TOSHIBA

E6581182⑩

Inverter application manual

About Selecting Capacity of Inverter

－Contents－

1. Selecting the capacity of the inverter

To drive a motor by the inverter, it should be important to select a proper capacity of a motor before selecting the capacity of the inverter.
When selecting the capacity of the inverter, each of items below will be converted into a numerical value to judge validity.

- Sufficient starting torque can be obtained?
- Acceleration can be attained within a specified time of period?
- Deceleration can be attained within a specified time of period?

1.1 Calculation equations for selecting the capacity of the inverter

The inertia at motor shaft J (GD^2) is required to calculate the capacity of the inverter. Note)
Use J (GD^2) to obtain necessary acceleration torque, steady-state torque, and deceleration torque.

In paragraph 1.1.1, select the inverter for the specified capacity of a motor and obtain minimum acceleration and deceleration times.
In paragraph 1.1.2, calculate a braking resistance capacity to shorten the deceleration time.

Matters to be attended:
When a three-phase induction motor is driven through commercial power supply, it is generally possible to output the starting torque at approximately 300% of the torque. In the inverter with the same capacity as above, however, it generally output the starting torque at 150 to 200 % of the torque for protection of a machine. Therefore, the applications below may require the capacity of the inverter or the capacities of both the inverter and motor to be increased.

- In the case that the starting torque 150% or more is required based on the motor selected
- In the case that the starting current exceeds the rated current of overload protection of the inverter (for example, 150% for 1 minutes and 165% for 2 seconds for VFAS1).
- In the case that an excessive short time is required for acceleration

Note): Use only either of SI system of units and MKS system of units for calculation.

Table 1. Conversion ratio of systems of units

Items	SI system of units	MKS system of units
Rotating speed	Rotating speed (min^{-1})	Rotating speed (rpm)
Torque	9.8 (N・m) [SI system of units = 9.8 × MKS system of units]	1 (kgf・m)
Inertia	$J=1/4GD^2$ ($kg・m^2$)	GD^2 ($kgf・m^2$)

1.1.1 Calculating acceleration and deceleration times

a) Acceleration time

The equation below t_a is generally used for the acceleration time of a motor. The acceleration time of the inverter ACC should be set longer than t_a.

Acceleration time $t_b = \frac{(J_M + J_L) + \Delta N}{9.549 \times (\alpha \times T_M - T_L)}$ (second): SI system of units

J_M : Inertia of motor (kg·m^2)
J_L : Inertia of load (converted into value at motor shaft) (kg·m^2)
ΔN : Difference of speed between before and after acceleration and deceleration (min^{-1})
T_L : Load torque (N·m)
T_M : Rated torque of motor (N·m)
α : 1.2 to 1.5 for V/f constant control, 1.5 to 2.0 for vector control: Note 1

Note 1:
α is the maximum momentary torque of inverter.
Example of maximum value of α:

Series/capacity	V/f constant control	Vector control
VF-nC3/nC1	1.2~1.5	1.5~2.0
VF-S15/S11/S9	1.2~1.5	1.5~2.0
VF-FS1	1.1	-
VF-AS1	1.2~1.5	1.5~2.0
VF-PS1	1.2	1.5
Small or middle capacity of VF-A7	1.2~1.5	1.5~2.0
Large capacity of VF-A7	1.2~1.5	1.5~1.8
Middle capacity of VF-P7	1.2	1.5
Large capacity of VF-P7	1.2	1.5

* Limited to an optimum setting of operation conditions
Normally use 1.2 for V/f constant control and 1.5 for vector control for calculation.

Acceleration time $t_b = \frac{(GD^2{}_M + GD^2{}_L) \times \Delta N}{375 \times (\alpha \times T_M - T_L)}$ (second)

$GD^2{}_M$: Inertia of motor (kgf·m^2)
$GD^2{}_L$: Inertia of load (converted into value at motor shaft) (kgf·m^2)
ΔN : Difference of speed between before and after acceleration and deceleration (min^{-1})
T_L : Load torque (kgf·m)
T_M : Rated torque of motor (kgf·m)
α : 1.2 to 1.5 for V/f constant control, 1.5 to 2.0 for vector control: Note 1

...... MKS system of units

* For the information on the rated torque of motor, refer to "Appendix 1. Data of motor."

