) of an inverter, etc. and a clean earthing (grounding) of an audio, sensor computer, etc.

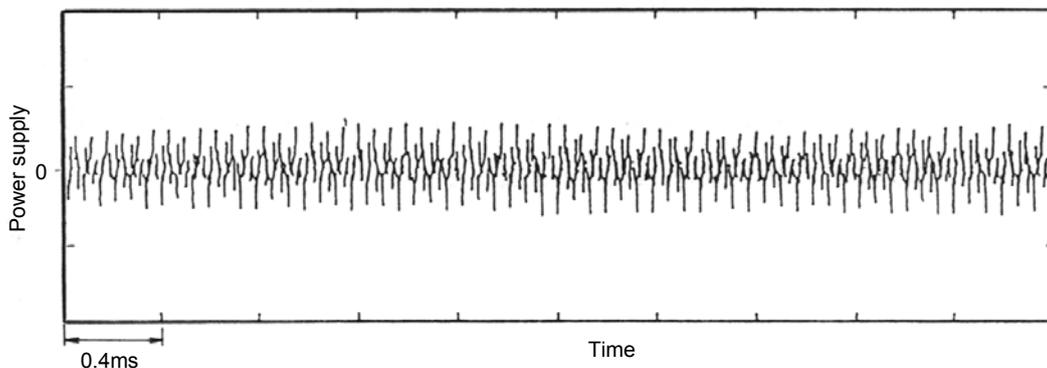


Fig. 5.22 Example of motor earth cable current when driven with the inverter
(Inverter: 200V system 0.75K, Motor: SF-JR 0.75kW 4P)

6. PROBLEMS IN THE USE OF INVERTER AND THE MEASURES

This chapter describes the reliability and life of inverters according to the installation environment and operating conditions as well as the precautions for them.

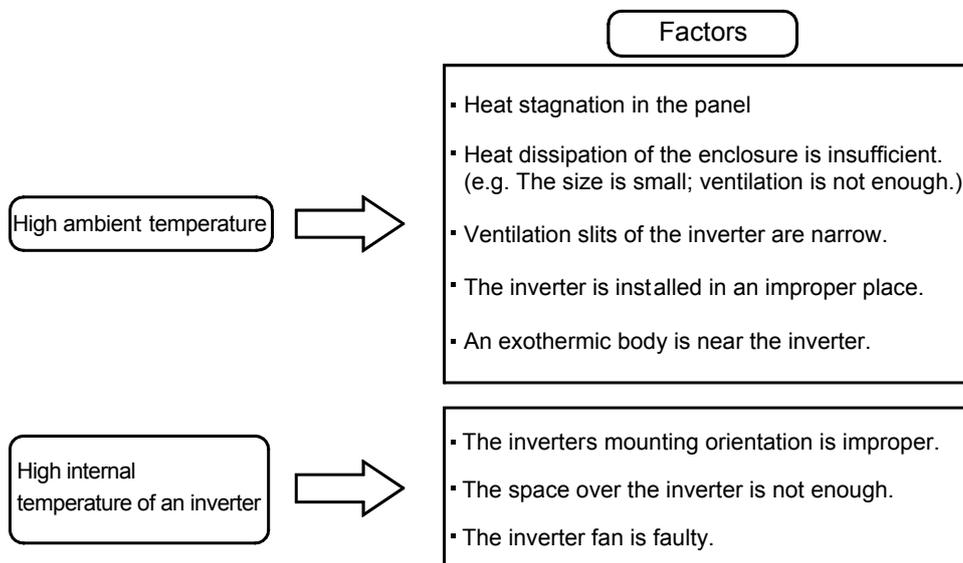
This chapter also describes the circuit designs, precautions for wiring and operation procedures to use inverters.

6.1 Environment and Installation Conditions

6.1.1 Reliability of the inverter and temperature

The life of an inverter is influenced by the ambient temperature. When an inverter is installed in a high ambient temperature or poorly installed for a wrong selection of the installation place, unexpected troubles such as a failure or damage may occur.

Those troubles are caused by the following factors.



6.1.2 Ambient temperature

The ambient temperature of an inverter is a temperature of the close periphery of an installed inverter.

1) Measure the temperature at the positions indicated in

Fig. 6.1.

2) The permissible temperature between -10°C and $+50^{\circ}\text{C}$.

(Too high or too low temperature may cause troubles.)

3) "In-panel temperature $+50^{\circ}\text{C}$, or less" means that the ambient temperature of the panel must be 40°C or less.

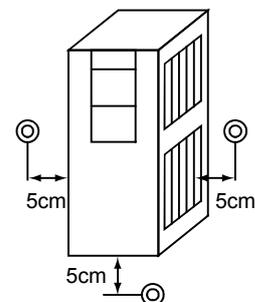


Fig. 6.1 Measurement of ambient temperature

Good to know for checking an inverter

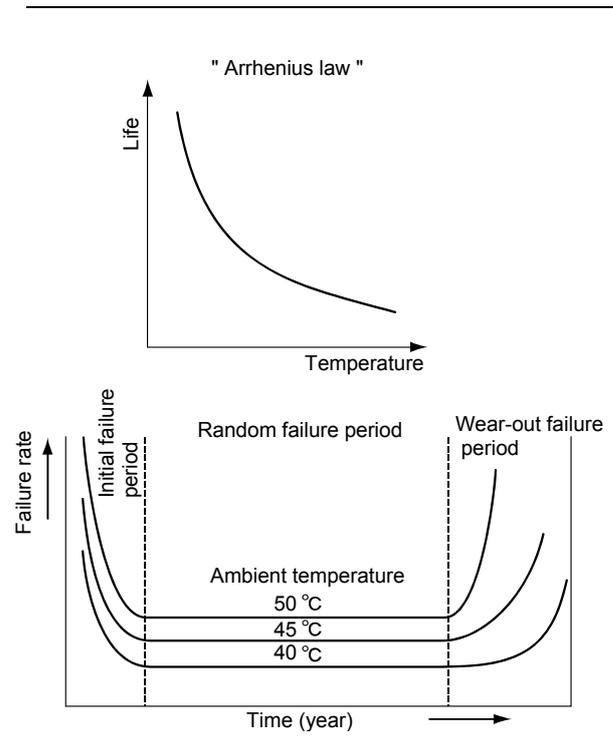
Life

The life of an inverter's electrolytic capacitor for smoothing decreases to half if the ambient temperature increases by 10 °C (18°F) (and doubles if decreases by 10 °C (18°F)) in accordance with the Arrhenius' law.

The lives of the other parts also highly depend on the temperature.

Failure rate and temperature

An inverter consists of many electronic parts such as semiconductor devices. The failure rate of these parts is closely related to the ambient temperature. Using them in the temperature as low as possible decreases the failure rate.



6.1.3 Heat generation of the inverter

The heat amount generated by an inverter varies depending on the inverter's capacity and the motor load factor.

In addition, the optional parts enclosed with an inverter such as a power factor improving reactor or brake unit (including a resistor) generate the relatively large heat amount. This should be taken into consideration when an enclosure is designed. Table 6.1 lists the generated heat amount.

Externally installing the semiconductor heatsink and built-in brake resistor using a heatsink outside attachment can radiate approximately 70% of the heat amount generated by the inverter to the outside of the enclosure.

Refer to Fig. 6.2 for how to use the heatsink outside attachment.

Table 6.1 Heat amount generated from the inverter and power factor improving reactor

Motor capacity (kW)	Heat amount generated from FREQROL-A700 (W)		Heat amount generated from power factor improving reactors (W)			
	200V	400V	FR-HEL		FR-HAL	
			200V	400V	200V	400V
0.4	50	50	6	6	10	16
0.75	70	65	7	7	14	23
1.5	110	75	8	8	20	30
2.2	140	100	11	11	24	43
3.7	190	150	13	13	33	46
5.5	260	200	17	17	40	52
7.5	360	250	19	19	46	52
11	520	300	23	23	60	60
15	670	400	26	26	75	60
18.5	770	550	29	29	74	76
22	940	650	34	34	82	74
30	1050	800	38	38	97	91
37	1270	1100	47	47	120	97
45	1610	1300	47	47	140	140
55	1880	1550	52	52	140	150
75	2530	1900	130	130	170	180
90	3110	2400	130	130		
110		2500	160	140	280	200
132		3000		140		
160		4000		170		
185		4200		230		400
220		5000		240		
250		5500		270		
280		6500		300		490
315		7000		360		
355		8000		360		530
400		9000		450		
450		10500		450		
500		11500		470		
560				500		1080

(Note) The heat amount generated by built-in brake resistors of 7.5K or less is not included.

6.1.4 Interference of heat in the enclosure and ventilation

The inverter and ventilation fan placement is another point to be noted when they are installed in an enclosure.

When multiple inverters are installed in an enclosure or a ventilation fan is installed, the ambient temperature of the inverters may rise and ventilation effect may be reduced depending on the installation position.

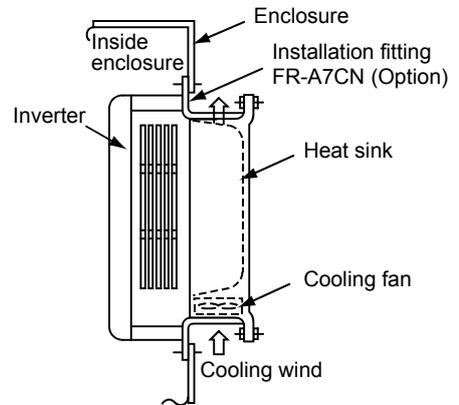


Fig. 6.2 How to use the heatsink outside attachment

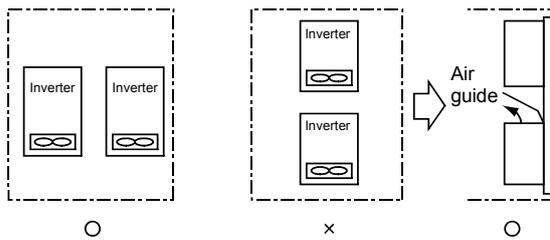


Fig. 6.3 Installation of multiple inverters

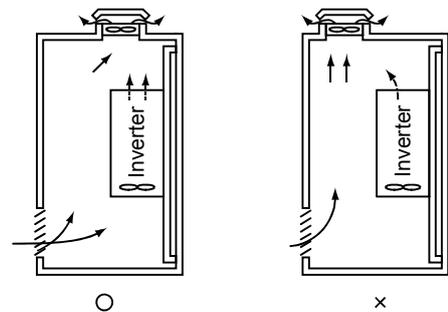


Fig. 6.4 Position of a ventilation fan

6.1.5 Placement of electrical-discharge resistor

When a BU type brake unit or externally-installed high-duty brake resistor (FR-ABR type) is used, sufficient measures against heat generated from resistors must be taken.

Consider a resistor to be a heater for cooling.

It is recommended to install electrical-discharge resistors outside the enclosure.

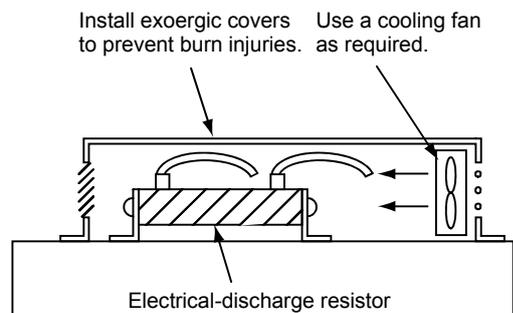


Fig. 6.5 Installation method of the resistor

Caution: The surface of the electrical-discharge resistors sometimes becomes as high as 300°C. Caution must be used for the material of the installing surface and the layout for the use of multiple resistors.

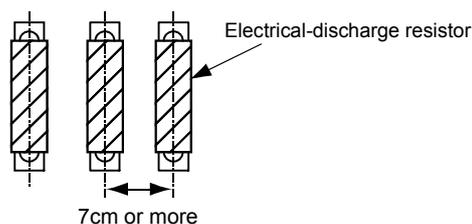


Fig 6.6 Layout of the resistors

6.1.6 Inverter mounting orientation

When an inverter is not mounted with a proper orientation, the inverter's heat dissipation extremely deteriorates. (The printed board of the control circuit is not cooled by a cooling fan.)

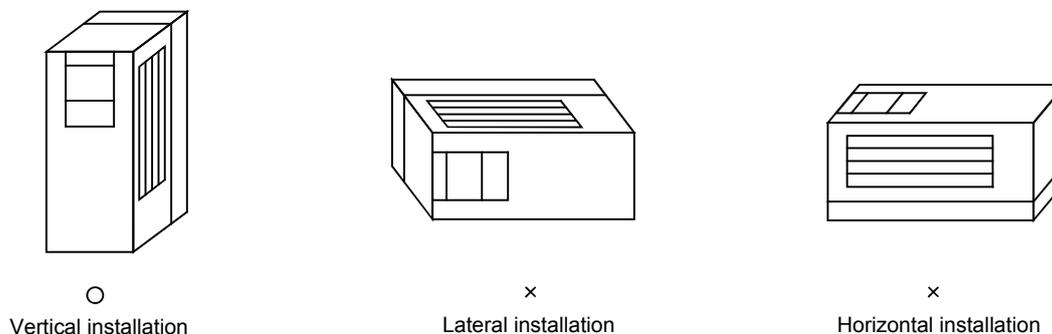


Fig. 6.7 Inverter mounting orientation

6.1.7 Standard specifications of installation environment (FREQROL-A₇₀₀ series 200V class)

Item	Description
Ambient temperature	-10°C to +50°C (non-freezing)
Ambient humidity	Relative humidity: 90%RH or less (non-condensing)
Ambience	Indoors: free from corrosive gas, explosive gas and flammable gas. Free from dust, dirt and oil mist.
Maximum altitude	1,000m or less above sea level
Vibration	5.9m/s ² or less (conforming to JIS C60068-2-6)
AC voltage/frequency	Three-phase, 200V to 220V 50Hz, 200 to 240V 60Hz
Permissible voltage fluctuation	170 to 242V 50Hz, 170 to 264V 60Hz
Permissible frequency fluctuation	± 5%

● Temperature

(1) Measures against high temperature

- (a) Use a forced ventilation system or similar cooling system. (Refer to Section 6.1.4.)
- (b) Install the panel in an air-conditioned electrical chamber.
- (c) Block direct sunlight.
- (d) Provide a shield or similar plate to avoid direct exposure to the radiated heat and wind of a heat source.
- (e) Ventilate the area around the panel well.

(2) Measures against low temperature

- (a) Provide a space heater in the panel.
- (b) Keep the inverter power on. (Keep the start signal of the inverter off.)

(3) Sudden temperature changes

- (a) Select an installation place where temperature does not change suddenly.
- (b) Avoid installing the inverter near the air outlet of an air conditioner.
- (c) If temperature changes are caused by opening/closing of a door, install the inverter away from the door.

● Humidity

Normally operate the inverter within the 45 to 90% range of the ambient humidity. Too high humidity will pose problems of reduced insulation and metal corrosion. On the other hand, too low humidity may produce a spatial electrical breakdown.

The insulation distance specified in JEM1103 "Control Equipment Insulator" is defined as humidity 45 to 85%.

(1) Measures against high humidity

- (a) Make the panel enclosed, and provide it with a hygroscopic agent.
- (b) Take dry air into the panel from outside.
- (c) Provide a space heater in the panel.

(2) Measures against low humidity

What is important in fitting or inspection of the unit in this status is to discharge your body (static electricity) beforehand and keep your body from contact with the parts and patterns, besides blowing air of proper humidity into the panel from outside.

(3) Measures against condensation

Condensation may occur if frequent operation stops change the in-panel temperature suddenly or if the outside-air temperature changes suddenly.

Condensation causes such faults as reduced insulation and corrosion.

- (a) Take the measures against high humidity in (1).
- (b) Keep the inverter power on. (Keep the start signal of the inverter off.)

6.1.8 Precautions for encasing the inverter in an enclosure

Refer to Fig. 6.8 for precautions for encasing the inverter in an enclosure.

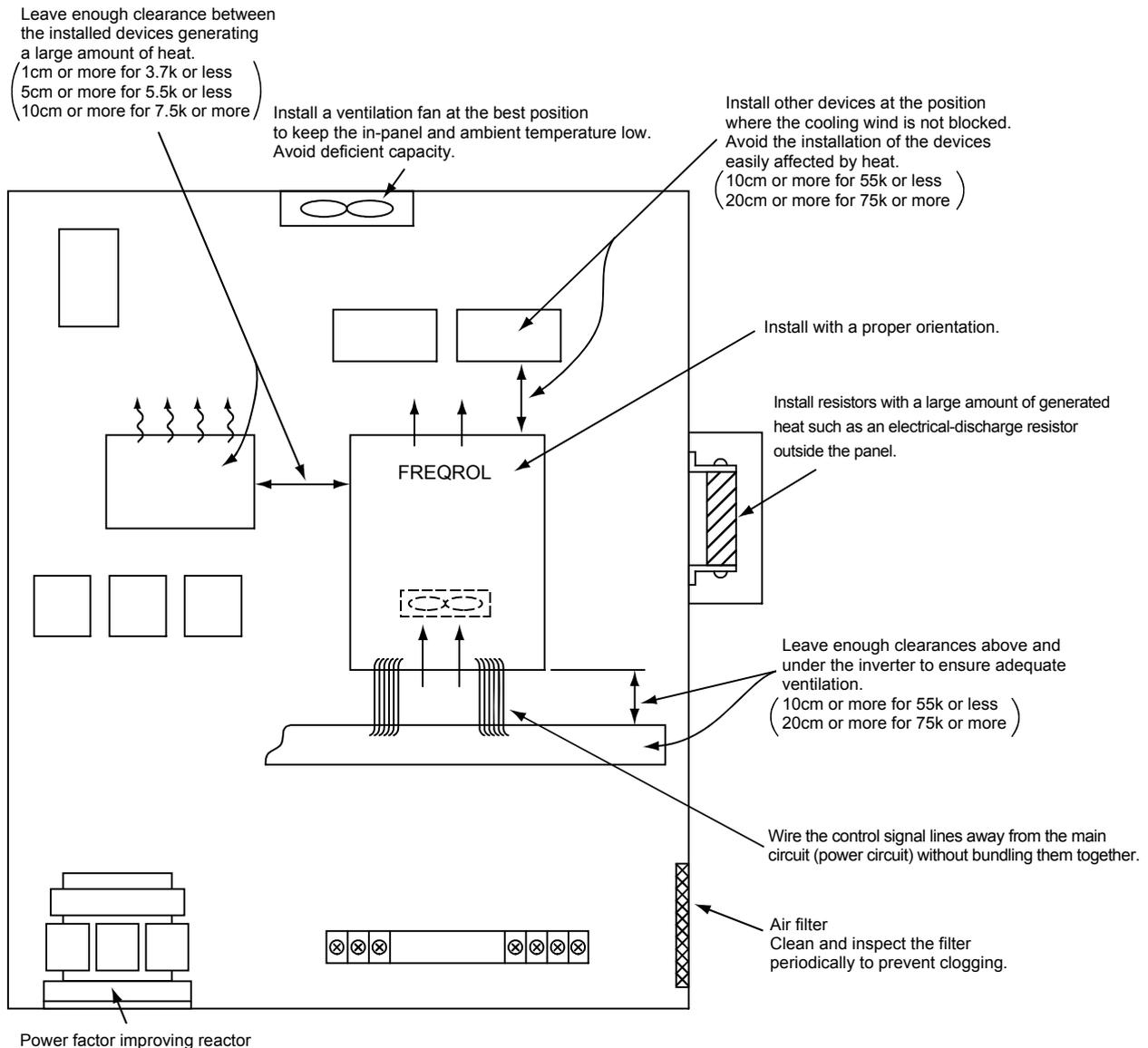


Fig. 6.8 Precautions for encasing the inverter in an enclosure

- Dust, dirt, oil mist

Dust and dirt will cause such faults as connection errors of contacts, reduced insulation resulting from moisture absorption of deposits, reduced cooling effects and in-panel temperature rise by filter clogging. In the atmosphere where conductive powder floats, dust and dirt will cause such faults as malfunction, deteriorated insulation and short circuit in a short time.

Since oil mist will cause similar conditions, it is necessary to take adequate measures.

Corrective action

(a) Place in a totally enclosed panel.

Take measures if the in-panel temperature rises.

(b) Purge air.

Pump clean air from outside to make the in-panel pressure higher than the outside-air pressure.

- Corrosive gas, salt damage

If the inverter is exposed to corrosive gas or to salt near a beach, the printed board patterns and parts will corrode and the relays and switches will result in poor contact.

In such places, take the measures given in (a) and (b).

- Explosive, flammable gases

As the inverter is non-explosion proof, it must be contained in an explosion proof enclosure. In places where explosion may be caused by explosive gas, dust or dirt, an enclosure cannot be used unless it structurally complies with the guidelines and has passed the specified tests. This makes the enclosure itself expensive (including the test charges).

The best way is to avoid installation in such places and install the inverter in a non-hazardous place.

- Highland

Use the inverter at the altitude of within 1000m.

If it is used at a higher place, it is likely that thin air will reduce the cooling effect and low air pressure will deteriorate dielectric strength.

- Vibration, impact

The vibration resistance of the inverter is up to 5.9m/s^2 * at 10 to 55Hz frequency as specified in JIS C60068-2-6.

Vibration or impact, if less than the specified value, applied for a long time, may make the mechanism loose or cause poor contact to the connectors. * 2.9m/s^2 according to the capacity

Especially when impact is imposed repeatedly, caution must be taken as the part pins are likely to break.

Corrective action

(a) Provide the panel with rubber vibration isolators.

(b) Strengthen the structure to prevent the panel from resonance.

(c) Install the panel away from sources of vibration.

6.1.9 When driving an explosion-proof motor with the inverter

When an explosion-proof motor is used with the inverter for drive, they must pass the specified exam. Please note the following for installation.