Load torque $T_L = \frac{9549 \times P_L}{N}$ (N·m) .... SI system of units
Shaft power : P_L (kW)
Speed of motor : N (min^{-1})

Load torque $T_L = \frac{975 \times P_L}{N}$ (kgf·m)
Shaft power : P_L (kW)
Speed of motor : N (rpm)

...... MKS system of units

If t_a<0 in the result of equation above, the capacity of the motor is insufficient.
If t_a is desired to shorten, it is necessary to increase the capacity of motor (at the same time, it is necessary to increase the capacity of the inverter).

Matter to be attended:
If the acceleration time of the inverter is set shorter than that of motor t_a, the stall prevention function or over-current protection of the inverter may operate.

Reference

The below shows the machines which generally have relatively large J and small J

Machines with large J	Machines with small J
Fan, blower (turbo), centrifugal separator, high-speed conveyer (30 to 50 m/sec. or more as a standard), crusher, press, and mixer	Pump, low-speed conveyer (5m/sec. or less as a standard)

b) Deceleration time

The equation below t_b is generally used for the deceleration time of a motor. The deceleration time of the inverter DEC should be set longer than t_b.

Deceleration time $t_b = \dfrac{(J_M + J_L) + \Delta N}{9.549 \times (\beta \times T_M + T_L)}$ (second) ･･･SI system of units

J_M : Inertia of motor ($kg \cdot m^2$)
J_L : Inertia of load (converted into value at motor shaft) ($kg \cdot m^2$)
ΔN : Difference of speed between before and after acceleration and deceleration (min^{-1})
T_L : Load torque ($N \cdot m$)
T_M : Rated torque of motor ($N \cdot m$)
β : In case of a braking resistor not used: 0.1 to 0.3 Note 2
In case of a standard-optional braking resistor used: 0.8
In case of a braking resistor with a minimum allowable resistance used: 0.8 to 1.5

Note 2:
Braking capacity only by the inverter (not using a braking resistor) depends on inverter's capacity.

Inverter capacity	**β**
0.1~3.7kW	**0.3～0.2**
5.5~55kW	**0.15～0.1**
75kW~	**0.1**

If the braking resistor with a minimum allowable resistance is used, normally set β coefficient to 1.0.

Deceleration time $t_b = \dfrac{(GD^2{}_M + GD^2{}_L) \times \Delta N}{375 \times (\beta \times T_M + T_L)}$ (second)

$GD^2{}_M$: Inertia of motor ($kgf \cdot m^2$)
$GD^2{}_L$: Inertia of load (converted into value at motor shaft) ($kgf \cdot m^2$)
ΔN : Difference of speed between before and after acceleration and deceleration (rpm)
T_L : Load torque ($kgf \cdot m$)
T_M : Rated torque of motor ($kgf \cdot m$)
β : In case of a braking resistor not used: 0.1 to 0.3 Note 2
In case of a standard-optional braking resistor used: 0.8
In case of a braking resistor with a minimum allowable resistance used: 0.8 to 1.5

…… MKS system of units

Matters to be attended

If the deceleration time of the inverter is set shorter than that of motor t_b, an actual deceleration time may be longer than the deceleration time t_b obtained by the equation above or over-voltage protection may operate.

If the motor is desired to stop in a shorter time than the deceleration time t_b obtained by the equation above, connect the optional braking resistor to the inverter to stop with power-generated braking.
(For the information on selection of braking resistors, refer to paragraphs below.)

1.1.2 Selecting braking resistors

When a large deceleration torque is required because of large inertia of load, the braking unit/braking resistor unit can be used to radiate regenerative energy.