(1) The existing commercial power-driven pressure-resistant explosion-proof motor or increased-safety explosion-proof motor cannot be driven by the inverter.

Acquiring TIIS Certification of Conformity is necessary for the combination of a motor and inverter to be used. The certification is managed by Technology Institution of Industrial Safety.

A pressure-resistant explosion-proof motor which has acquired TIIS Certification of Conformity beforehand in combination with an inverter drive can be used by combining another inverter. However, the inverter must be the same model (up to the model's capacity) used when the certification has been approved and the operation is limited to the range under the certified conditions.

Mitsubishi Electric offers pressure-resistant explosion-proof motors dedicated to an inverter drive and inverters for them. Refer to a catalog for details.

(2) When the rating to be used is out of the certified range or the model which has not passed TIIS Certification of Conformity needs to be used, a new certification must be acquired for it.

(3) Refer to an instruction manual of the inverter when using options.

(4) Using an increased-safety explosion-proof motor with an inverter is not economical for the strict restrictions against the operation conditions (loss reduction, cooling effect improvement, etc.) and also for the costs to take the test.

Using a pressure-resistant explosion-proof motor which has passed TIIS Certification of Conformity is recommended.

(5) The inverter is a non-explosion proof structure. Always install it in a non-hazardous place.

Good to know for checking an inverter

When an inverter-drive explosion-proof motor used for constant torque is needed, using one (which has passed TIIS Certification of Conformity) with one or two ranks higher capacity is economical.

6.2 Wiring of Inverter

6.2.1 Terminal connection diagram

Catalogs describe the connection condition of each terminal for the inverter drive. The specifications of these terminals and precautions for use are given below using FREQROL-A700 series as an example.

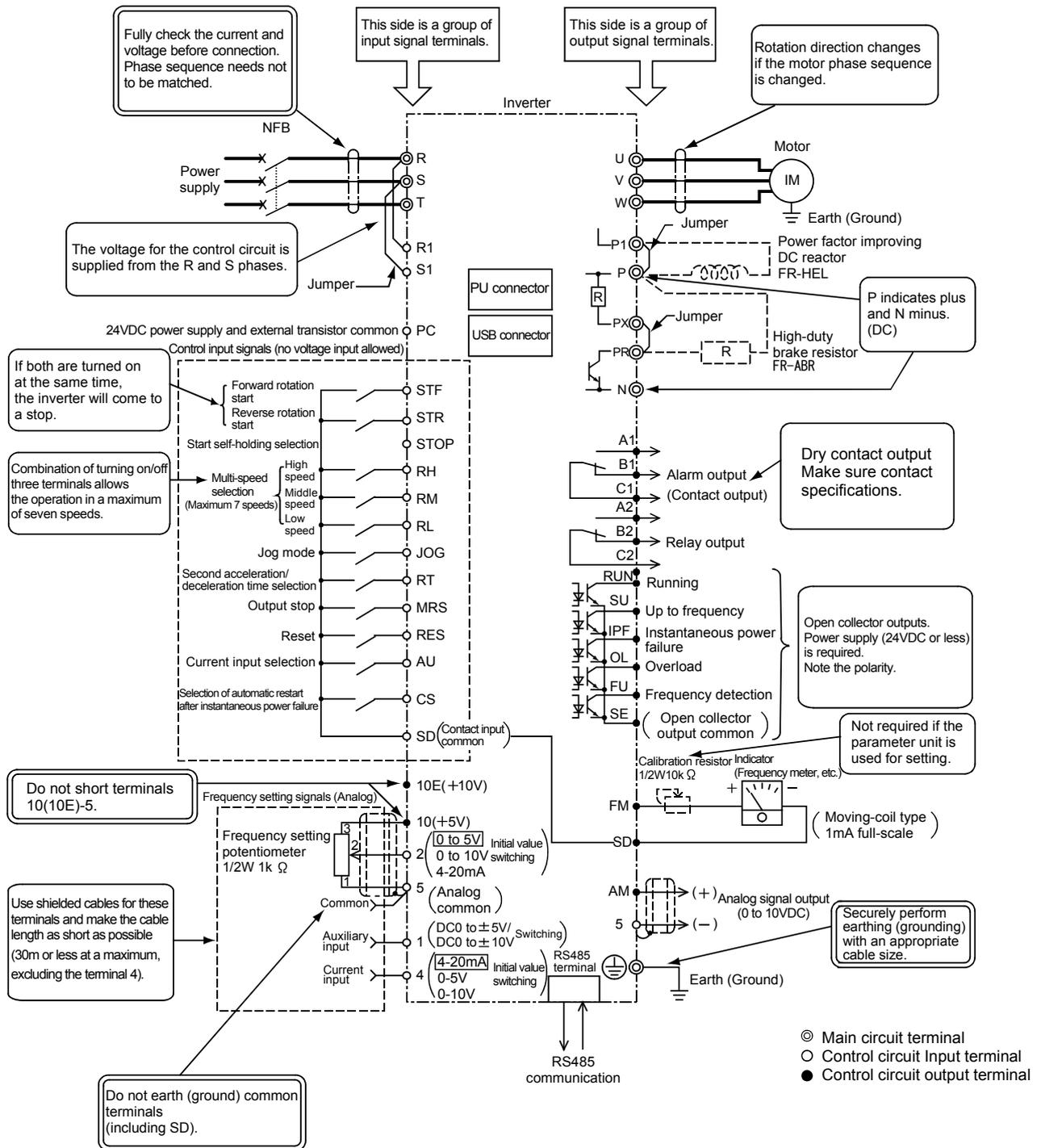


Fig. 6.9 Terminal connection diagram

6.2.2 Wiring of the main circuit

The main circuit is the power circuit (high voltage in lines). Incorrect wirings may damage the inverter and also jeopardize the operators. The following shows the points that easily cause miswiring.

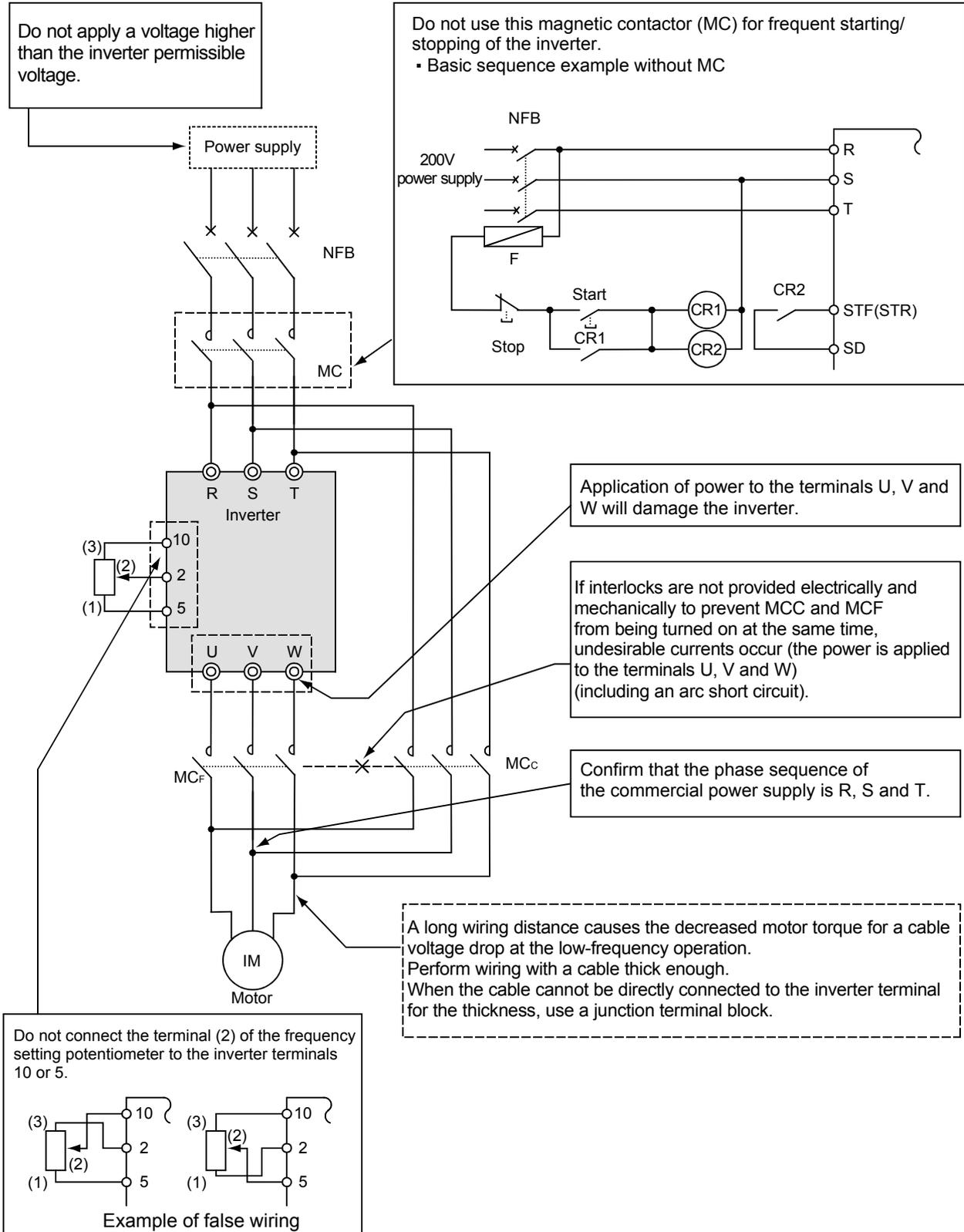


Fig. 6.10 Main circuit wiring

6.2.3 Wiring of the control circuit

The following table lists the I/O terminal types and common terminals equipped with the inverter.

Terminal	Type	Terminal example	Common terminal
Input terminals	Contact (or open collector)	Start signal (STF, STR) Select signal (RH, RM, RL, AU, etc.)	SD or PC (Power common ⊕)
	Analog	Frequency setting signal (2, 1, 4, etc.)	5
Output terminals	Contact	Alarm output (A, B)	C
	Open collector	Running signal (RUN, SU, OL, IPF, FU)	SE
	Pulse train	For indicator (frequency meter (FM))	SD
	Analog	For analog signal output (AM)	5

(1) Connection to input terminals

1) Contact or open collector input terminal (Isolated from the inverter internal circuit)

Each terminal operates for its function by causing a short circuit to the common terminal SD. The carry current for the input signals is micro-current (4 to 6mADC). Therefore, switches or relays for micro-current (twin contacts, etc.) must be used to prevent contact faults.

Note the contact error.

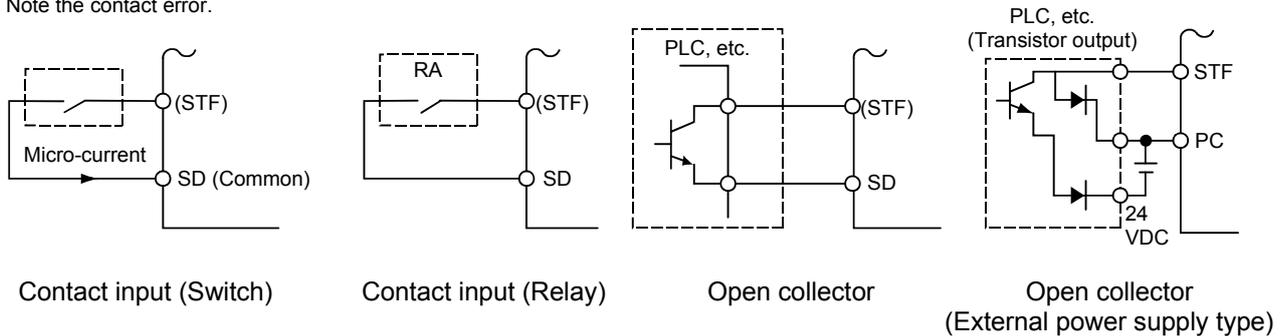


Fig. 6.11 Connection for input signals

2) Analog input terminals (Non-isolated from the inverter internal circuit)

Perform the wiring fully away from the 200V (400V) power circuit lines without bundling them together.

The shielded cable should be used to avoid the influence of external noises.

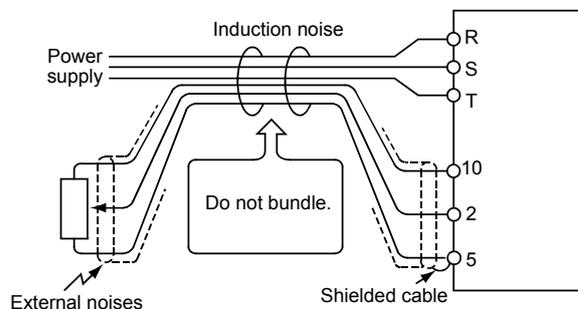


Fig. 6.12 Connection example of frequency setting input terminals

3) Proper connection of frequency setting potentiometer

Improper connection of the frequency setting potentiometer terminals without referring to the terminal symbols will affect the operation of the inverter.

The resistance value is an important factor to select a frequency setting potentiometer.

<Specification> Wire-wound, 2W, 1kΩ, B characteristic

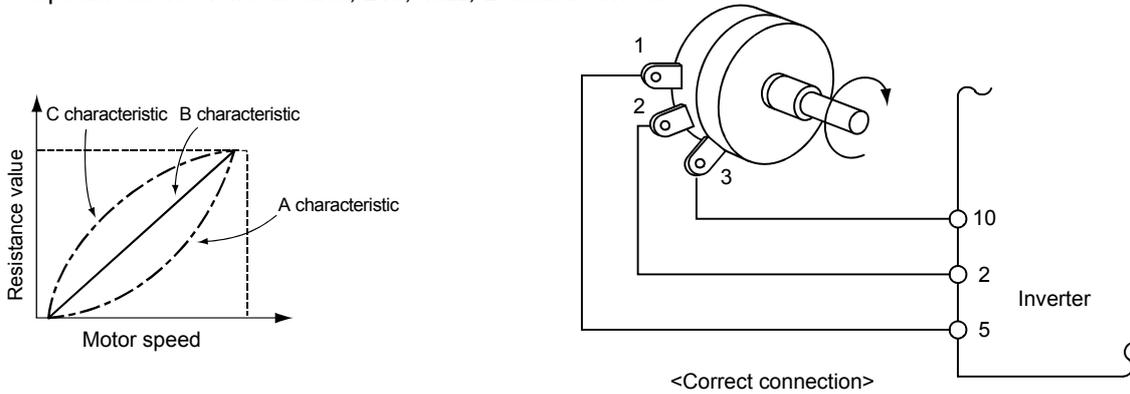
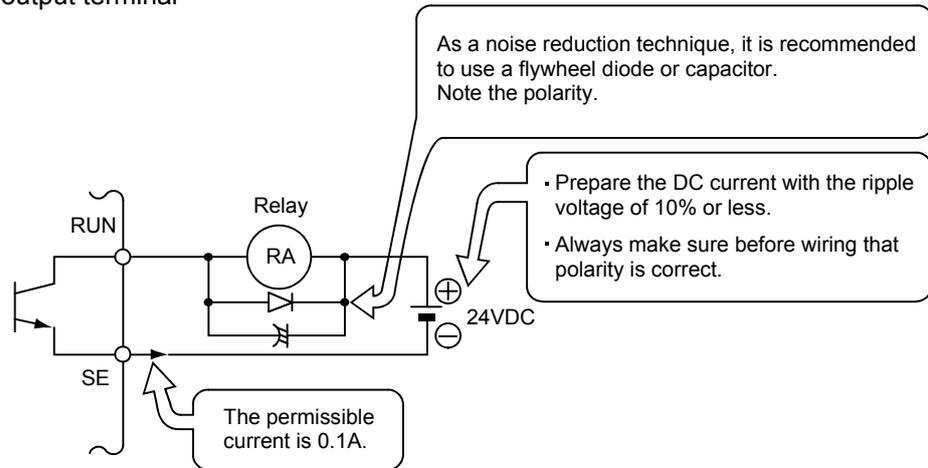


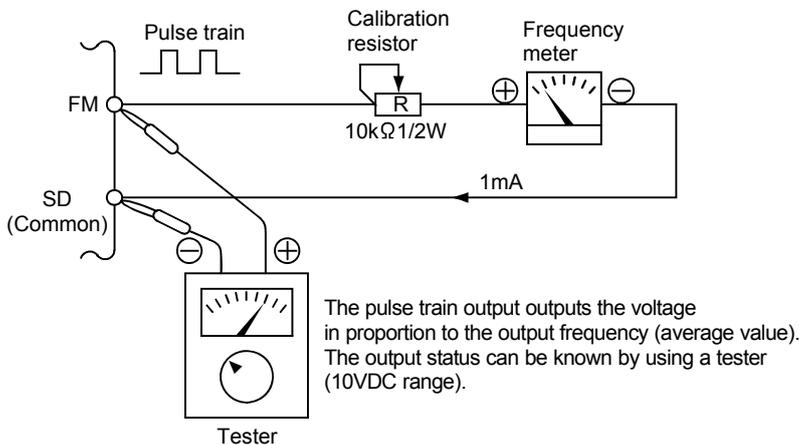
Fig. 6.13 Connection of frequency setting potentiometer

(2) Connection to output terminals

① Open collector output terminal



② Pulse train output terminal



③ Analog signal output (0 to 10VDC)

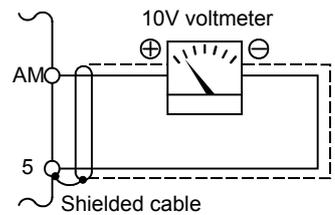


Fig 6.14 Connection of output signal terminals

6.2.4 Wiring length of I/O cables

The restriction varies according to each I/O terminal. Especially for control signals, the input part is isolated by photocoupler for improving noise resistance. However, the isolation measure is not taken for the analog input.

Therefore, the special caution must be used for the wiring for the frequency setting signal by taking a measure such as making the cable length as short as possible to protect the signal from the external noise. The indication of the permissible cable length for each signal and the measures taken when the length is exceeded are shown in Fig. 6.15.

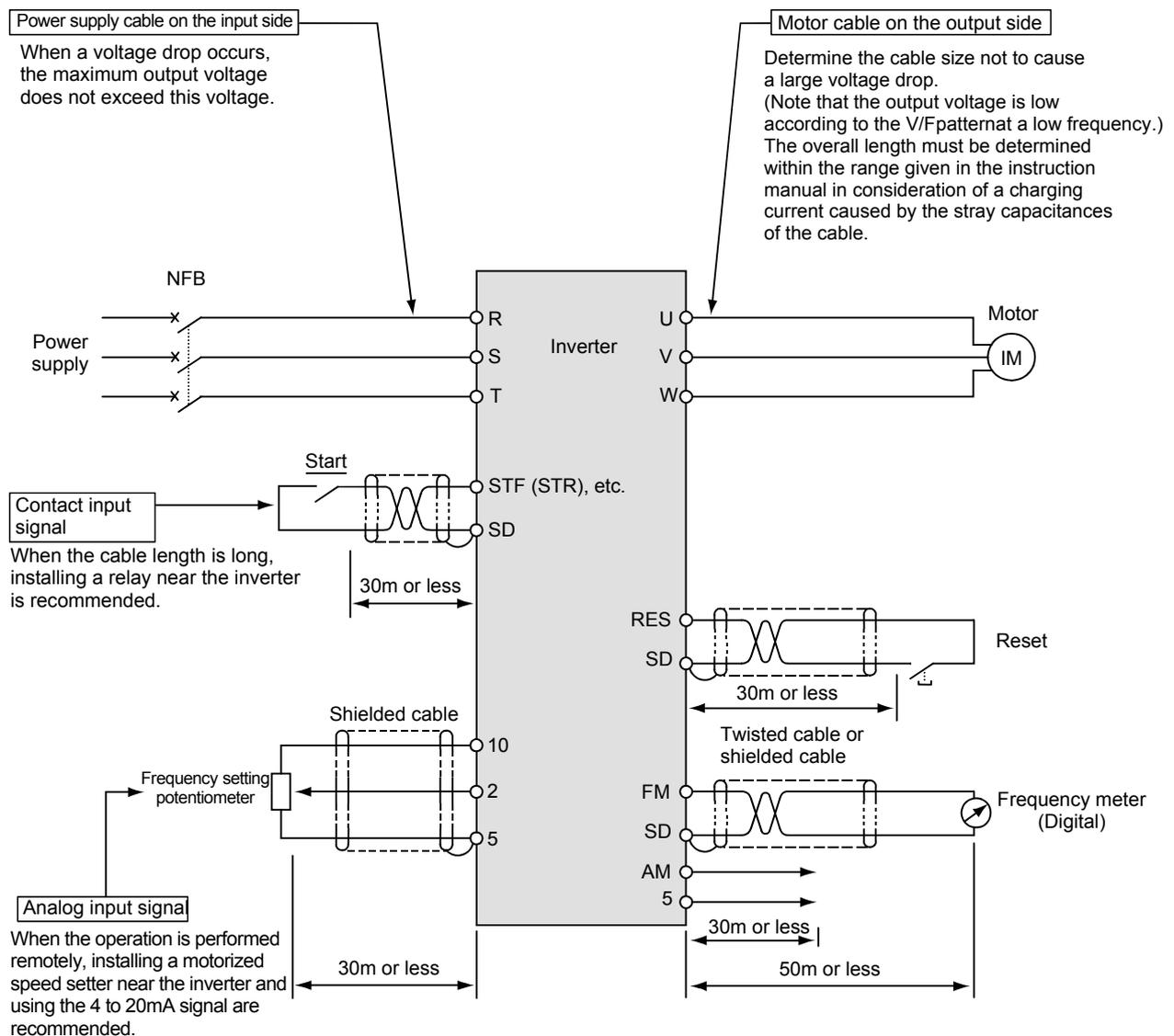


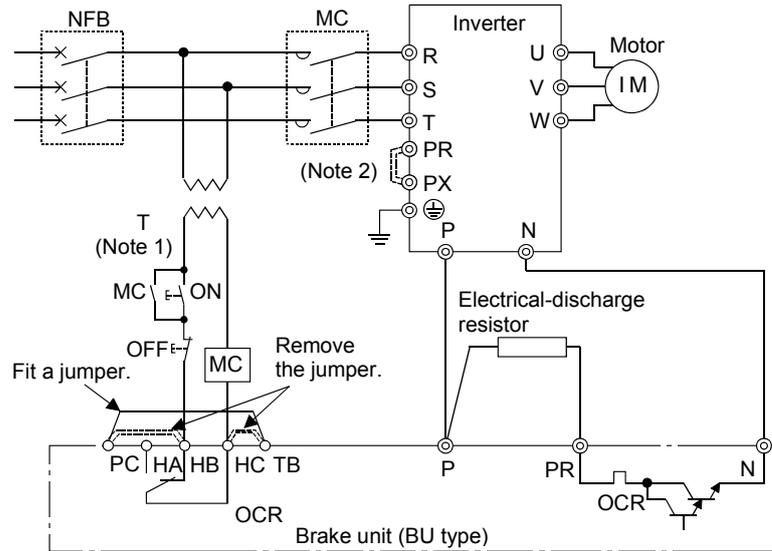
Fig. 6.15 Wiring length of I/O cables

6.2.5 Wiring for the BU type brake unit

(1) Connect a BU type brake resistor paired with a resistor to the inverter terminal P-N.

Note Never connect the brake unit terminals P and N inversely.

Always match the terminal symbols P-N to that of the inverter. Incorrect connection may damage the inverter.



(Note 1) When the power supply is 400V class, install a step-down transformer.
 (Note 2) For capacity 7.5K or less, remove the jumper across terminals PR-PX.

Fig. 6.16 Wiring method for the brake unit

(2) The wiring length between the inverter and the BU type brake unit or between the BU type brake unit and the electrical-discharging resistor is restricted to be a maximum of 5m. When the wiring length is more than 2m and less than 5m, a twisted cable must be used for wiring.

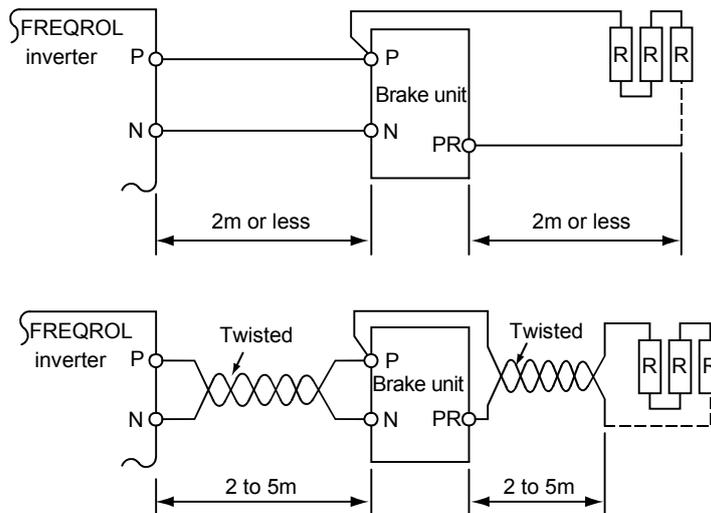


Fig. 6.17 Wiring length for the brake unit

6.2.6 Wiring for the FR-BU type brake unit

- (1) Connect an FR-BU type brake unit paired with an FR-BR type resistor unit to the inverter terminals P-N.

Note Never connect the brake unit terminals P and N inversely.

Always match the terminal symbols P-N to that of the inverter. Incorrect connection may damage the inverter.

For safety, prepare a circuit where an alarm contact of the brake unit or resistor unit shuts off the inverter primary side magnetic contactor.

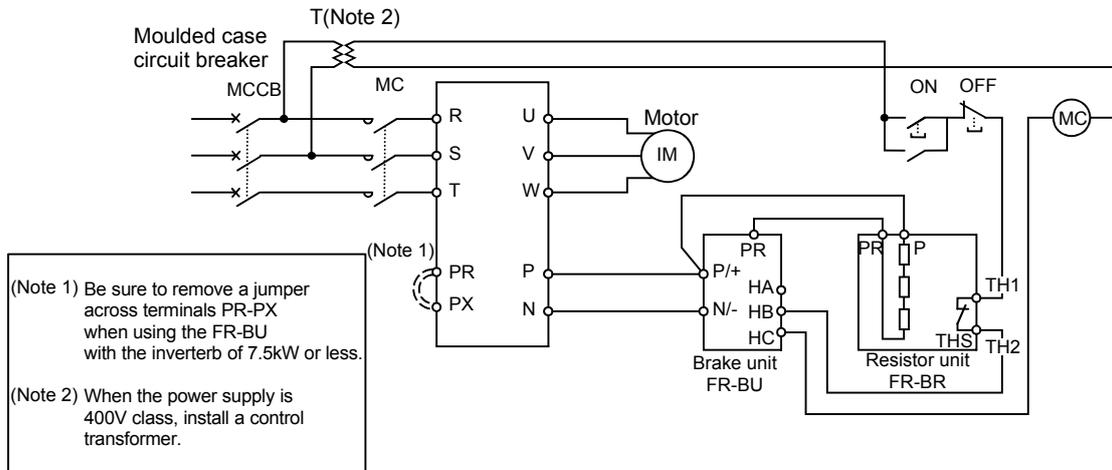


Fig. 6.18 Wiring method for the brake unit

- (2) There is a restriction for a cable length between the inverter and the FR-BU type brake unit or between the FR-BU type brake unit and the FR-BR type resistor unit.

When the wiring length is more than 5m and less than 10m, a twisted cable must be used for wiring.

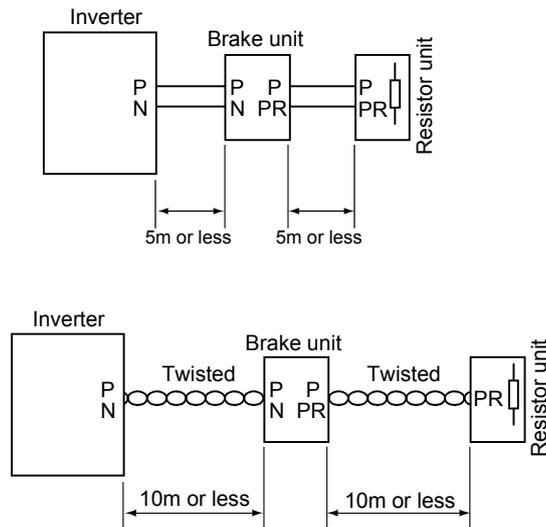


Fig. 6.19 Wiring length for the brake unit

*Refer to the FREQROL-A700 catalog for the MT-BU5 (75k or more) type brake unit.

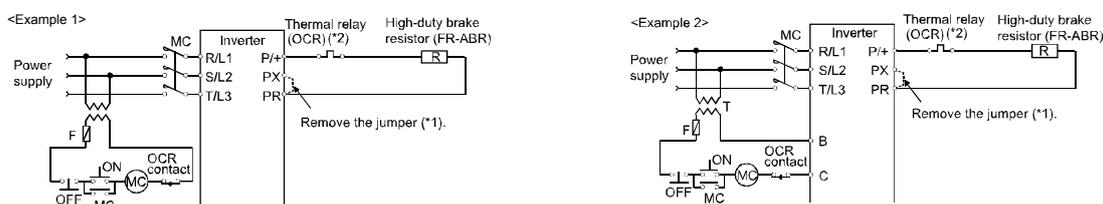
6.2.7 Wiring for the high-duty brake resistor (FR-ABR)

The built-in brake resistor is connected across terminals P and PR. Remove the jumper across terminals PR-PX when the built-in brake resistor does not have enough thermal capability for high-duty operation.

Then, fit the high-duty brake resistor to the terminals P and PR.

(Note) Do not connect resistors other than the high-duty brake resistor.

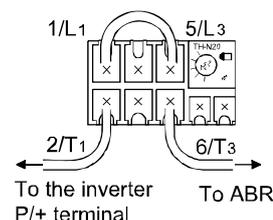
Using the following sequences is recommended to prevent the overheat and burnout of the brake resistor when the regenerative brake resistor is damaged.



*1 Since the 11K or more inverter is not provided with the PX terminal, a jumper need not be removed.

*2 Refer to the table below for the type number of each capacity of thermal relay and the diagram below. (When using a 11k or more brake resistor, always install the thermal relay.)

Power supply voltage	High-duty brake resistor	Thermal relay type (Mitsubishi products)	Contact rating
200V	FR-ABR-0.4K	TH-N20CXHZ-0.7A	110VAC 5A, 220VAC 2A (AC11 class) 110VAC 0.5A, 220VDC 0.25A (DC11 class)
	FR-ABR-0.75K	TH-N20CXHZ-1.3A	
	FR-ABR-2.2K	TH-N20CXHZ-2.1A	
	FR-ABR-3.7K	TH-N20CXHZ-3.6A	
	FR-ABR-5.5K	TH-N20CXHZ-5A	
	FR-ABR-7.5K	TH-N20CXHZ-6.6A	
	FR-ABR-11K	TH-N20CXHZ-11A	
	FR-ABR-15K	TH-N20CXHZ-11A	
FR-ABR-22K	TH-N60-22A		
400V	FR-ABR-H0.4K	TH-N20CXHZ-0.24A	
	FR-ABR-H0.75K	TH-N20CXHZ-0.35A	
	FR-ABR-H2.2K	TH-N20CXHZ-0.9A	
	FR-ABR-H3.7K	TH-N20CXHZ-1.3A	
	FR-ABR-H5.5K	TH-N20CXHZ-2.1A	
	FR-ABR-H7.5K	TH-N20CXHZ-2.5A	
	FR-ABR-H11K	TH-N20CXHZ-6.6A	
	FR-ABR-H15K	TH-N20CXHZ-6.6A	



7. PERIPHERAL DEVICES AND OPTIONS

7.1 Types of Peripheral Devices and Points to Understand

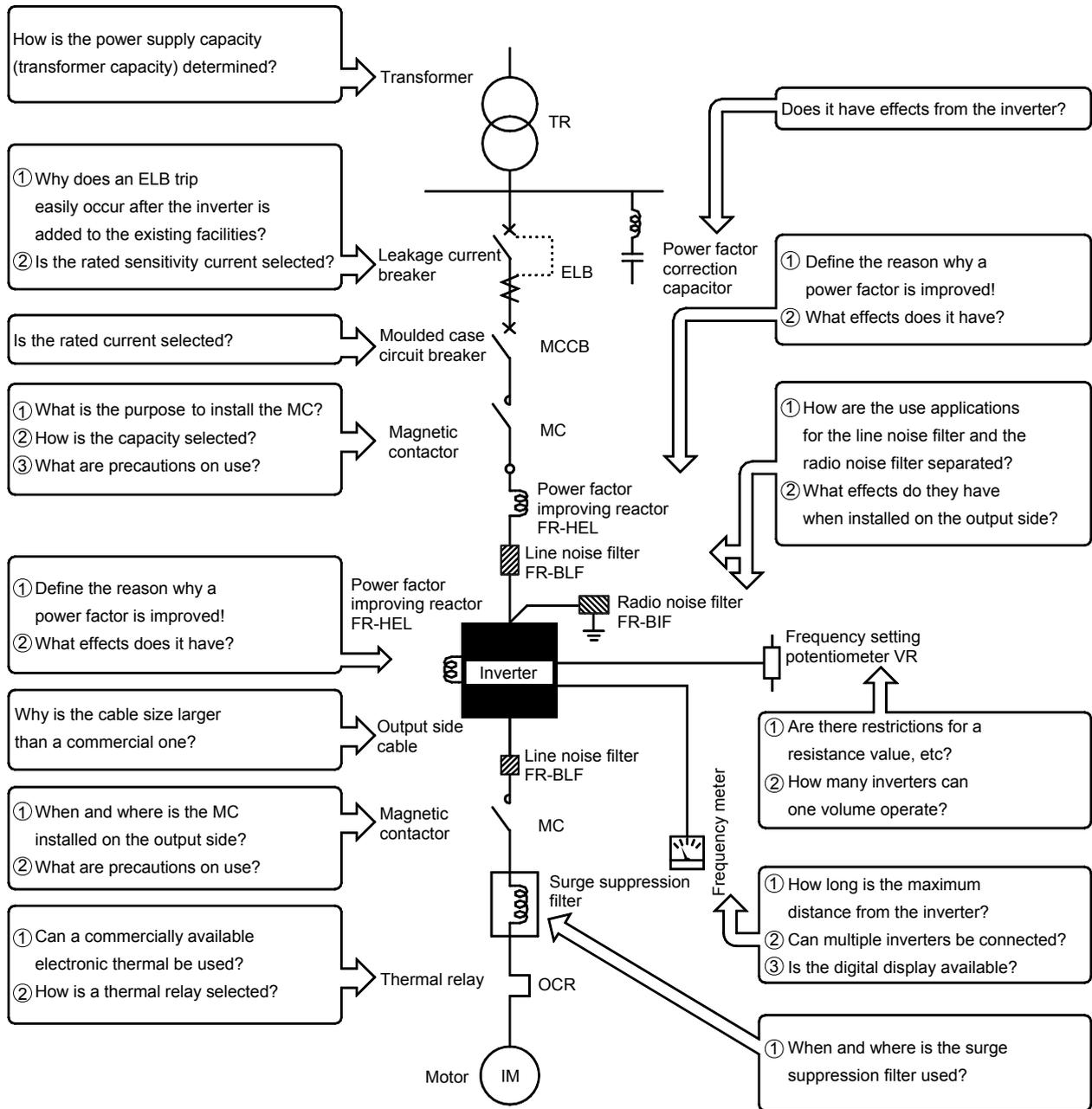


Fig. 7.1 Peripheral devices

7.2 Inverter Options

To use a general-purpose inverter more effectively, various options can be used for improving the characteristics such as an applied operation.

Table 7.1 Types and applied examples of FREQROL-A700 series inverter options

Classification	Requested specifications	Examples of applied options
Operation	<ul style="list-style-type: none"> To set the operation frequency with a digital switch 	FR-A7AX (16-bit digital input)
	<ul style="list-style-type: none"> To set the operation frequency with a PLC To monitor the output frequency, output voltage and output current simultaneously To perform the remote operation of the inverter To perform the automatic operation of the inverter To perform the inverter operation with a PC or PLC To change a parameter remotely 	FR-A7NC (CC-Link)
	<ul style="list-style-type: none"> To start the inverter easily To set a parameter with a PC easily 	FR-Configurator (FR-SW2-SETUP-WJ) (Inverter setup software)
	<ul style="list-style-type: none"> To set a parameter with direct input The parameter unit displayed in English is required. 	FR-PU07 (Parameter unit)
	<ul style="list-style-type: none"> To install the inverter in an enclosure and mount the parameter unit to a door To operate near the inverter 	FR-CB201, 03, 05 (Connection cable)
Output signal	<ul style="list-style-type: none"> To drive the AC relay and a contactor with the inverter output signal 	FR-A7AR (Relay output)
Power factor improvement	<ul style="list-style-type: none"> The power supply capacity must be larger if the inverter power factor is low. The inverter is installed near a large-capacity power supply. 	FR-HAL, FR-HEL※ (Power factor improving reactor)
Harmonic suppression	<ul style="list-style-type: none"> Effects of harmonics on the power supply is worrying. 	FR-HC (High power factor converter)
Measures against noise	<ul style="list-style-type: none"> It is harder to hear a radio due to noise if the inverter is installed. 	FR-BIF (Radio noise filter) FR-BLF (Line noise filter)
	<ul style="list-style-type: none"> A leakage current of the inverter is worrying. 	FR-BLF (Line noise filter)
Braking capability UP	<ul style="list-style-type: none"> To decelerate quickly even if the inertia moment of a machine is large The enough braking capacity is required since acceleration/deceleration is frequently performed. 	BU, FR-BU type brake unit (Brake unit + Brake resistor) FR-CV, FR-RC type power regeneration converter
Applied operation	<ul style="list-style-type: none"> To make various settings To perform the line control and synchronous operation 	FR series manual controller
Installation	<ul style="list-style-type: none"> To place the exothermic section of the inverter outside the enclosure and make it smaller than the panel size 	FR-A7CN Heatsink outside attachment

* Supplied for the inverters of 75K or more

7.3 Power Supply Capacity

The power supply capacity (transformer capacity) on the inverter input side can be calculated by Formula (7.1).

$\text{Power supply capacity} = \frac{\text{Motor capacity (kW)}}{\text{Total efficiency of the inverter} \times \text{Inverter power factor}} \text{ [kVA]} \dots\dots\dots (7.1)$ <p style="text-align: center;">(Total efficiency of the inverter = Motor efficiency × Inverter efficiency)</p>
--

The inverter power factor varies depending on the load and power supply conditions. Therefore, set the power supply capacity (transformer capacity) to 1.2 to 1.5 times as large as the inverter output kVA with the assumption that the inverter efficiency is 0.6 to 0.8 and in consideration for the influence of a voltage drop at a power-on of the inverter. The power factor of the inverter with the power factor improving reactor is calculated with FR-BEL: 0.93 and FR-BAL: 0.88.

The power supply capacity (kVA) is described in a catalog.

7.4 Moulded Case Circuit Breaker (MCCB)

MCCB is used to prevent the power supply side distribution line from being damaged due to an overload and a current at short-circuited.

- 1) Selecting the rated current

For selecting the MCCB breaking capacity, refer to "Mitsubishi No-Fuse Breaker Instruction Manual".

- 2) Selecting the rated current

The size of the inverter input current (effective value) varies depending on the input current form factor. The input current form factor is affected by the power supply impedance.

Therefore, set the rated current to 1.4 times or more as large as the input current effective value in consideration for the influence of the harmonic components as well as for the size of the effective value.

- 3) For selecting the MCCB type and the rated current to avoid the false tripping at the peak value of the inrush current at power on, refer to "Selection of peripheral devices" in the catalog.

7.5 Earth Leakage Current Breaker (ELB)

1) Leakage current of cable path

Since the inverter output waveform includes high frequency components, the leakage current of the cable path from the inverter to the motor during the inverter operation becomes larger than that during the commercial operation.

Therefore, if the inverter is used for the existing facilities, the ELB may trip.

2) Selecting the rated sensitivity current

Calculate the rated sensitivity current from the continuous leakage current of the cable and motor.

The size of the continuous leakage current varies according to conditions such as the motor capacity, cable length, insulation type and cable laying.

The output side leakage current during the inverter operation is approximately 3 times as large as that with the commercial power supply.

In addition, if Mitsubishi New Super NV is used, the same sensitivity current as for the commercial operation can be selected.

7.6 Input Side Magnetic Contactor (MC)

(1) Necessity of installation

The purposes of installing the magnetic contactor (MC) on the input side are described as follows.

- 1) To avoid restarting by power restoration at an occurrence of the instantaneous power failure
- 2) To disconnect the inverter from the power supply at inverter fault or maintenance

When cycle operation or heavy-duty operation is performed with an optional brake resistor connected, overheat and burnout of the electrical-discharge resistor can be prevented if a regenerative brake transistor is damaged due to insufficient heat capacity of the electrical-discharge resistor and excess regenerative brake duty.

- 3) To rest the inverter for an extended period of time (Use MC to save power.)

For cautions for turning on/off the input side magnetic contactor (MC), refer to Section 3.5.5.

(2) Capacity selection method

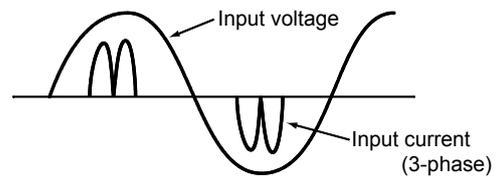
Since installing the input side magnetic contactor (MC) is not for the start/stop of the inverter, the electrical life does not lead to problems. Select a capacity which meets the inverter input current.

Refer to "Selection of peripheral devices" in the catalog for selecting the input side magnetic contactor (MC).

Good to know for checking an inverter

Since the inverter has a large-capacity smoothing electrolytic capacitor on the converter circuit, it is seen as a capacitor input type rectifier from the power supply side.

Therefore, the pulsed current for charging the capacitor flows to the inverter input side. This current form factor is reduced greater than the sine wave current for the commercial power supply, and the power factor becomes lower.



Inverter stop

Inverter stop refers to when the base circuit for the transistor is shut off. The inverter does not stop until the deceleration time elapses even if the start terminal (STF or STR) is turned off. Also, the inverter continues to operate, though the motor stops if the output side MC is turned off. Therefore, turn off the start terminal or turn on the output stop terminal (MRS or reset terminal RES) to shut off the base circuit for the transistor.

If the inverter is turned off, however, the inverter stops since the base circuit for the transistor is shut off immediately. Even if turned on, the inverter keeps the output stop until the start signal is turned on.

7.7 Surge Suppression Filter

In the PWM type inverter, a surge voltage attributable to wiring constants is generated at the motor terminals. Especially for a 400V class motor, the surge voltage may deteriorate the insulation. When the 400V class motor is driven by the inverter, consider the following measures.

7.7.1 Corrective action

It is recommended to perform any of the following actions.

(1) Rectifying the motor insulation

For the 400V class motor, use an insulation-enhanced motor.

Specifically,

- 1) Specify the "400V class inverter-driven insulation-enhanced motor".
- 2) For the dedicated motor such as the constant-torque motor and low-vibration motor, use the "inverter-driven, dedicated motor".

(2) Suppressing the surge voltage on the inverter side

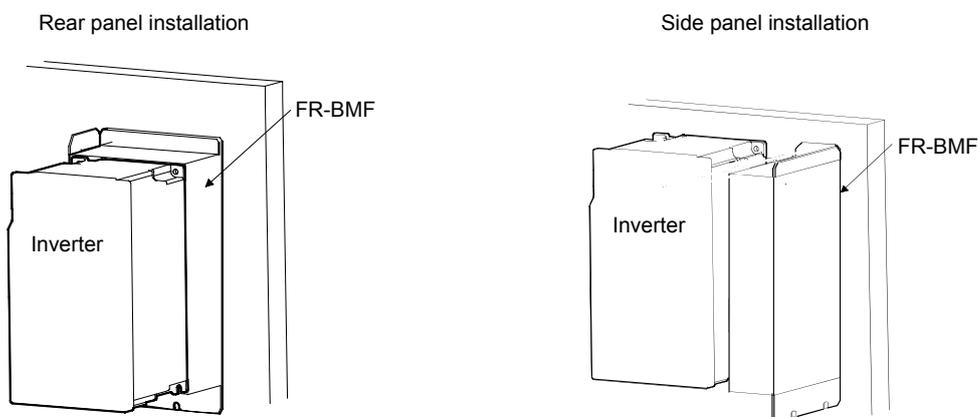
Connect a filter on the secondary side of the inverter to suppress the surge voltage so that the terminal voltage of the motor is 850V or less.

When using our inverter to drive the motor, connect an optional surge voltage suppression filter on the secondary side of the inverter.

For the surge voltage suppression filter, FR-ASF-H□□K or FR-BMF-H□□K is selectable.

FR-BMF-H□□K can be installed on the rear panel (up to 22K) or side panel of the inverter and is available for designing in various panels.

For using the surge voltage suppression filter, the maximum wiring length must be within 100m, and the carrier frequency within 2kHz.

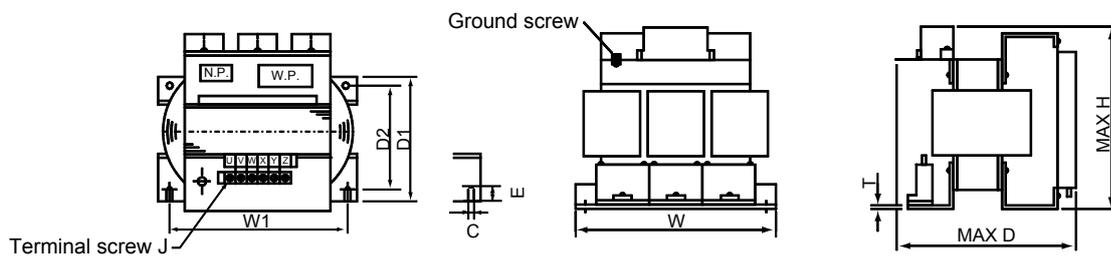


7.7.2 Outline dimension drawings

(1) FR-ASF-H□□K

Model	Applicable inverter	Dimensions (mm)										Approx. mass (kg)
		W	D	H	T	W1	D1	D2	C × E	Terminal screw J	Installation screw	
FR-ASF-H1.5K	0.4K/0.75K/1.5K	220	160	193	2.3	200	134	95	6 × 17	M4	M5	8.0
FR-ASF-H3.7K	2.2K/3.7K	220	180	200	3.2	200	155	115	6 × 18	M4	M5	11
FR-ASF-H7.5K	5.5K/7.5K	280	215	250	3.2	255	191	125	8 × 24	M6	M6	20
FR-ASF-H15K※	11K/15K	335	285	260	6	310	235	200	φ 10	M6	M8	28
FR-ASF-H22K※	18.5K/22K	335	349	340	6	310	281	240	φ 10	M8	M8	38
FR-ASF-H37K※	30K/37K	375	429	465	6	350	—	340	φ 10	M8	M8	59
FR-ASF-H55K※	45K/55K	395	594	465	6	370	—	490	φ 10	M10	M8	78

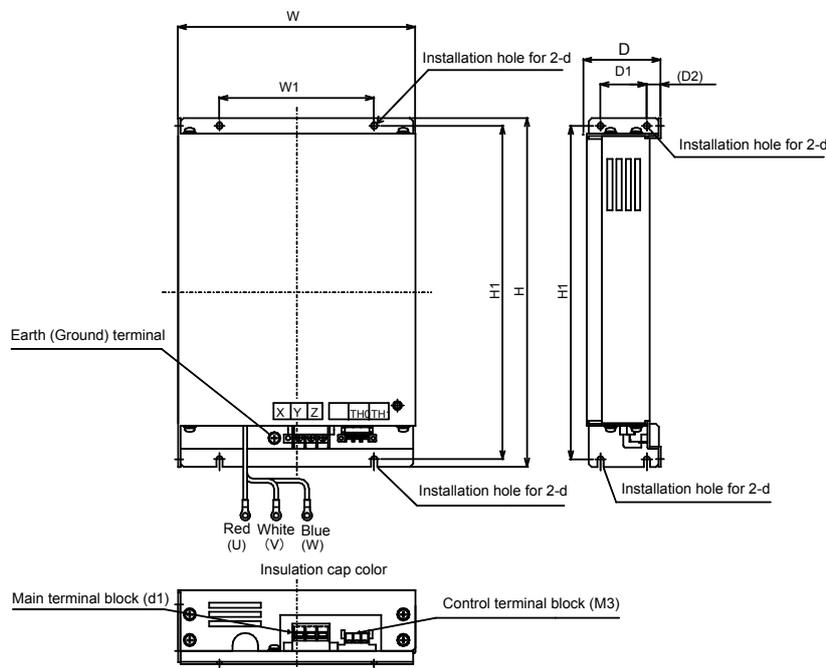
*For H15K or later, some configurations differ.



Surge voltage suppression filter FR-ASF-H□□K

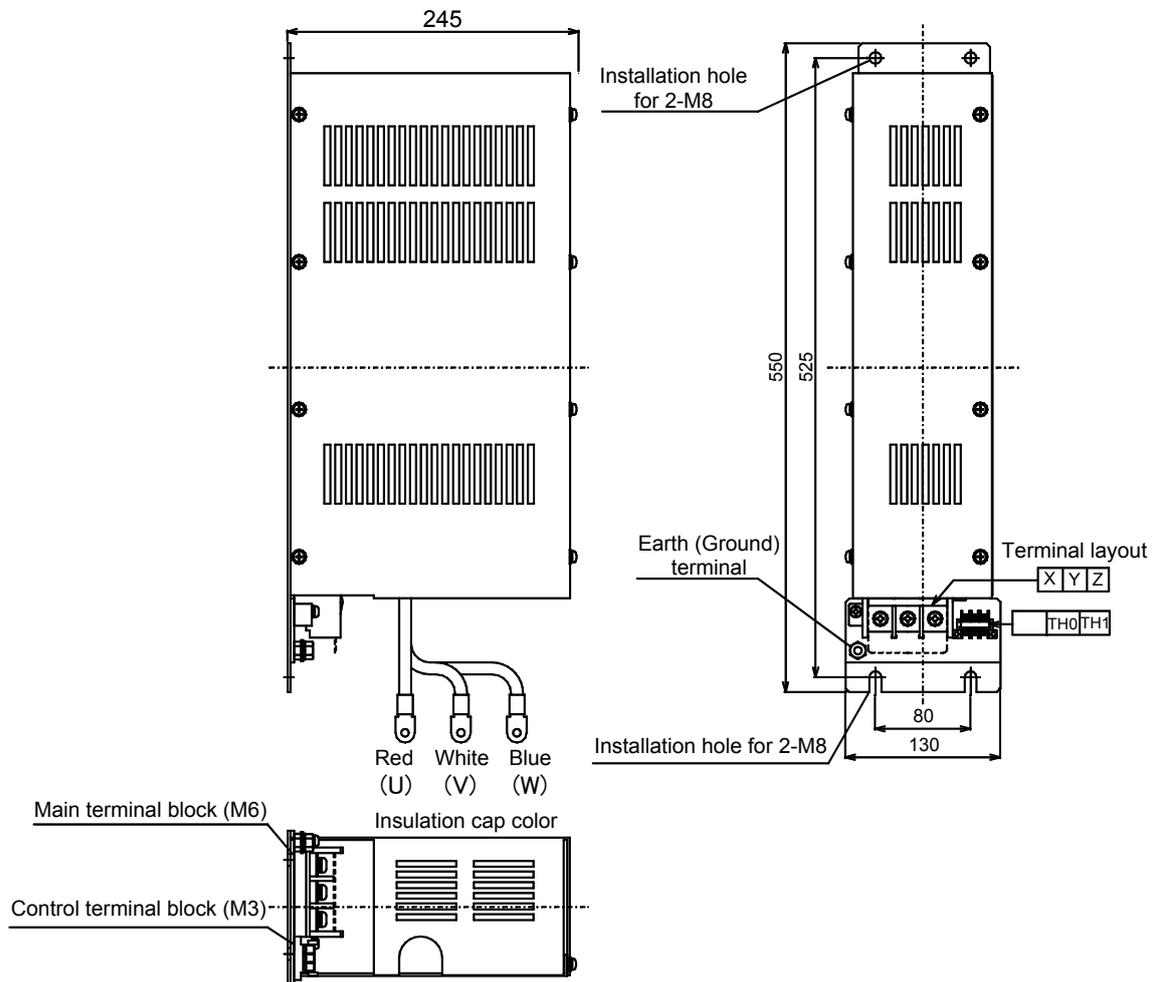
(2) FR-BSF-H□□K

FR-BMF-H7.5K to H22K



Model	Dimensions (mm)								
	W	W1	H	H1	D	D1	D2	d	d1
FR-BMF-H7.5K	230	150	340	325	75	45	13.5	M5	M4
FR-BMF-H7.5K,H22K	260	180	500	480	100	50	31	M8	M5

FR-BMF-H37K



Good to know

For the inverter of 75K or more, the motor voltage and current can be made to nearly sine wave shaped by providing a sine wave filter on the output side.

As a result of this, the same characteristic as when the motor is driven with a sine wave power supply is obtained and the following result can be expected.

- 1) Low noise
- 2) Surgeless
- 3) Motor loss reduction (use of standard motor)

7.8 Output Side Magnetic Contactor (MC)

As a general rule, the magnetic contactor (MC) installed on the inverter output side must not be turned on during the inverter operation. When the output side magnetic contactor (MC) is turned on during the operation, an overcurrent trip occurs in the inverter due to the large start current.

The output side magnetic contactor (MC) can be shut off during the operation. However, the motor coasts to stop at that time.

The purposes of installing the magnetic contactor (MC) on the output side are described as follows:

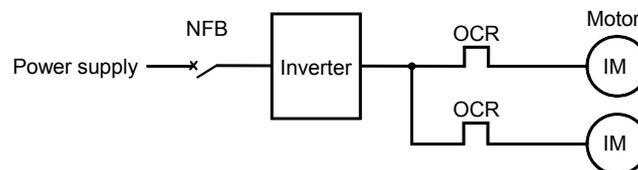
- 1) To configure the commercial power supply-inverter switch-over circuit
- 2) To switch multiple motors with one inverter (Switch the motors during an inverter stop.)
- 3) To need to disconnect the motor from the cable path in the operation cycle while it is at a stop.

For cautions on turning on/off the output side magnetic contactor (MC), refer to Section 3.5.4.

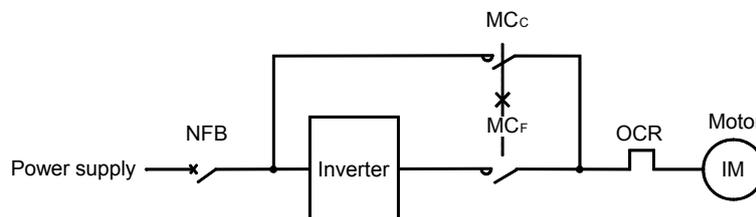
7.9 Thermal Relay (OCR)

(1) The overload protection of the standard motor is performed with the inverter built-in electronic thermal. However, the protection cannot be performed for the following cases, and therefore install a thermal relay between the motor and the inverter.

- 1) To drive multiple motors with a single inverter



- 2) To drive a special motor whose thermal characteristic differs from that of the standard motor
[Example] Submersible motor, multi-pole motor (8 poles or more) or other motors
- 3) To perform the commercial power supply-inverter switchover operation



- (2) Thermal setting value

Thermal setting value is a current value at 50Hz on the motor rating plate.

- (3) Since the inverter output waveform is not a sine wave and includes high frequency components, a commercially available electronic thermal relay cannot be used

7.10 Cable Size of Main Circuit

Select the cable size of the main circuit according to the voltage, current, ambient temperature and wiring distance.

(1) Inverter input side

Select a cable size which meets the input current. (Refer to the size shown in a catalog.)

(2) Inverter output side

Select a cable size which meets the motor current as well as on the input side. Especially, if the wiring distance between the inverter and motor is long, the decrease of motor output torque and the increase of heat generation may occur due to the voltage drop. Select an adequate size. The size shown in a catalog is selected for the distance of 20m.

Good to know for checking an inverter

Since the inverter output voltage is almost proportional to the output frequency, the output voltage is smaller in the low-frequency range, and the voltage drop ratio [%] is larger even if the voltage drop [V] of a cable is same as at 50 to 60Hz.

7.11 Power Factor Improving Reactor (Either FR-HAL or FR-HEL)

(1) Purpose for use

Since the power factor on the inverter input side is low, connect the power factor improving reactor to the inverter input side (for FR-HAL) or the inverter DC side (for FR-HEL) to improve the power factor.

(2) Effects

The power factor is approximately 88% for the power factor improving AC reactor (FR-HAL), and approximately 93% for the power factor improving DC reactor (FR-HEL). The following effects are obtained in addition to the power factor improvement.

- 1) The power supply capacity can be decreased. <<Since the power factor improves>>
- 2) Rated values of the equipments used on the inverter input side can be reduced. <<Since the input current becomes lower>>
- 3) The harmonic components included in the input side current decrease.
- 4) The increase of the capacitor terminal voltage due to the transitional increase of the power supply voltage is suppressed to prevent the overvoltage trip (OV1 to OV3).

(3) Capacity selection

Select the capacity according to the motor capacity and the voltage specification.

For the power factor improving AC reactor (FR-HAL), a voltage drop of approximately 2% occurs (at the rated load). Caution is required for the insufficient torque.

7.12 Inverter Setup Software

FR Configurator(FR-SW2-SETUP-WJ)

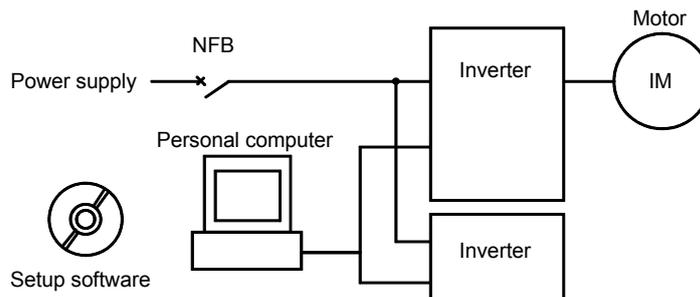
The inverter setup software provides a comfortable operating environment of the inverter as a support tool for operations from startup to maintenance of the inverter.

The parameter setting, monitoring, etc. are enabled efficiently on the Windows screen of a personal computer.

(1) Functions

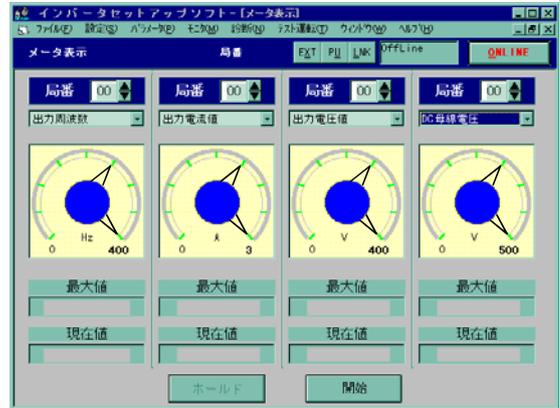
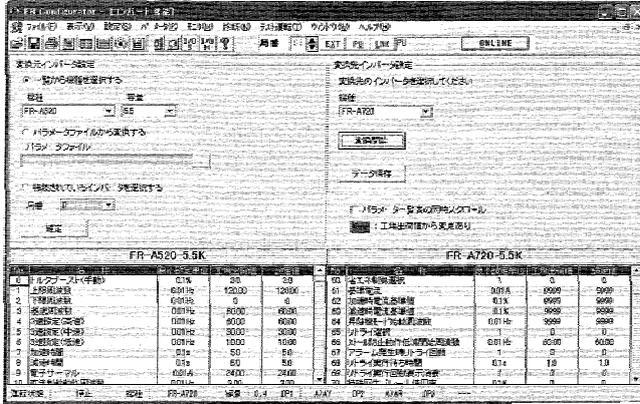
- Parameter setting and edit..... The All list format, Functional List Format, Individual List Format, Basic Settings, I/O terminals Allocation and Convert Function are provided.
- Monitoring..... The Data display, I/O terminal monitor, Oscilloscopes and Status Monitor are provided.
- Test operation Used to judge whether the inverter can operate normally without an operation sequence to the inverter.
- Diagnosis..... Internal diagnosis for judging the inverter operation status
- System setting..... Used to perform the data write and data read to multiple inverter systems.
- File..... Used to save the parameters, operation data, etc. to a hard disk or floppy disk.
- Windows..... Multiple screens can be displayed.

(2) System configuration



(Note: A commercially available converter is required for RS-232C.)

(3) Screen examples



Excerpts from operations of convert function (Inverter unconnected)

By starting FR Configurator, the following screen is displayed.

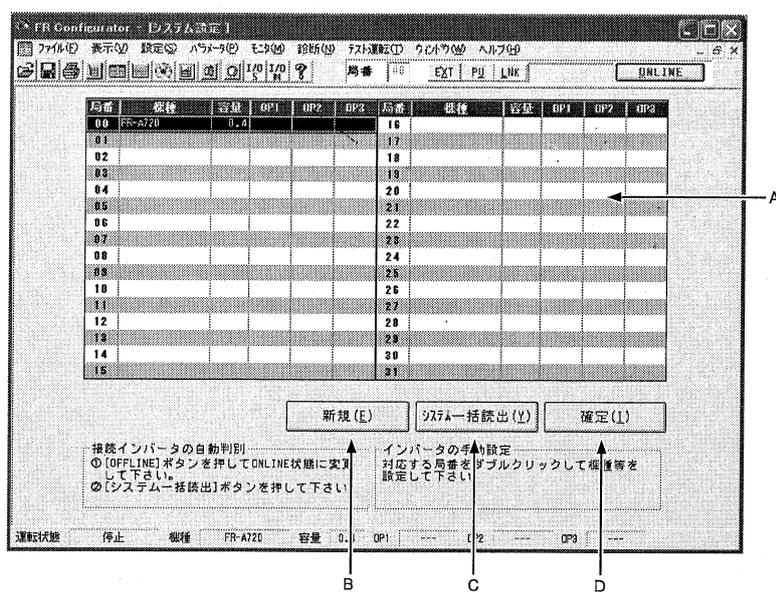
This section describes the setting for the station number, model, capacity and plug-in option of inverter to be connected. The inverters can be set from 00 to 31 stations.

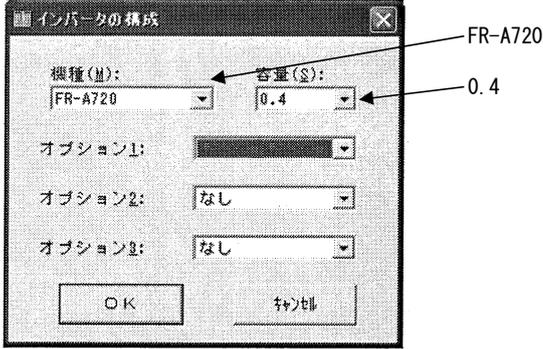
The connected inverter system can be also read all at once.

POINT

Double-click on the line of the station number to display the VFD structure panel of the inverter.

After adding or changing the inverter model (e.g. FR-A720) or capacity (e.g. 0.4K), make sure to press the **Confirmed** button.

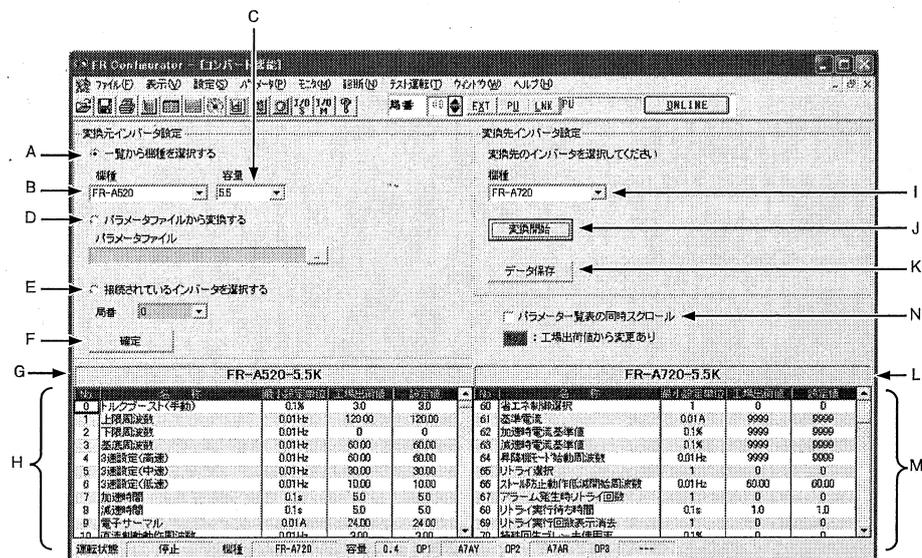


No.	Name	Function and description
A	System setting	<p>Sets the environment of an inverter from 00 to 31 stations. Select a model and capacity of inverter. Set a type of plug-in option when using a plug-in option.</p> <p>By double-clicking on the line of station number to be set, the "VFD Structure" panel is displayed.</p> <p>Set model, capacity and option, and press the OK button to complete the setting. With the same procedures, set all the inverter stations to be connected.</p> 
B	New button	By clicking the New button, the edited system setting and communication setting are initialized (cleared), and a new system is set.
C	System Read button	<p>Before pressing the System Read button, change the system to the online mode by pressing the ONLINE button. In the online mode, the system is in the status of communicating with the inverter. By clicking the System Read button, the models, capacities and options of all stations (0 to 31 stations) are read, and connected (communicable) stations are displayed.</p> <p>Automatically confirmed after the read.</p> <p>When the system setting has been already registered, the verification is performed.</p> <p>When the verification result is different from the read data, display the result of checking, and select to change the settings or not.</p>
D	Confirmed button	The data set the system setting can be confirmed. When the setting of the system configuration is changed manually, make sure to confirm using the Confirmed button.

Converting parameters automatically at the replacement of the conventional model [Convert Function]

By selecting the [Convert Function] command in the [Parameter] menu, the parameters of the conventional model inverter can be automatically converted to those of FR-A700/F700 series of the same model type.

Source inverter	Target inverter
FR-A520, FR-A520L, FR-V520, FR-V520L	FR-A720
FR-A540, FR-A540L, FR-V540, FR-V540L	FR-A740
FR-F520, FR-F520L	FR-F720
FR-F540, FR-F540L	FR-F740



[Source inverter setting section]

No.	Name	Function and description
A	Source model selection setting	Turning on the checkbox to select the model and the capacity from the list.
B	Source model selection	Selects the model of source inverter from the list in the combo box.
C	Source capacity selection	Selects the capacity of source inverter from the list in the combo box.
D	Parameter file conversion setting	Turning on the checkbox makes the parameter file input field valid. Input the storage place for the parameter file (PRM file).
E	Connected inverter selection	Turning on the checkbox makes the station number selection available. Specify the station number of source inverter.
F	Fixation button	Clicking Fixation after making the source inverter setting, and then the target inverter setting can be made.
G	Source model /capacity display	Displays the model and capacity of the read parameter.
H	Source parameter data list	Lists the data of the read parameter. The setting value can be changed.
I	Target model	Selects the model of target inverter from the list in the combo box.

	selection	
J	Start Conversion button	Clicking here starts the conversion.
K	Save Data button	Clicking the Save Data button displays the Save as dialogue, and the parameter data is saved with specifying a file. The format of the file is Parameter file (PRM file) only.

[Source inverter setting section]

No.	Name	Function and description
L	Target model/capacity display	Displays the inverter model and capacity of the converted parameter.
M	Target parameter data list	Displays the converted parameter list. The setting value can be changed. The number of parameter whose setting has been made is displayed in red.

No.	名称	最小設定値	工場出荷	設定値
	速度制御ゲイン	0.1%	9999	100.0

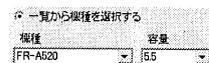
[Common section]

No.	Name	Function and description
N	Simultaneous scroll of the list of parameters	Checked : When either of the source or target parameter lists is scrolled, the other list is also scrolled. Not checked: When either of the source or target parameter lists is scrolled, the other list does not scroll.

Procedure

- Conversion procedure by selecting a model from a list

(1) Check "Select the model from the list" in the "Set VFD from which conversion is made" selection and select the model and capacity of the source inverter.No.A,B,C



(2) Click **Fixation**.

When it is fixed, the parameters of the selected model and capacity are displayed as a list.No.F

No.	名称	最小設定値	工場出荷値	設定値
0	トルクブースト(手動)	0.1%	8.0	8.0
1	上限周波数	0.01Hz	120.00	120.00
2	下限周波数	0.01Hz	0	0
3	高周波数	0.01Hz	60.00	60.00
4	3速設定(高速)	0.01Hz	60.00	60.00
5	3速設定(中速)	0.01Hz	30.00	30.00
6	3速設定(低速)	0.01Hz	10.00	10.00
7	加速時間	0.1s	5.0	5.0
8	減速時間	0.1s	5.0	5.0
9	電子サーマル	0.01A	24.00	24.00
10	再生制動電圧	0.05V	0.00	0.00

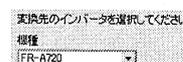
(3) When the parameter setting value of the utilized source inverter has been changed, input the changed value in the Set Value column.

No.	名称	最小設定値	工場出荷値	設定値
0	トルクブースト(手動)	0.1%	8.0	8.0
1	上限周波数	0.01Hz	120.00	60
2	下限周波数	0.01Hz	0	0
3	高周波数	0.01Hz	60.00	60.00

Displayed in green when the setting value is changed.

When changing the Pr.1 setting value to "g60Hz"

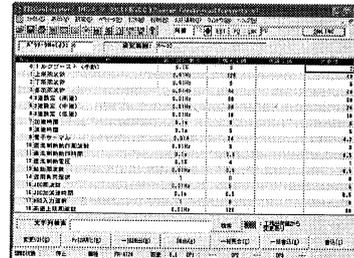
(4) Select the model of the target inverter.
(Only models convertible with FR Configurator are selectable.) No.I



(5) Click **Start Conversion** to display the parameter conversion result as a list. No.J

(6) Click **Save Data** to save the conversion result in the parameter file (PRM).No.K

(7) Display the All List Format or the Functional List Format from Parameter of the menu, and open the saved parameter file (PRM).



(8) Change the target inverter to ONLINE and click **Blk Write**.

The parameter setting value is written in the inverter, and conversion is completed.

Since the inverter is not connected in this demonstration, writing to the inverter cannot be performed.

8. MAINTENANCE/INSPECTION

A general-purpose inverter is a static unit mainly consisting of semiconductor devices. Daily inspection must be performed to prevent any fault from occurring due to the adverse effects of the operating environment, such as temperature, humidity, dust, dirt and vibration, changes in the parts with time, service life, and other factors.

8.1 Precautions for Maintenance and Inspection

For some time after the power is switched off, a high voltage remains in the smoothing capacitor. When accessing the inverter for inspection, wait until the charge lamp is turned off, and then make sure that the voltage across the main circuit terminals P-N of the inverter is not more than 30VDC using a tester, etc.

8.2 Inspection Items

(1) Daily inspection

- Basically, check for the following faults during operation.
 - 1) Whether the motor operates properly as set
 - 2) Improper installation environment
 - 3) Cooling system fault
 - 4) Unusual vibration and noise.
 - 5) Unusual overheat and discoloration
- During operation, check the inverter input voltages using a tester.

(2) Periodic inspection

- Check the areas inaccessible during operation and requiring periodic inspection.
 - 1) Cooling system fault Clean the air filter, etc.
 - 2) Tightening check and retighteningThe screws and bolts may become loose due to vibration, temperature changes, etc.
 - 3) Check the conductors and insulating materials for corrosion and damage.
 - 4) Measure the insulation resistance.
 - 5) Check and change the cooling fan and relay.

(Note) A general-purpose inverter has a power supply indication, which tells that the inverter is in operation, and error (alarm) indications at trouble occurrences. Understand the contents of these indications. Also, check the data of the electronic thermal relays, acceleration/deceleration time, etc. using the parameter unit, and record their setting values for normal operation.

For the inspection items and criteria of the daily and periodic inspections, refer to the table provided on the next page.

Daily and periodic inspection

Area of inspection	Inspection item	Inspection point	Interval		Corrective action at alarm occurrence	Customer's check	
			Daily	Periodic *2			
General	Surrounding environment	Check the ambient temperature, humidity, dirt, corrosive gas, oil mist, etc.	○		Improve environment.		
	Overall unit	Check for unusual vibration and noise.	○		Confirm where the faulty area is, and tighten accordingly.		
	Power supply voltage	Check that the main circuit voltages and control voltages are normal. *1	○		Inspect the power supply.		
Main circuit	General	(1) Check with megger (across main circuit terminals and earth (ground) terminal). (2) Check for loose screws and bolts. (3) Check for overheat traces on the parts. (4) Check for stain.		○ ○ ○ ○	Contact the manufacturer. Retighten. Contact the manufacturer. Clean.		
	Conductors, cables	(1) Check conductors for distortion. (2) Check cable sheaths for breakage and deterioration (crack, discoloration, etc.).		○ ○	Contact the manufacturer. Contact the manufacturer.		
	Transformer/reactor	Check for unusual odor and abnormal increase in whining sound.	○		Stop the device and contact the manufacturer.		
	Terminal block	Check for damage.		○	Stop the device and contact the manufacturer.		
	Smoothing aluminum electrolytic capacitor	(1) Check for liquid leakage. (2) Check for safety valve projection and bulge. (3) Visual check and judge by the life check of the main circuit capacitor.		○ ○ ○	Contact the manufacturer. Contact the manufacturer.		
	Relay/contactor	Check that the operation is normal and no chatter is heard.		○	Contact the manufacturer.		
	Resistor	(1) Check for crack in resistor insulation. (2) Check for a break in the cable.		○ ○	Contact the manufacturer. Contact the manufacturer.		
Control circuit/protective circuit	Operation check	(1) Check that the output voltages across phases with the inverter operated alone is balanced. (2) Check that no fault is found in protective and display circuits in a sequence protective operation test.		○ ○	Contact the manufacturer. Contact the manufacturer.		
	Parts check	All parts	(1) Check for unusual odor and discoloration. (2) Check for serious rust development.		○ ○	Stop the device and contact the manufacturer. Contact the manufacturer.	
		Aluminum electrolytic capacitor	(1) Check for liquid leakage in a capacitor and deformation trace. (2) Visual check and judge by the life check of the control circuit capacitor.		○ ○	Contact the manufacturer.	
Cooling system	Cooling fan	(1) Check for unusual vibration and noise. (2) Check for loose screws and bolts. (3) Check for stain.	○	○ ○ ○	Replace the fan. Retighten. Clean.		
	Heatsink	(1) Check for clogging. (2) Check for stain.		○ ○	Clean. Clean.		
	Air filter, etc.	(1) Check for clogging. (2) Check for stain.		○ ○	Clean or replace. Clean or replace.		
Display	Display	(1) Check that display is normal. (2) Check for stain.	○	○	Contact the manufacturer. Clean.		
	Meter	Check that reading is normal.	○		Stop the device and contact the manufacturer.		
Load motor	Operation check	Check for vibration and abnormal increase in operation noise.	○		Stop the device and contact the manufacturer.		

*1 It is recommended to install a device that monitors power supply voltages applied to the inverter.

*2 A year or two is recommended as a cycle of periodic inspection. However, this may differ depending on the installation environment.

For periodic inspection, consult the nearest Mitsubishi FA Center.

8.3 Replacement of Parts

An inverter consists of many electronic parts such as semiconductor devices.

The following parts may deteriorate with age because of their structures or physical characteristics, leading to reduced performance or fault of the inverter. For preventive maintenance, the parts must be replaced periodically.

For FREQROL-A700 and F700 series, use the life check function as a guidance of parts replacement.

(1) Cooling fan

The cooling fan, which is used for heat-generating parts such as the main circuit semiconductor devices, has a bearing. This bearing is estimated to serve for approximately 87600 hours (for the FREQROL-A700 and F700 series). This is equivalent to approximately 10 years if the unit with the cooling fan is continuously operated without any stop. Replace the whole cooling fan when replacing. Exceptionally, when unusual noise and/or vibration is noticed during inspection, the cooling fan must be replaced immediately.

The FREQROL-A700 and F700 series provide a function to set the ON/OFF control of the cooling fan. With the ON/OFF control, the service life of the cooling fan can be extended. Replacement is also made easily with a cassette.

(2) Smoothing capacitor

A large-capacity aluminum electrolytic capacitor is used for smoothing in the main circuit DC section, and an aluminum electrolytic capacitor is used for stabilizing the control power in the control circuit. Their characteristics are deteriorated by the adverse effects of ripple currents, etc. The replacement intervals greatly vary with the ambient temperature and operating conditions. When the inverter is operated in air-conditioned, normal environment conditions, replace the capacitors about every 10 years (for the FREQROL-A700 and F700 series).

When a certain period of time has elapsed, the capacitors will deteriorate more rapidly. Check the capacitors at least every year (less than six months if the life will be expired soon).

The appearance criteria for inspection are as follows:

- 1) Case: Check the side and bottom faces for expansion.
- 2) Sealing plate: Check for remarkable warp and extreme crack.
- 3) Explosion-proof valve: Check valves for significant extension, and check valves that have operated
- 4) Check for external crack, discoloration, fluid leakage, etc. Judge that the capacitor has reached its life when the measured capacitance of the capacitor reduced below 85% of the rating.

(3) Relays

To prevent a contact fault, etc., relays must be replaced according to the cumulative number of switching times (switching life).

The following table shows replacement criteria for the inverter parts. Note that parts with a short service life such as lamps must be replaced at periodic inspection.

Replacement parts of inverter (FREQROL-A700, F700 series)

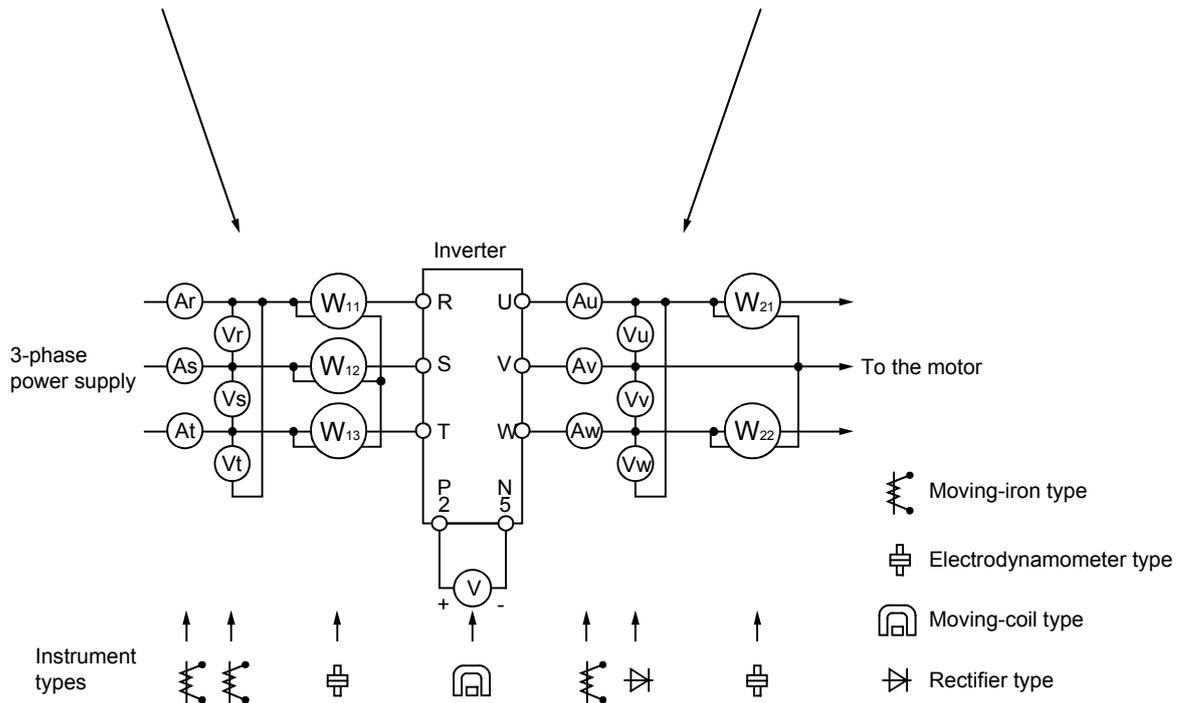
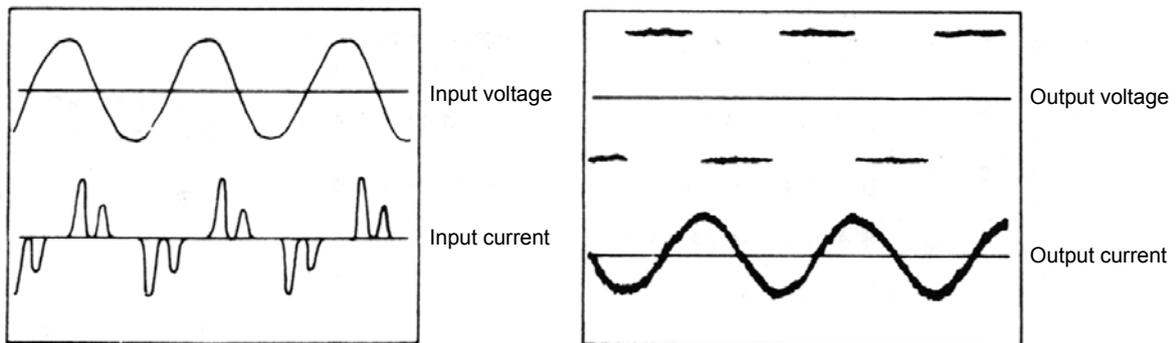
Part name	Standard replacement interval	Description
Cooling fan	10 years	Replace with a new product (as required).
Main circuit smoothing capacitor	10 years	Replace with a new product (as required).
On-board smoothing capacitor	10 years	Replace with a new board (as required).
Relays	—	Replace as required.

8.4 Measurement of Main Circuit Voltages, Currents and Powers

- Measurement of voltages and currents

Since the voltages and currents on the inverter power supply and output sides include harmonics, measurement data depends on the circuits measured.

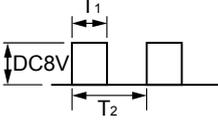
When instruments for commercial frequency are used for measurement, measure the following circuits with the instruments given on the next page.



Examples of measuring points and instruments

Measuring points and instruments

Measuring item	Measuring point	Measuring instrument	Remarks (reference measured value) *	
Power supply voltage V ₁	R-S, S-T, T-R	Moving-iron type AC voltmeter	Within permissible commercial power supply AC voltage fluctuation (Refer to Section 6.1.7 "Specifications".)	
Power supply side current I ₁	R, S, and T line currents	Moving-iron type AC ammeter		
Power supply side power P ₁	R, S, T and R-S, S-T, T-R	Electrodynamic type single-phase wattmeter	P ₁ =W ₁₁ +W ₁₂ +W ₁₃ (3-wattmeter method)	
Power supply side power factor Pf ₁	Calculate after measuring power supply voltage, power supply side current and power supply side power. $Pf_1 = \frac{P_1}{\sqrt{3} \cdot V_{1l1}} \times 100\%$			
Output side voltage V ₂	U-V, V-W, W-U	Rectifier type AC voltmeter (Note 1) (not the moving-iron type)	Difference between the phases is within ± 1% of the maximum output voltage.	
Output side current I ₂	U, V and W line currents	Moving-iron type AC ammeter (Note 2)	Current should be equal to or less than rated inverter current. Difference between phases is 10% or less.	
Output side power P ₂	U, V, W and U-V, V-W	Electrodynamic type single-phase wattmeter	P ₂ =W ₂₁ +W ₂₂ 2-wattmeter method (or 3-wattmeter method)	
Output side power factor Pf ₂	Calculate in a similar manner to the power supply side power factor. $Pf_2 = \frac{P_2}{\sqrt{3} V_2 \cdot I_2} \times 100\%$			
Converter output	P-N	Moving-coil type (Tester, etc.)	POWER lamp turns on. 1.35 × V ₁ Maximum 380V (760V) during regeneration	
Frequency setting signal	2(+)-5	Moving-coil type (Tester and such may be used) (Internal resistance: 50kΩ or larger)	0 to 5VDC/0 to 10VDC	"5" is common.
	1(+)-5		0 to ± 5VDC/0 to ± 10VDC	
	4(+)-5		4 to 20mADC	
10(+)-5	5VDC			
Frequency setting power supply	10E(+)-5		10VDC	

Frequency meter signal	FM(+)-SD	Moving-coil type (Tester and such may be used) (Internal resistance: 50kΩ or larger)	Approx. 5VDC at maximum frequency (without frequency meter)	"SD" is common.
	AM(+)-5		 <p>Pulse width T1: Adjust with Pr. 900 Pulse cycle T2: Set with Pr. 55 (valid only for frequency monitor)</p>	
Start signal Select signal	STF, STR, RH, RM, RL, JOG, RT, AU, STOP, CS(+)-SD	Approx. 10VDC at maximum frequency (without frequency meter)		
Reset	RES(+)-SD	When open 20 to 30VDC ON voltage: 1V or less		
Output stop	MRS(+)-SD			
Alarm signal	A-C B-C	Moving-coil type (Tester, etc.)	Continuity check<Normal> <Abnormal> A-C Discontinuity Continuity B-C Continuity Discontinuity	

(Note 1) Since a tester produces a large error, correct value cannot be measured by a tester.

(Note 2) When the carrier frequency exceeds 5KHz, do not use this instrument since using it may increase eddy-current losses produced in metal parts inside the instrument, leading to burnout. In this case, use an approximate-effective value type.

* Values in parentheses indicate those for the 400V series.

8.5 List of Alarm Display

The following table shows error sources that are shown on the display of the operation panel when erroneous operation is detected.

(FREQROL-A700 series)

Operation panel indication		Name	
Error message	E---	E---	Alarm history
	HOLD	HOLD	Operation panel lock
	Er1~ Er4	Er1 to 4	Parameter write error
	rE1~ rE4	rE1 to 4	Copy operation error
	Err.	Err.	Error
Alarms	OL	OL	Stall prevention (overcurrent)

Operation panel indication		Name	
Major fault	EILF	E.ILF*	Input phase failure
	EOLT	E.OLT	Stall prevention
	E.GF	E.GF	Output side earth (ground) fault overcurrent
	E.LF	E.LF	Output phase failure
	E.OHT	E.OHT	External thermal relay operation
	E.PTC	E.PTC*	PTC thermistor operation

Alarms	<i>oL</i>	oL	Stall prevention (overvoltage)
	<i>rb</i>	RB	Regenerative brake pre-alarm
	<i>TH</i>	TH	Electronic thermal relay pre-alarm
	<i>PS</i>	PS	PU stop
	<i>MT</i>	MT	Maintenance signal output
	<i>CP</i>	CP	Parameter copy
	<i>SL</i>	SL	Speed limit indication (speed restriction output)
Major fault	<i>F_n</i>	FN	Fan failure
	<i>E_{OC1}</i>	E.OC1	Overcurrent shut-off during acceleration
	<i>E_{OC2}</i>	E.OC2	Overcurrent shut-off during constant speed
	<i>E_{OC3}</i>	E.OC3	Overcurrent shut-off during deceleration or stop
	<i>E_{OV1}</i>	E.OV1	Regenerative overvoltage shut-off during acceleration
	<i>E_{OV2}</i>	E.OV2	Regenerative overvoltage shut-off during constant speed
	<i>E_{OV3}</i>	E.OV3	Regenerative overvoltage shut-off during deceleration or stop
	<i>E_{THT}</i>	E.THT	Inverter overload shut-off (electronic thermal relay function)
	<i>E_{THM}</i>	E.THM	Motor overload shut-off (electronic thermal relay function)
	<i>E_{FIN}</i>	E.FIN	Heatsink overheat
	<i>E_{IPF}</i>	E.IPF	Instantaneous power failure
	<i>E_{UVT}</i>	E.UVT	Undervoltage

Major fault	<i>E_{OPT}</i>	E.OPT	Option alarm
	<i>E_{OP1} ~ E_{OP3}</i>	E.OP1 to OP3	Communication option alarm
	<i>E₁ ~ E₃</i>	E. 1 to E. 3	Option alarm
	<i>E_{PE}</i>	E.PE	Parameter storage device alarm
	<i>E_{PUE}</i>	E.PUE	PU disconnection
	<i>E_{RET}</i>	E.RET	Retry count excess
	<i>E_{PE2}</i>	E.PE2*	Parameter storage device alarm
	<i>E₆ / E₇ / E_{CPU}</i>	E. 6/E. 7/CPU	CPU error
	<i>E_{CTE}</i>	E.CTE	Operation panel power supply short circuit, RS-485 terminal power supply short circuit
	<i>E_{P24}</i>	E.P24	24VDC power supply output short circuit
	<i>E_{CDO}</i>	E.CDO*	Output current detection value excess
	<i>E_{IOH}</i>	E.IOH*	Inrush current limit circuit alarm
	<i>E_{SER}</i>	E.SER*	Communication error (inverter)
	<i>E_{AIE}</i>	E.AIE*	Analog input error
	<i>E_{OS}</i>	E.OS	Overspeed occurrence
	<i>E_{OSd}</i>	E.OSD	Speed deviation excess detection
	<i>E_{ECT}</i>	E.ECT	Open cable detection
<i>E_{Od}</i>	E.OD	Position error large	
<i>E_{MB1} ~ E_{MB7}</i>	E.MB1 to E.MB7	Brake sequence error	

* If an error occurs when using with the FR-PU04, "Fault 14" is displayed on the FR-PU04.

Operation panel indication		Name
Major fault	<i>EEP</i>	E. EP Encoder phase error
	<i>E. bE</i>	E. BE Brake transistor error detection
	<i>EUSB</i>	E. USB* USB communication error
	<i>E. 13</i>	E.13 Internal circuit error
	<i>E. 11</i>	E.11 Opposite rotation deceleration error

* If an error occurs when using with the FR-PU04, "Fault 14" is displayed on the FR-PU04.

8.6 Abnormal Phenomenon and Check Points

POINT!

If the cause is still unknown after every check, it is recommended to initialize the parameters (initial value) then re-set the required parameter values and check again.

8.6.1 Motor does not rotate as commanded.

1) Check the Pr. 0 "Torque boost" setting.

2) Check the main circuit.

- Check that a proper power supply voltage is applied. (Operation panel display is provided.)
- Check that the motor is connected properly.
- Check that the jumper across P/+-P1 is connected.

3) Check the input signals.

- Check that the start signal is input.
- Check that both the forward and reverse rotation start signals are not input simultaneously.
- Check that the frequency command value is not zero. (If the frequency command is 0Hz and the start signal is entered, the LED of FWD or REV on the operation panel flickers.)
- Check that the AU signal is on when the frequency setting signal is 4 to 20mA.
- Check that the output stop signal (MRS) or reset signal (RES) is not on.
- Check that the CS signal is not off with automatic restart after instantaneous power failure function is selected (Pr. 57 ≠ "9999").
- Check that the sink or source jumper connector is fitted securely.

4) Check the parameter settings.

- Check that the Pr. 78 "Reverse rotation prevention selection" is not selected.
- Check that the Pr. 79 "Operation mode selection" setting is correct.
- Check that the bias and gain (calibration parameters C2 to C7) settings are correctly made.
- Check that the Pr. 13 "Starting frequency" setting is not greater than the running frequency.
- Check that frequency settings of each running frequency (such as multi-speed operation) are not zero. Check especially that the Pr. 1 "Maximum frequency" is not zero.
- Check that the Pr. 15 "Jog frequency" setting is not lower than the Pr. 13 "Starting frequency" value.

5) Inspect the load

- Check that the load is not too heavy.
- Check that the shaft is not locked.

8.6.2 Motor generates abnormal noise.

- No carrier frequency noises (metallic noises) are generated.
 - Soft-PWM operation to change the motor tone into an unoffending complex tone is factory-set to valid by the Pr. 72 "PWM frequency selection".
Adjust Pr. 72 "PWM frequency selection" to change the motor tone.
- Check that the gain value is not too high during the real sensorless vector control or vector control. Check the value of the Pr. 820 (Pr. 830) "Speed control P gain" when speed control is exercised and the Pr. 824 (Pr. 834) "Torque control P gain" when torque control is exercised.
- Check for any mechanical looseness.
- Contact the motor manufacturer.

8.6.3 The motor generates heat abnormally.

- Check that the fan for the motor is running. (Check for dirt accumulated.)
- Check that the load is not too heavy. Lighten the load if too heavy.
- Check that inverter output voltages (U, V, W) are balanced.
- Check that the Pr. 0 "Torque boost" setting is correct.
- Check that the motor type is set. To do this, check the Pr. 71 "Applied motor" setting.
- When using any other manufacturer's motor, perform offline auto tuning.

8.6.4 The motor rotates in opposite direction.

- Check that the phase sequence of output terminals U, V and W is correct.
- Check that the start signals (forward rotation, reverse rotation) are connected properly.

8.6.5 Speed greatly differs from the setting.

- Check that the frequency setting signal is correct. (Measure the input signal level.)
- Check that Pr. 1, Pr. 2, Pr. 19 and the calibration parameters C2 to C7 are correct.
- Check that the input signal lines are not affected by external noise. (Use shielded cables.)
- Check that the load is not too heavy.
- Check that the Pr. 31 to Pr. 36 (frequency jump) settings are correct.

8.6.6 Acceleration/deceleration is not smooth.

- Check that the acceleration and deceleration time settings are not too short.
- Check that the load is not too heavy.
- Check that the torque boost setting (Pr. 0, Pr. 46, Pr. 112) is not too large to activate the stall function (torque limit).

8.6.7 Motor current is large.

- Check that the load is not too heavy.
- Check that the Pr. 0 "Torque boost" setting is correct.
- Check that the Pr. 3 "Base frequency setting" is correct.
- Check that the Pr. 19 "Base frequency voltage" is correct.
- Check that the Pr. 14 "Load pattern selection" is appropriate.

8.6.8 Speed does not increase.

- Check that the Pr. 1 "Maximum frequency" setting is correct. (If you want to run the motor at 120Hz or more, set Pr. 18 "High speed maximum frequency".)
- Check that the load is not too heavy. (In agitators, etc., load may become heavier in winter.)
- Check that the torque boost setting (Pr. 0, Pr. 46, Pr. 112) is not too large to activate the stall function (torque limit).
- Check that the brake resistor is not connected to terminals P/+P1 accidentally.

8.6.9 Speed varies during operation.

When advanced magnetic flux vector control or real sensorless vector control is exercised, the output frequency varies with load fluctuation between 0 and 2Hz. This is a normal operation and is not a fault.

1) Inspect the load.

- Check that the load is not varying.

2) Check the input signals.

- Check that the frequency setting signal is not varying.
- Check that the frequency setting signal is not affected by noise. Input filter to the analog input terminal using Pr. 74 "Input filter time constant" and Pr. 822 "Speed setting filter 1".
- Check for a malfunction due to undesirable currents when the transistor output unit is connected.

3) Others

- Check that the value of Pr. 80 "Motor capacity" and Pr. 81 "Number of motor poles" are correct to the inverter capacity and motor capacity under the advanced magnetic flux vector control and real sensorless vector control.
- Check that the wiring length is not exceeding 30m when the advanced magnetic flux vector or real sensorless vector control is exercised.
Perform offline auto tuning.
- Check that the wiring length is not too long for the V/F control.

8.6.10 Operation mode is not changed properly.

If the operation mode does not change correctly, check the following:

1) Inspect the load.

.....Check that the STF or STR signal is off.
When it is on, the operation mode cannot be changed

2) Parameter setting

.....Check the Pr. 79 setting.
When the Pr. 79 "Operation mode selection" setting is "0" (initial value), the inverter is placed in the external operation mode at input power-on. At this time, press  on the operation panel (press  when the parameter unit (FR-PU04/FR-PU07) is used) to switch to the PU operation mode. For other values (1 to 4, 6, 7), the operation mode is limited accordingly.

8.6.11 Control panel (FR-DU07) display is not operating.

- Check that the operation panel is connected to the inverter securely.

8.6.12 POWER lamp does not turn on.

- Check that wiring and installation are made securely.

8.6.13 Parameter write cannot be performed.

- Make sure that operation is not being performed (signal STF or STR is not ON).
- Make sure that you are not attempting to set the parameter in the external operation mode.
- Check Pr. 77 "Parameter write selection".
- Check Pr. 161 "Frequency setting/key lock operation selection".

8.7 Protective Function

When a protective function (major fault) is activated, power the inverter off and power it on again, or reset the inverter using the reset terminal (RES). (Alternatively, reset the inverter using the Help menu of the PU.)

(1) Error message

A message regarding operational troubles is displayed. Output is not shut off.

Function name	Description	Display	Check point	Corrective action
Operation panel lock	Appears when operation was tried during operation panel lock.	HOLD		Press  for 2s to release lock.
Parameter write error	Appears when an error occurred during parameter writing	Er1	Check the settings of Pr. 77, Pr. 31 to Pr. 36, and Pr. 100 to Pr. 109. Check the connection of the PU and inverter.	
		Er2	Check the Pr. 77 setting. Check that the inverter is not operating.	
		Er3	Check the settings of the calibration parameters C3, C4, C6 and C7.	
		Er4	Check that the operation mode is "PU operation mode". Check the Pr. 77 setting.	
Copy operation error	Appears when an error occurred during parameter copying.	rE1		Make parameter copy again.
		rE2	Check that the FWD or REV LED is lit or flickering.	Perform again after stopping operation.
		rE3	Check for the parameter setting of the source inverter and inverter to be verified.	Press  to continue the verification.
		rE4	Check that the verified inverter is the same model. Check that operation is not stopped by switching off the power supply while reading parameter copy or by disconnecting the operation panel.	Use the same model for parameter copy and verification.
Error	Appears when the RES signal is on or the PU and inverter cannot make normal communication.	Err		Turn off the RES signal. Check the connection of the PU and inverter.

(2) Alarm

When the protective function is activated, the output is not shut off.

Function name	Description	Display	Check point	Corrective action
Stall prevention (overcurrent)	Appears during overcurrent stall prevention.	OL	Check that the load is not too heavy. Check that the setting values of Pr. 0 and Pr. 13 are not too large. Check that the setting values of Pr. 7 and Pr. 8 are not too short.	Reduce the load weight. Change the settings of Pr. 0, 7, 8, 13 and 14. Increase capacities of the motor and inverter.
Stall prevention (overvoltage)	Appears during overvoltage stall prevention. Appears while the regeneration avoidance function is activated.	oL	Check for sudden speed reduction. Check that the regeneration avoidance function is used.	Increase the deceleration time using Pr. 8.
PU stop	Appears when  on the operation panel was pressed during external operation.	PS	Check for a stop made by pressing  of the operation panel.	Turn the start signal off and release with  .
Regenerative brake pre-alarm	Appears when the regenerative brake duty reaches or exceeds 85% of the setting of Pr. 70. If the regenerative brake duty reaches 100%, a regenerative overvoltage (E. OV_) occurs.	RB	Check that the brake resistor duty is not high. Check that the settings of Pr. 30 and Pr. 70 are correct.	Increase the deceleration time. Correct Pr. 30 and Pr. 70.
Electronic thermal relay pre-alarm	Appears when the integrating value of the electronic thermal relay function reaches or exceeds 85% of the Pr. 9 setting. If it reaches 100% of the Pr. 9 setting, a motor overload shut-off (E. THM) occurs.	TH	Check for large load or sudden acceleration. Check that the Pr. 9 setting is appropriate.	Reduce the load weight or the number of operation times. Set an appropriate value in Pr. 9.
Maintenance signal output	Appears when the cumulative energization time has exceeded the maintenance output timer set value.	MT	Check that the Pr. 503 setting is not larger than the Pr. 504 setting.	Write "0" to Pr. 503.
Parameter copy	Appears when parameters are copied between models with capacities of 55K or less and 75K or more.	CP		Set the initial value in Pr. 989.
Speed limit indication	Displays when the speed restriction level is exceeded during torque control.	SL	Check that the torque command is not larger than required. Check that the speed restriction level is not low.	Decrease the torque command value. Increase the speed restriction level.

(3) Minor fault

When the protective function is activated, the output is not shut off. The minor fault signal can also be output by setting the parameters.

(Set "98" in any of Pr. 190 to Pr. 196 (output terminal function selection).)

Function name	Description	Display	Check point	Corrective action
Fan failure	Appears when the cooling fan stops due to a fault or when operation different from the setting of Pr. 244 is performed during speed reduction. This indication is involved only in the inverter that contains a cooling fan.	FN	Check the cooling fan for a fault.	Replace the fan.

(4) Major fault

When the protective function is activated, the inverter output is shut-off and an alarm output is provided.

Function name	Description	Display	Check point	Corrective action
Overcurrent shut-off during acceleration	Appears when the inverter output current rose to or above about 220% of the rated current during acceleration.	E.OC1	Check for sudden acceleration. Check for output short circuit.	Increase the acceleration time (Shorten the downward acceleration time in vertical lift application.). Check the wiring for output short circuit.
Overcurrent shut-off during constant speed	Appears when the inverter output current rose to or above about 220% of the rated current during constant-speed operation.	E.OC2	Check for sudden load change. Check for output short circuit.	Keep load stable. Check the wiring for output short circuit.
Overcurrent shut-off during deceleration or stop	Appears when the inverter output current rose to or above about 220% of the rated current during deceleration or a stop.	E.OC3	Check for sudden speed reduction. Check for output short circuit. Check for too fast operation of the motor's mechanical brake.	Increase the deceleration time. Check the wiring for output short circuit. Check the mechanical brake operation.
Regenerative overvoltage shut-off during acceleration	Appears when regenerative energy causes the inverter's internal main circuit DC voltage to reach or exceed the specified value during acceleration, or when a surge voltage occurs in the power supply system causing the shut-off to operate.	E.OV1	Check for too slow acceleration. (e.g. during downward acceleration in vertical lift load)	Decrease the acceleration time. Utilize the regeneration avoidance function.
Regenerative overvoltage shut-off during constant speed	Appears when regenerative energy causes the inverter's internal main circuit DC voltage to reach or exceed the specified value during constant-speed operation, or when a surge voltage occurs in the power supply system causing the shut-off to operate.	E.OV2	Check for sudden load change.	Keep load stable. Utilize the regeneration avoidance function. Use the brake unit or power regeneration common converter as required.
Regenerative overvoltage shut-off during deceleration or stop	Appears when regenerative energy causes the inverter's internal main circuit DC voltage to reach or exceed the specified value during deceleration or stop, or when a surge voltage occurs in the power supply system causing the shut-off to operate.	E.OV3	Check for sudden speed reduction.	Increase the deceleration time. Reduce the number of operation times. Utilize the regeneration avoidance function. Use the brake unit or power regeneration common converter as required.
Inverter overload shut-off (electronic thermal relay function)	Appears when inverse-time characteristics cause the electronic thermal relay to be activated to protect the output transistors due to that a current not less than 150% of the rated output current flows and overcurrent shut-off does not occur (220% or less).	E.THT	Check the motor for use under overload.	Reduce the load weight. Increase capacities of the motor and inverter.
Motor overload shut-off (electronic thermal relay function)	Appears when the electronic thermal relay function built in the inverter detects motor overheat exceeding the specification value due to overload or reduced cooling capability during constant-speed operation.	E.THM	Check the motor for use under overload. Check that the Pr. 71 setting is correct.	Reduce the load weight. For a constant-torque motor, set the constant-torque motor in Pr. 71. Increase capacities of the motor and inverter.

Function name	Description	Display	Check point	Corrective action
Heatsink overheat	Appears when the heatsink overheated causing the temperature sensor to be activated.	E.FIN	Check for too high ambient temperature. Check for heatsink clogging. Check that the cooling fan is stopped.	Set the ambient temperature to within the specifications. Clean the heatsink. Replace the cooling fan.
Instantaneous power failure	Appears when a power failure occurs for longer than 15ms (this also applies to inverter input shut-off), causing the instantaneous power failure protective function to be activated to prevent the control circuit from malfunctioning. If a power failure persists for longer than 100ms, the alarm warning output is not provided, and the inverter restarts if the start signal is on upon power restoration. (The inverter continues operating if an instantaneous power failure is within 15ms.)	E.IPF	Find the cause of instantaneous power failure occurrence.	Remedy the instantaneous power failure. Prepare a backup power supply for instantaneous power failure. Set the automatic restart after instantaneous power failure function.
Brake transistor error detection	Appears when an error occurred in the brake circuit, e.g. damaged brake transistors.	E.BE	Reduce the load inertia. Check that the frequency of using the brake is proper.	Replace the inverter.
Undervoltage	If the power supply voltage of the inverter decreases, the control circuit will not perform normal functions. In addition, the motor torque will be insufficient and/or heat generation will increase. To support such trouble prevention, this indication appears when the power supply voltage decreases to approx. 150VAC (300VAC in the 400V class) or lower.	E.UVT	Check for start of large-capacity motor. Check that a jumper or DC reactor is connected across terminals P/+ -P1.	Check the power supply system equipment such as power supply. Connect a jumper or DC reactor across terminals P/+ -P1.
Input phase failure	Appears when one of the three phase power input opened with the function enabled in Pr. 872.	E.ILF	Check for a break in the cable for the three-phase power supply input.	Repair a brake portion in the cable.
Stall prevention	Appears 3s after the output frequency decreased to 0.5Hz due to the stall prevention being activated.	E.OLT	Check the motor for use under overload.	Reduce the load weight. Increase capacities of the motor and inverter.
Output side earth (ground) fault overcurrent	Appears when an earth (ground) fault occurred on the inverter's output side (load side).	E.GF	Check for an earth (ground) fault in the motor and connection cable.	Remedy the earth (ground) fault portion.
Output phase failure	Appears when one of the three phases (U, V, W) on the inverter's output side (load side) opens.	E.LF	Check the wiring. Check that the motor is normal. Check that the capacity of the motor used is not smaller than that of the inverter.	Check the wiring. Change the setting of Pr. 251.
External thermal relay operation	Appears when the external thermal relay provided for motor overheat protection or the internally mounted temperature relay in the motor, etc. switches on.	E.OHT	Check for motor overheating. Check that the value of 7 is set correctly in any of Pr. 178 to Pr. 189.	Reduce the load or the number of operation times.

Function name	Description	Display	Check point	Corrective action
PTC thermistor operation	Appears when the motor overheat status is detected for 10s or more by the external PTC thermistor input connected to the terminal AU.	E.PTC	Check the connection between the PTC thermistor switch and thermal protector. Check the motor for operation under overload. Check that Pr. 184 is enabled.	Reduce the load weight.
Option alarm	Appears when the AC power supply is accidentally connected to R/L1, S/L2, and T/L3 with the high power factor converter connected, or when torque command by the plug-in option is selected using Pr. 804 "Torque command source selection" and no plug-in option is mounted. Also appears if the plug-in optional switch for manufacturer use is switched.	E.OPT	Check that the AC power supply is not connected to the terminals R/L1, S/L2, T/L3 when a high power factor converter or power regeneration common converter is connected. Check that the plug-in option for torque command setting is connected.	Check the Pr. 30 setting and wiring. Check for connection of the plug-in option. Check the Pr. 804 setting. Switch back the plug-in optional switch for manufacturer use.
Communication option alarm	Appears when a communication line error occurred in the communication option.	E.OP1 to OP3	Check for a wrong option function setting and operation. Check that the plug-in option unit is plugged into the connector securely. Check for a break in the communication cable. Check that the terminal resistor is installed.	Check the option function setting, etc. Connect the plug-in option securely. Check that the communication cables are connected properly.
Option alarm	Appears when a contact fault or the like of the connector between the inverter and communication option occurs or when a communication option is fitted to the connector 1 or 2.	E. 1 to E. 3	Check that the option unit is plugged into the connector securely. Check for excess electrical noises around the inverter. Check that the communication option is not fitted to the connector 1 or 2.	Connect the option securely. Take measures against noises if there are devices producing excess electrical noises around the inverter. Fit the communication option to the connector 3.
Parameter storage device alarm (control circuit board)	Appears when an error occurred in stored parameters. (EEPROM failure)	E.PE	Check for too many number of parameter write times.	Replace the inverter.
Parameter storage device alarm (main circuit board)	Appears when an error occurred in stored parameters. (EEPROM failure)	E.PE2		Replace the inverter.
PU disconnection	Appears when a communication error between the PU and inverter occurred, the communication interval exceeded the permissible time during the RS-485 communication with the PU connector, or communication errors exceeded the number of retries during the RS-485 communication.	E.PUE	Check that the FR-DU07 or parameter unit is fitted tightly. Check the Pr. 75 setting.	Fit the FR-PU07 or parameter unit securely.

Function name	Description	Display	Check point	Corrective action
Retry count excess	Appears when the operation was not restarted normally within the set number of retries.	E.RET	Find the cause of error occurrence.	Identify the cause of the error preceding this error indication.
CPU error	Appears when a communication error occurred in the built-in CPU.	E. 6 E. 7 CPU	Check for devices producing excess electrical noises around the inverter.	Take measures against noises if there are devices producing excess electrical noises around the inverter.
Operation panel power supply short circuit, RS-485 terminal power supply short circuit	Appears when the RS-485 terminal power supply or operation panel power supply (PU connector) is shorted.	E.CTE	Check for a short circuit in the PU connector cable. Check that the RS 485 terminals are connected correctly.	Check the PU and cable. Check the connection of the RS-485 terminal.
Brake sequence error	Appears when a sequence error occurs during use of the brake sequence function.	E.MB1 to 7	Find the cause of error occurrence.	Check the set parameters and wiring.
Overspeed occurrence	Appears when the motor speed exceeds the set over speed level during the encoder feed back control or vector control.	E.OS	Check that the Pr. 374 setting is correct. Check that the number of encoder pulses differ from the actual number of encoder pulses.	Set Pr. 374 and Pr. 369 correctly.
Speed deviation excess detection	Appears when the motor speed is increased or decreased under the influence of the load, etc. during the vector control and cannot be controlled in accordance with the speed command value.	E.OSD	Check that the Pr. 285 and Pr. 853 settings are correct. Check for sudden load change. Check that the number of encoder pulses differ from the actual number of encoder pulses.	Set Pr. 285, Pr. 853 and Pr. 369 correctly. Keep load stable.
Open cable detection	Appears when the encoder signal is shut off during the orientation control, encoder feed back control or vector control.	E.ECT	Check for a break in the cable of the encoder signal. Check that the encoder specifications are correct. Check for a loose connector. Check that the switch setting of the FR-A7AP is correct. Check that power is applied to the encoder.	Remedy the break. Use an encoder which meets the specifications. Check the connection. Correct the switch setting of the FR-A7AP. Supply power to the encoder.
Position error large	Appears when the difference between the position command and position feedback exceeded the reference during the position control.	E.OD	Check that the position detecting encoder mounting orientation matches the parameter. Check that the load is not large. Check that the Pr. 427 and Pr. 369 settings are correct.	Check the parameters. Reduce the load weight. Set Pr. 427 and Pr. 369 correctly.
Encoder phase error	Appears when the rotation command of the inverter differs from the actual motor rotation direction detected from the encoder during offline auto tuning.	E.EP	Check for mis-wiring of the encoder cable. Check the Pr. 359 setting.	Perform connection and wiring securely. Set Pr. 359 correctly.

Function name	Description	Display	Check point	Corrective action
24VDC power supply output short circuit	Appears when the 24VDC power supply output from the PC terminal is shorted.	E.P24	Check for a short circuit in the PC terminal output.	Remedy the short circuit portion.
Output current detection value excess	Appears when the output current has exceeded the setting of Pr. 150.	E.CDO	Check the settings of Pr. 150, Pr. 151, Pr. 166 and Pr. 167.	
Inrush current limit circuit alarm	Appears when the resistor of the inrush current limit circuit overheats.	E.IOH	Check that frequent ON/OFF is not repeated.	Change the system to the one where frequent ON/OFF is not repeated. Replace the inverter.
Communication error (inverter)	Appears when a communication error occurred during the RS-485 communication with the RS-485 terminals.	E.SER	Check the RS-485 terminal wiring.	Perform wiring of the RS-485 terminals properly.
Analog input error	Appears when 30mA or more is input or a voltage (7.5V or more) is input with the terminal 2/4 set to current input.	E.AIE	Check the settings of Pr. 73 and Pr. 267.	Either give a frequency command by current input or set Pr. 73 and Pr. 267 to voltage input.
USB communication error	Appears when communication has broken for the period of time set in Pr. 548.	E.USB	Check the USB communication cable.	Change the setting of Pr. 548. Check the USB communication cable.
Opposite rotation deceleration error	Appears when reverse deceleration cannot be performed during the real sensorless vector control due to difference in the motor constant.	E.11	Check the setting of Pr. 71. Check that both the offline and online auto tunings were performed.	Check the Pr. 71 setting. Perform offline auto tuning, then enable online auto tuning.
Internal circuit error	Appears when an internal circuit error occurred.	E.13		Replace the inverter.

CAUTION

- If protective functions of E.ILF, E.PTC, E.PE2, E.PE, E.OD, E.CDO, E.IOH, E.SER, E.AIE, E.USB are activated when using the FR-PU04, "Fault 14" is displayed.

Also when the alarm history is checked on the FR-PU04, the display is "E.14".

8.8 Exercising with the Training Kit

There is a training kit (the FR-A demonstration machine) available, which is to confirm motor performance and inverter controllability/function in the operating condition that a motor is connected to an inverter and a load.

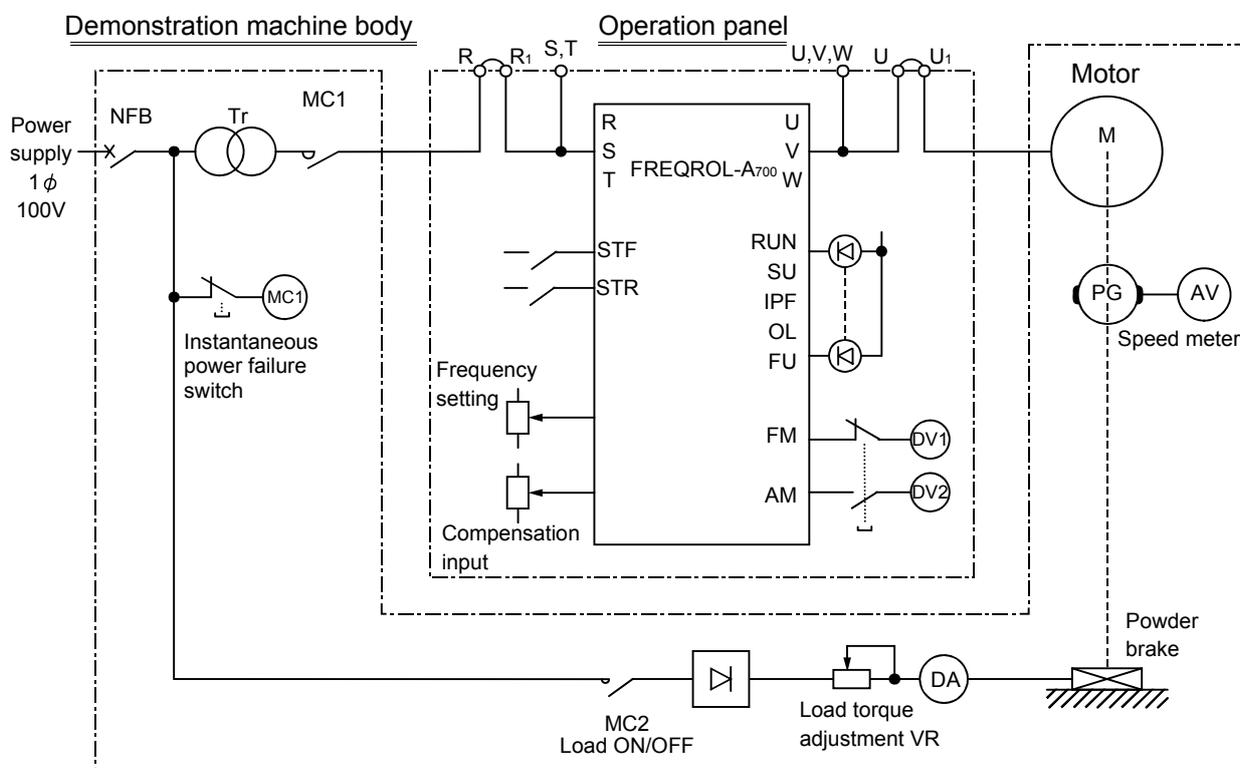
Use the training kit to obtain experiential knowledge in the said contents.

8.8.1 Test operations

The following items can be confirmed with the FR-A demonstration machine.

- (1) Difference in generated torque between low-speed operations by the advanced magnetic flux vector control, real sensorless vector control, and V/F control.
- (2) Acceleration/deceleration performance in accordance with the load weight
- (3) Inverter operation, monitor (for terminal I/O status, troubleshooting functions), etc. by the interactive parameter unit
- (4) Output terminals assignment function
- (5) Life check

8.8.2 Configuration of the demonstration machine



8.8.3 Description of the demonstration machine

The demonstration machine consists of an operation panel and a power supply load box.

(1) Operation panel

The operation panel is as shown below.

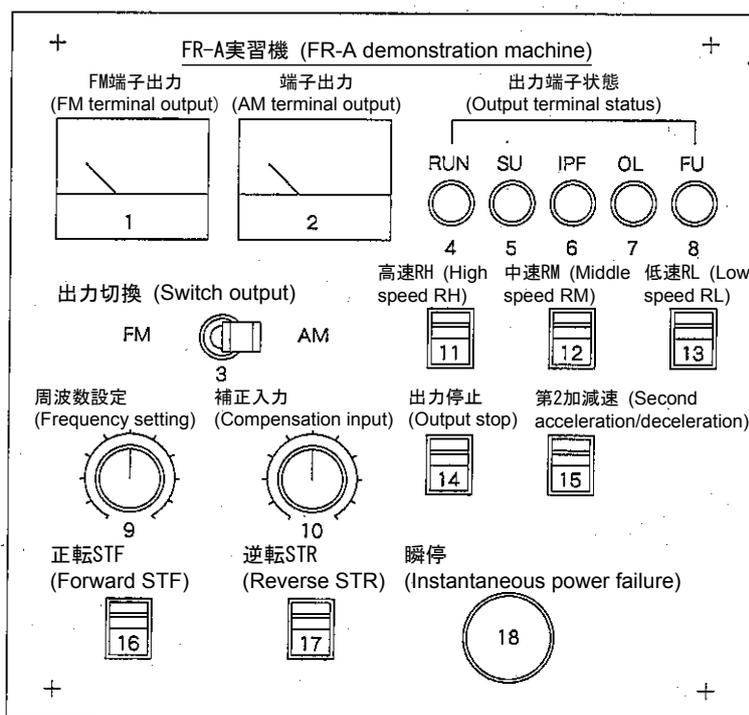


Fig. 8.1 Operation panel

- 1) FM 端子出力(FM terminal output)..... Displays output frequency (pulse output) from the inverter.
- 2) AM 端子出力(AM terminal output)..... Displays output frequency (analog output) from the inverter.
- 3) 出力切換(Switch output)..... Switches the terminal enabled for inverter output frequency between FM 端子出力(FM terminal output) and AM 端子出力(AM terminal output).
- 4) RUN Turns on when output frequency becomes higher than the starting frequency, indicating that the inverter is in operation.
- 5) SU..... Turns on when output frequency enters in the range of $\pm 10\%$ of the set frequency, indicating that frequency increase has completed.
- 6) IPF..... Turns on when the instantaneous power failure function or the undervoltage protective function is activated, indicating that an instantaneous power failure occurred.

- 7) OL Turns on when the current limit function activated the stall prevention function, indicating an overlord alarm.
- 8) FU Turns on when output frequency reaches or exceeds the optionally set detection frequency, indicating a frequency detection.
- 9) 周波数設定(Frequency setting) Allows the set frequency to be output with analog voltage.
- 10) 補正入力(Compensation input) Allows extra voltage to be added to the analog voltage set with 周波数設定(Frequency setting).
- 11) 高速(High speed)..... Selects "高速(High speed)" from the multi-speed setting.
RH
Note that up to seven different speeds are available in combination with "中速(Middle speed)" and "低速(Low speed)".
- 12) 中速(Middle speed) Selects "中速(Middle speed)" from the multi-speed setting.
R
Note that up to seven different speeds are available in combination with "高速(High speed)" and "低速(Low speed)".
- 13) 低速(Low speed)..... Selects "低速(Low speed)" from the multi-speed setting.
RL
Note that up to seven different speeds are available in combination with "高速(High speed)" and "中速(Middle speed)".
- 14) 出力停止(Output stop) Stops the inverter output.
MRS
- 15) 第2加減速(Second acceleration/deceleration)
RT Selects second acceleration/deceleration time.
- 16) 正転(Forward)..... Forward rotation start signal
STF
- 17) 逆転(Reverse)..... Reverse rotation start signal
STR
- 18) 瞬停(Instantaneous power failure) Shuts off the power supply for the inverter.

(2) Power supply load box

The power supply load box is as shown below.

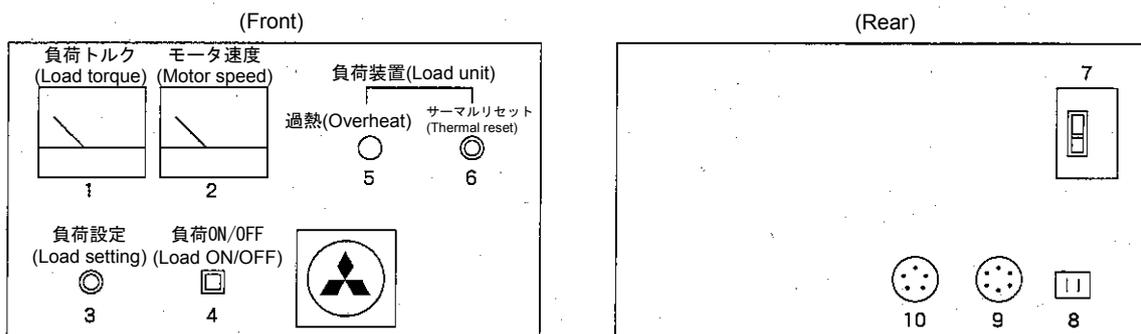


Fig. 8.2 Power supply load box

-
- 1) 負荷トルク(Load torque) Indicates the load torque applied to the motor.
 - 2) モータ速度(Motor speed) Indicates the motor speed.
 - 3) 負荷設定(Load setting)..... Sets the load applied to the motor.
 - 4) 負荷 ON/OFF(Load ON/OFF) A switch to turn on and off the load on the motor.
 - 5) 過熱(Overheat)..... Turns on when overheat is generated on the motor's load.
 - 6) サーマルリセット(Thermal reset)..... Resets the thermal relay when overheat is generated on the motor's load.
 - 7) 電源 NF(Power supply noise filter) Power supply noise filter for the demonstration machine
 - 8) Outlet 100VAC outlet for external output
 - 9) Connector 1 100VAC input connector
 - 10) Connector 2 Connector for motor output and load

(3) Precautions for use

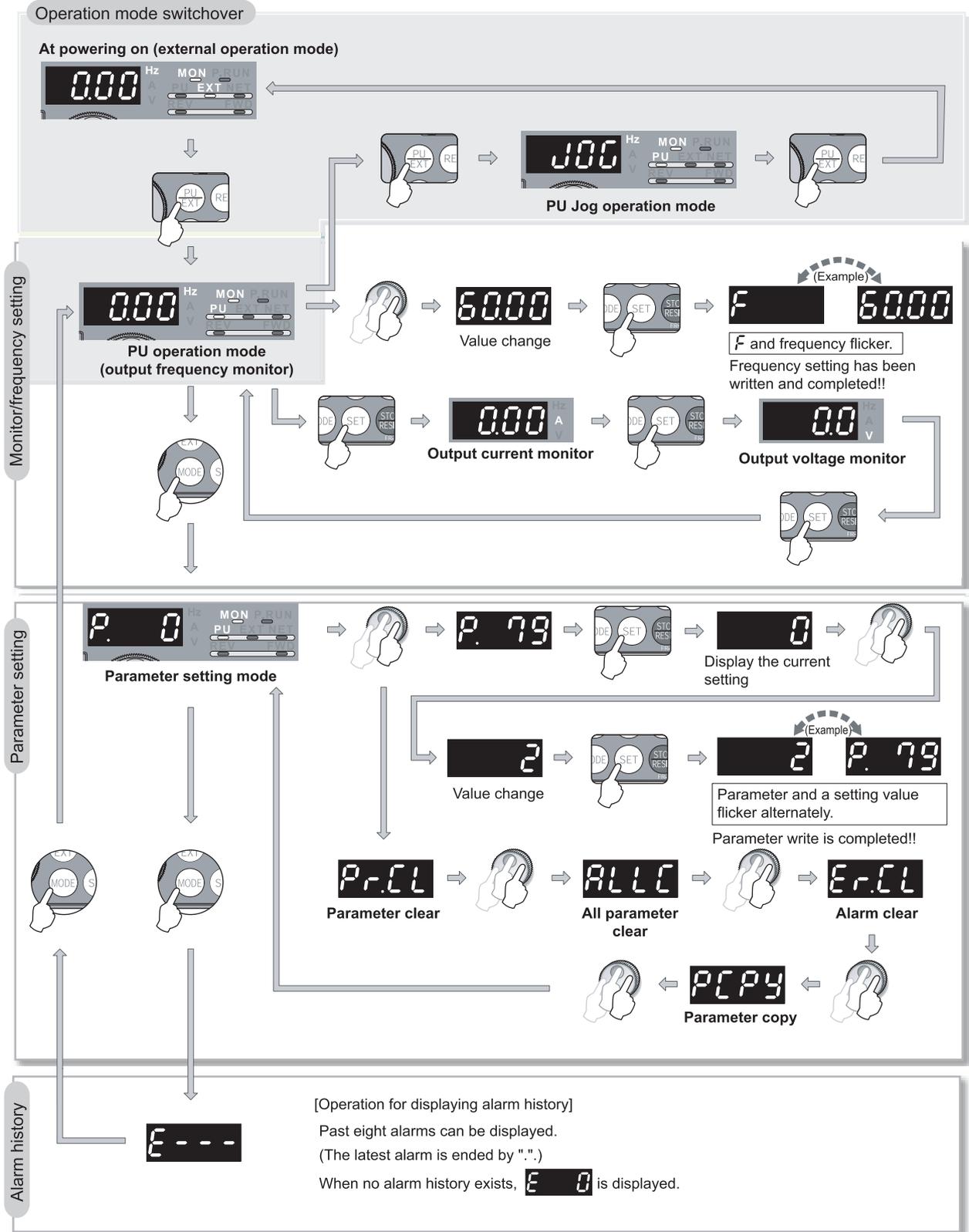
- (1) Set the maximum frequency to 60Hz.
- (2) Set the acceleration/deceleration time to one second or longer.

Technically, frequency can be set higher than 60Hz and acceleration time can be set shorter than 1 second. However, setting those values may damage the machine due to the use of the powder brake, pilot generator (PG) and timing belt.

- (3) Do not leave the demonstration machine for a long time with the 負荷 ON/OFF(Load ON/OFF) switch set to ON and the 負荷設定(Load setting) VR high.

8.8.4 How to use the operation panel FR-DU07

(1) Basic operation



(2) All clear

POINT

- Set "1" in "ALLC parameter clear" to initialize all parameters. (Parameters are not cleared if "1" is set in Pr. 77 "Parameter write selection".)

Operation

Display

1. Screen at powering on
The monitor display appears.



2. Press **PU/EXT** to choose the PU operation mode.



3. Press **MODE** to choose the parameter setting mode.



4. Turn **ROTOR** until "Pr. CL", "ALLC" appears.



5. Press **SET** to read the currently set value.
"0"(initial value) appears.



6. Turn **ROTOR** clockwise to change it to the setting value of "1".



7. Press **SET** to set.



Flicker ... Parameter setting complete!!

- Turn **ROTOR** to read another parameter.
- Press **SET** to show the setting again.
- Press **SET** twice to show the next parameter.

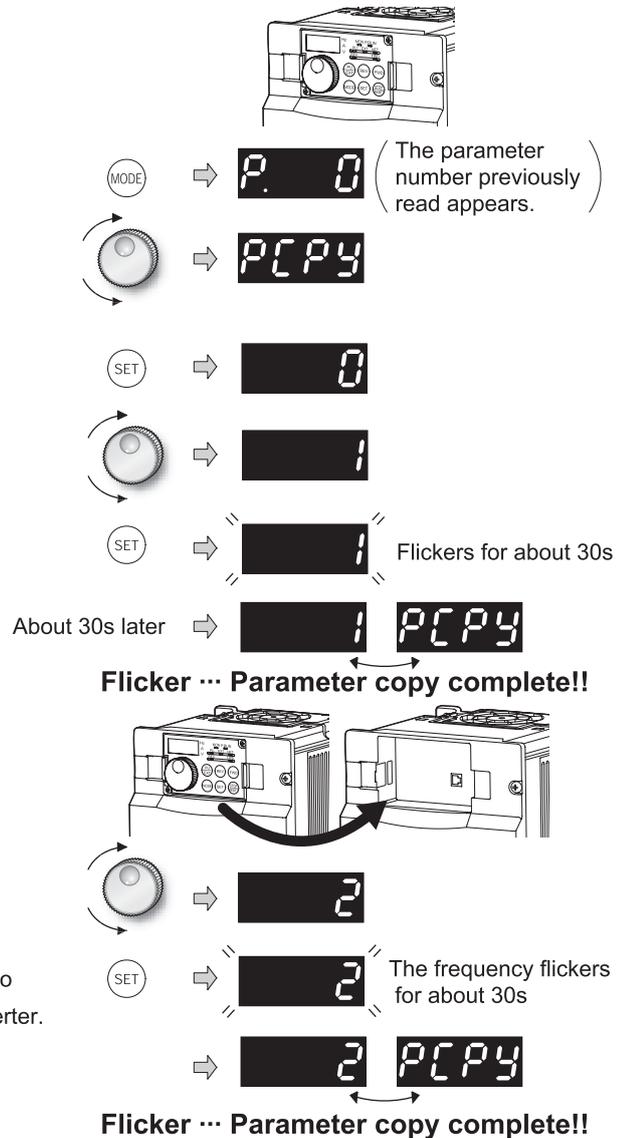
(3) Parameter copy

Parameter settings can be copied to multiple inverters.

Operation

1. Connect the operation panel to the copy source inverter.
 • **Connect it during a stop.**
2. Press **(MODE)** to choose the parameter setting mode.
3. Turn **(◀)** until **PCPY** (parameter copy) appears.
4. Press **(SET)** to read the currently set value.
 "0" (initial value) appears.
5. Turn **(◀)** to change it to the setting value "1".
6. Press **(SET)** to copy the source parameters to the operation panel.
7. Connect the operation panel to the copy source inverter.
8. After performing steps 2 to 5, turn **(◀)** to change it to "2".
9. Press **(SET)** to write the parameters copied to the operation panel to the destination inverter.
10. When copy is completed, "2" and "PCPY" flicker.
11. After writing the parameter values to the copy destination inverter, always reset the inverter, e.g. switch power off once, before starting operation.

Display



(3) Monitor **MON** **READ** **DC Peak V** **READ**

To display the target data before any other data after pressing **MON** , press the **WRITE** key.

(4) Parameter read

PU **PrSET** **Enter the target parameter No.** **READ**
↑ e.g. **9**

(5) Parameter setting change

Overwrite the read parameter value by the target parameter value **WRITE** Completed
↑ e.g. **1.3**

(6) Frequency meter calibration

1) Using the PU, perform operation in 60Hz.

2) **PU** **PrSET** **9** **0** **0** **READ**

3) Press the up-down keys **↑** and **↓** to move the reading of the frequency meter.

Set the reading to the command value (60Hz), and press **WRITE**.

(7) Parameter copy

Setting values of up to three inverters can be copied.

Read parameters from the source inverter.

Example

PU **FUNC** **FRCpy set** **READ** **Copy area1** **READ**

Press the up-down key.

The set parameter value of individual inverters can be copied to each of areas 1, 2, and 3.

Name example: 112 to 223

→ **ヨミダシ** **READ** **112** **↓** **12** **READ** **2↓** **2** **READ** **223** **WRITE** **WRITE**

Up-down key Up-down key Up-down key

Write to the target inverter.

Example

PU **FUNC** **FRCpy set** **READ** **Copy area1** **READ**

Up-down key

Name example

→ **Write VFD** **READ** **223** **WRITE** Reset the inverter

Up-down key

(8) User group function

This function allows only setting-required parameters to be displayed.

Among all parameters, max. 16 parameters can be registered.

Register

Example Example

Pr. 8 5 sec. Register

Delete

 Press the up-down key Press the up-down key

Delete

Confirm registration

Press the up-down key

To display, read and write only registered parameters, preset "1" in Pr. 160.

Pr. 160 1

Parameter numbers displayed change from all parameter numbers to the parameter numbers that are registered in the user group.

To reset this setting, change the set value in Pr. 160 from "1" to "0".

8.8.6 Basic tasks before starting up an inverter

(1) Clear all parameters (when using an inverter that has previously been used)

(2) Check input and output signals (sequence check)

Use the FUNC function of the PU to check that signals are input or output.

PU **FUNC** **Selectop** **READ**

Press the up-down key

(3) Set the basic parameters

Examples:

1) Maximum frequency (Pr. 1)

PU **PrSET** **1** **READ** **6** **0** **WRITE**

2) Electronic thermal O/L relay (Pr. 9)

PU **PrSET** **9** **READ** **1** **.** **3** **WRITE**

3) Frequency setting signal gains (Pr. 125)

PU **PrSET** **125** **READ** **6** **0** **WRITE**

↑ 50 in Tokyo

(4) Calibrate the frequency meter

(5) Select an operation mode

In Pr. 79, select one of the followings: only external operation, only PU operation, both external and PU operations.

(External operation and PU operation can be switched over with factory setting.)

The key here is to select an operation mode after parameters are set for each function.

8.8.7 Operation of inverter (principle-related matter)

(1) Confirming the behavior of inverter DC voltage (V/F control)

Confirm how the DC voltage in the inverter behaves in the following conditions. Use a monitor function to read the values.

Operating condition	DC voltage Vdc (V)	Reference value
1) When an inverter is at a stop		313
2) During operation at 60Hz (without loads)		303
3) During operation at 60Hz (with 100% load)		290

Operation procedure: **PU** **FUNC** **モニタ** **READ** Vdc **READ**

Press the up-down key.

(2) Regenerative overvoltage

Check how the DC voltage behaves in the condition that the motor decelerates to a stop from the speed of 60Hz in the deceleration time of 0.5 seconds. (Display the peak Vdc on the monitor.)

	DC voltage Vdc(V)
1) Without loads	
2) With 100% load	

Operation procedure: **PU** **FUNC** **モニタ** **READ** **DC Peak V** **READ**

Press the up-down key.

After the operation is finished, set the deceleration time back to the original value.

(3) Confirming output voltage (V/F control)

Confirm output voltage with the torque boost (Pr. 0) set to 6%. Use a monitor function to read output voltage.

Check the relation between the logical value and the monitored value **PU** **MON** **SHIFT**

SHIFT **Vモニタ**

Calculated value ... Calculated output voltage value to the output frequency

Monitored value 1)When "9999" is set in Pr. 19

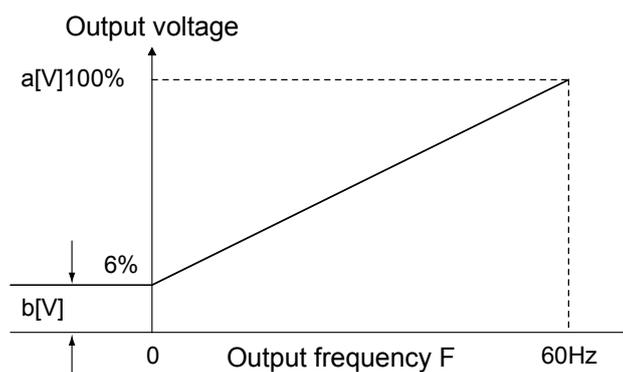
Monitored value 2)When the value of power supply voltage is set in Pr. 19 (output voltage is 200V during operation at 60Hz)

PU **PrSET** **19** **READ** **200** **WRITE**

Output frequency (Hz)	Calculated value V (Monitored value 2))	Monitored value 1) (V)	Monitored value 2) (V)
6			
10			
20			
30			
50			
60			

Logical calculation value

$$V = [(a-b)/60] F + b \text{ (v)}$$



For parameters, refer to the catalog of FREQROL-A700.

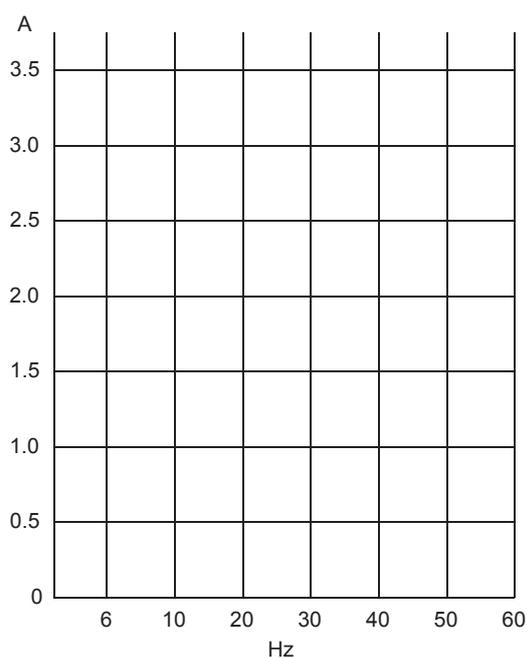
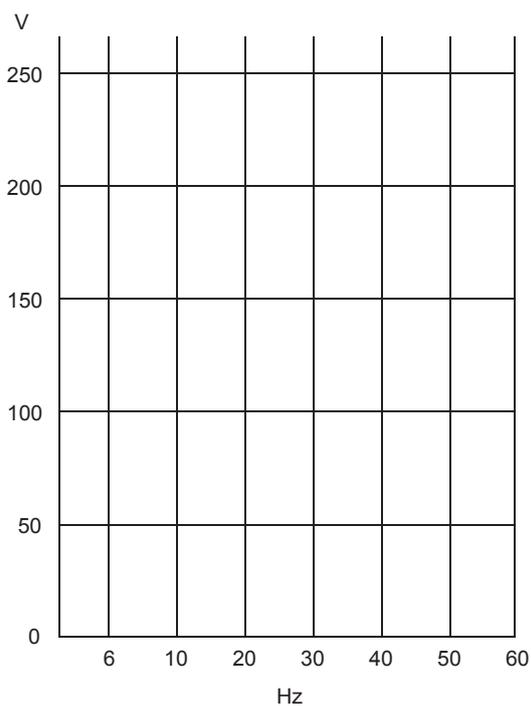
8.8.8 Torque boost function and real sensorless vector function (Confirming operations of V/F control and real sensorless vector control)

(1) Changes in current and voltage in accordance with the V/F control and torque boost setting value
Calculate output current and output voltage when the setting value of the torque boost is changed.

1) Multi-speed operation in various frequencies

Conditions: V/F control Standard torque boost Pr. 14=0 (Rated torque load)

		F(HZ)	6	10	20	30	40	50	60	Abbreviation
No load	Pr0=6	Voltage (V)								V1
		Current (A)								A1
		V/F								
No load	Pr0=30	Voltage (V)								V2
		Current (A)								A2
		V/F								
90% load	Pr0=6	Voltage (V)								V3
		Current (A)								A3
		V/F								
Pr60=4 energy-saving mode										V4
No load	Pr0=6	Voltage (V)								
		Current (A)								A4



2) PU operation at 2Hz

Torque boost setting	Load	Output current (A)	Output voltage (V)
6%	0		
	100		
30%	0		
	100		

<Confirming generated torque>

- 1) Increase the load magnitude with torque boost 6% until the motor stops.
Stop the inverter when the motor stopped.
- 2) Set the torque boost to 30% and start the inverter. Check the motor rotation.
- 3) Increase the load, and confirm the current value of when the motor has stopped.

(2) Real sensorless vector control

- 1) Record the load torque value (percentage of the meter) of when the motor has stopped in the above torque boost 30% operation.
- 2) Perform auto tuning in the real sensorless vector control. (Refer to the following.)
Confirm the followings in the operation of the real sensorless vector control mode.

- Operation frequency 2Hz

Load (%)	Output current (A)	Output voltage (V)	Output frequency (Hz)
0			
100			

<Confirming generated torque>

Provide the motor with the load that stopped the motor in the torque boost 30% operation. Check the motor rotation in this case.

How to perform auto tuning in the real sensorless vector control

1) Parameter setting

- 1) Motor type setting Pr. 71=3 (for a standard motor)
- 2) Motor setting Pr.80=0.4(kW) Pr.81=4(P)
- 3) Control method Pr. 800= 10 (for speed control)
- 4) Torque limit Pr.810=0、 Pr.22=200(%)
- 5) Tuning method setting Pr. 83=200(V), Pr. 84=60(Hz), Pr. 96=101. (tuning with rotation)
Setting "1" in Pr .96 allows tuning without rotation.
- 6) Electronic thermal relay setting Pr.9=1.3(A)

2) Tuning operation

Press **MON**.

- 1) In the PU operation mode, press **FWD** or **REV** to start tuning.

After the tuning completes, the display shows TUNE Completed 103 or 3.

Press **STOP** to terminate the operation.

- 2) In the external operation mode, turn on the forward rotation switch or reverse rotation switch provided on the operation panel.

After completed, turn off the forward rotation switch or reverse rotation switch.

3) Exiting the real sensorless vector control (Returning to the V/F control)

Set "9999" in Pr. 80 and Pr. 81.

For parameters, refer to the catalog of FREQROL-A700.

8.8.9 Inverter-protection-related matter (V/F control)

(1) Electronic thermal relay (motor overheat protection)

1) Operate the electric thermal relay

Set 0.6A in Pr. 9 (electric thermal relay) and perform operation at 6Hz. A trip will occur in 20 to 30 seconds.

Confirm Hz, I and V of when a trip is occurred by pressing **MON** ·· **SHIFT** ·· **SHIFT** .

2) Set "1" in Pr. 76 (alarm code output selection) and make a trip occur.

Check the result. IPF and FU of the demonstration machine turn on. → Set Pr. 76 back to "0" after this exercise.

3) Use the retry function

Set Pr. 67 to three times and Pr. 68 to 5 seconds, and then check a result of pressing **FWD** .
Perform retry.

4) During operation, check the operation status of the electric thermal relay.

Set "10" in Pr. 52 (monitor output signal selection) and press **FWD** .

Check the display status on the monitor.

Hz
A
%
Pu

5) Check the pre-alarm function.

In addition to step 4, set "8" in Pr. 191 (output terminal function selection) and make the lamp SU turn on.

6) Reset signal

The followings are how to enable external reset signals during abnormal operation as well as disable the signals when they are input during normal operation.

- Use the reset switch on the operation panel to use reset signals.
- Confirm that "15" is set in Pr. 75 (reset selection).

After the above exercise, set Pr. 9 (electric thermal relay) back to 1.3A.

(2) Operation of the stall prevention function (V/F control)

Check the operation status at motor start in the condition that 35% is set in Pr. 22 (stall prevention activation level) and 0.5 seconds is set as acceleration time. Rotate the motor with 100% load at 60Hz.

--OL appears on the PR display. Check the motor rotation status.--

After the operation is finished, set the acceleration time back to the original value.

For parameters, refer to the catalog of FREQROL-A700.

8.8.10 Operation-related matter (V/F control)

(1) Confirm how many seconds it takes to reach 30Hz with acceleration time set to 5 seconds.

sec.

Note that the setting of Pr. 20 (acceleration/deceleration reference frequency) is relevant.

(2) Perform multi-speed operation of seven speeds.

Set any, different frequency in Pr. 4 to 6 and Pr. 24 to 27, and perform the operation.

(Note that the demonstration machine does not have terminals for multi-speed operation of 15 speeds.)

Set "1" in Pr. 28 to make auxiliary input variable.

(3) Use the parameter unit (PU) to start a motor (forward or reverse rotation). Adjust the frequency setting potentiometer on the operation panel or set multi-speed operation mode to make frequency settings.

-- Set "4" in Pr. 79 (operation mode selection). --

(4) To make the electric brake activate smoothly, inverter output must be turned off immediately after the start signal is turned off.

Use Pr. 250 (stop selection) to realize this. Perform the following and check the resulting operation.

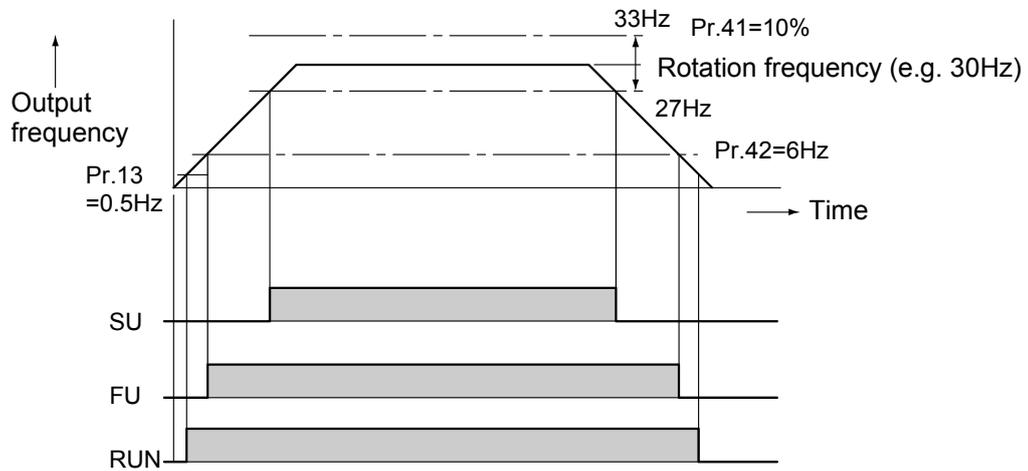
-- Set Pr. 250 to 0.1(S). --

-- Alternatively, set Pr. 250 to 0(S). --

(5) Check the operation of DC control. Set "3" and "10" in Pr. 10, "0.5" and "5" in Pr. 11, and "0" and "4" in Pr. 12.

(6) Check detected output frequency.

Set Pr. 13, 41 and 42.



(7) Change the monitor display and frequency setting to the machine speed.

Example: Change Pr. 37 from "0" to "50" or change Pr. 144 from "4" to "104".

For parameters, refer to the catalog of FREQROL-A700.

8.8.11 Safety-measure-related functions

(1) [Overspeed prevention] by applying a limit to the maximum output frequency

- 1) Check the set value of the maximum frequency setting (Pr. 1).
- 2) Make a gain frequency setting for frequency setting signals (e.g. Pr. 125).
 - Set a gain so that the output frequency is 65Hz when the frequency setting potentiometer is turned to max.

When Pr. 125 is set to 65Hz.

Remark: Gain can be adjusted in C4 (Pr. 903). The parentheses indicate the procedures for the FR-PU07.

Pr. 903 (FR-PU07) 65 Hz

PU **PrSET** **903** **READ** **READ** **6** **5** **WRITE**

Turn the frequency setting potentiometer to max. **WRITE**

C.4 (operation panel FR-DU07)

PU **MODE** P. 0 Turn the dial **C4** **SET** Turn the frequency setting potentiometer to max. **SET**

(2) [Minimum speed guarantee] by applying a limit to the minimum output frequency

- 1) Use the minimum frequency setting (Pr. 2).
 - Check the running frequency when turning the start signal on with the minimum frequency set to 10Hz.
- Set Pr. 7 (acceleration time) to approximately 20 seconds for this exercise.

(3) [Overrun prevention, drop prevention] by the timing that the electromagnetic brake activates

- 1) Output frequency detection (Pr. 42, Pr. 43)
- 2) Brake sequence function (Pr. 278 to 285)

(4) [Incorrect input prevention]

- 1) Reset input selection (Pr. 75)
- 2) Reverse rotation prevention (Pr. 78)

(5) [Misoperation prevention]

- 1) Disconnected PU detection, PU stop selection (Pr. 75)
- 2) PU operation interlock, operation mode external signal switching (Pr. 79)
 - Set "0" in Pr.76 and Pr.191 so that the lamp SU turns on during PU operation. (RUN function assignment)

(6) [Resonance operation prevention]

1) Frequency jump (Pr. 31 to 36)

(7) [Automatic restart after instantaneous power failure]

Set "0" in Pr. 57 and Pr. 162, and "6" in Pr. 183.

Turn on the second acceleration/deceleration (CS function) switch.

Set the operation mode to the external operation mode, and make an instantaneous power failure occur.

For parameters, refer to the catalog of FREQROL-A700.

8.8.12 Life check of inverter parts (FREQROL-A700)

(1) Measuring a capacity of the main circuit capacitor and displaying a service life

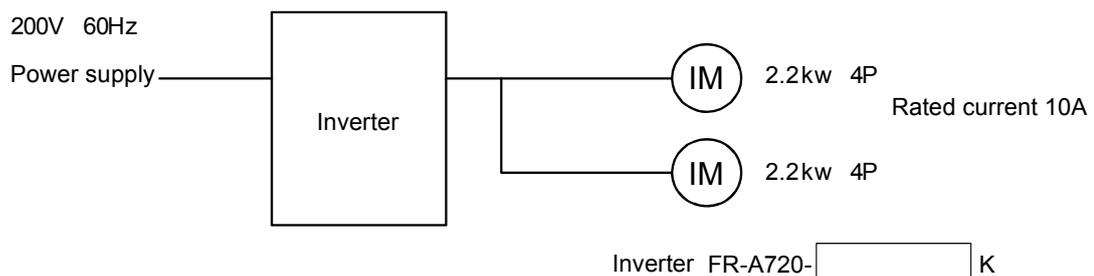
1. Confirm that the motor is connected and at a stop.
2. Set "1" in Pr. 259.
3. Turn off the power supply. Measure a capacity of the capacitor at this time.
4. Confirm that the POWER lamp has been turned off, and then turn the power supply on again.
5. Confirm that "3" (measurement completion) is set in Pr. 259, and then confirm Pr. 258 for life display.

(2) Confirm Pr. 256 for life display of the inrush current control circuit and Pr. 257 for life display of the control circuit capacitor.

For parameters, refer to the catalog of FREQROL-A700 series.

8.8.13 Selection-related matter

(1) Select the inverter capacity most suitable for the parallel operation shown below.



(Note) The rated motor current is 10A.

INVERTER SCHOOL TEXT

INVERTER PRACTICAL COURSE

MODEL	
MODEL CODE	1A2P21
SH(NA)-060012ENG-A(0609)MEE	

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When exported from Japan, this manual does not require application to the Ministry of Economy, Trade and Industry for service transaction permission.

Specifications subject to change without notice.