The braking torque when using a standard optional braking resistor is approximate 80% of the rated torque.
The braking torque when using a braking resistor with a minimum allowable resistance is 80 to 150% of the rated torque (see appendix 4).
* In case of the braking resistor not used:

Inverter capacity	braking torque
0.1~3.7kW	30%~20%
5.5~55kW	15%~10%
75kW~	10%

The equation below shows the calculation of the capacity of braking resistor. (The equation is for selecting the capacity of the braking resistor for deceleration.)

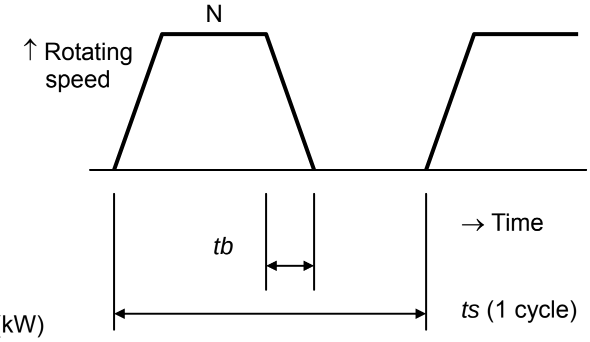


Figure. Operation cycles

T_b = Deceleration torque (N·m)
T_L = Load torque (N·m)
η = Machine efficiency
N_1 = Speed before deceleration (min^{-1})
N_2 = Speed after deceleration (min^{-1})

Required deceleration torque $T_B = T_b - \eta \times T_L (N \cdot m)$

Regenerative electric power $P_B = \frac{T_B \times (N_1 + N_2)}{9549} \times \frac{1}{2}$ (kW)

Average regenerative electric power $\overline{P_B} = P_B \times \%ED$ (kW)

$(\%ED = \frac{tb}{ts})$

Resistance $R \leq \frac{(Vdc)^2}{0.105 \times T_B * (N_1 - N_2)} \times \frac{1}{1.2}$ Note 3)

Vdc = 360V for 200V system, 720V for 400V system

The capacity of the braking resistor P_R (kW) is selected so that $P_R > \overline{P_B}$ and $P_R > P_B / 5$ (note)
When selecting the resistor, de-rate the selection above to about 1.5 times.
If the capacity of the resistor of the standard braking unit is insufficient in the calculation above, it is required to increase the capacity of the resistor. In that case, change only the capacity of the resistor not the value of it.
(note): "5" is resistor's rating for short time.
5: PBR series, 10: DGP series
In case of using your own selected resistor, please confirm this to resistor's supplier.

MKS system of units:

T_b = Deceleration torque (kgf·m)
T_L = Load torque (kgf·m)
η = Machine efficiency
N_1 = Speed before deceleration (rpm)
N_2 = Speed after deceleration (rpm)

Required deceleration torque $T_B = T_b - \eta \times T_L$ (kgf·m)

Regenerative electric power $P_B = \frac{T_B \times (N_1 + N_2)}{975} \times \frac{1}{2}$ (kW)

Average regenerative electric power $\overline{P_B} = P_B \times \%ED$ (kW)

$(\%ED = \frac{tb}{ts})$

Resistance $R \leq \frac{(Vdc)^2}{1.027 \times T_B * (N_1 - N_2)} \times \frac{1}{1.2}$ Note 3)

Vdc = 360V for 200V system, 720V for 400V system

Note 3:
The resistance of the braking resistor to be selected should be a minimum allowable resistance or more (see appendix 4).

1.2 Selection procedure for the inverter capacity

When selecting the inverter capacity, follow the procedure below to confirm that each value satisfies the specifications of the motor and inverter applicable.

Items to be calculated:

a. Load torque
b. Inertia
c. Acceleration torque
d. Deceleration torque (Selecting the braking resistor: paragraph 1.1.2)

1.2.1 Confirming the load torque and motor capacity

Temporarily select the motor capacity using a load torque.
(If the motor capacity has been decided, confirm the rated torque of motor > load torque converted into a value at a motor shaft.

Load torque at a motor shaft $(T_L) < \frac{9549 \times P_M}{N}$ (N·m) ·································· SI system of units

Temporarily selected motor capacity $(P_M) > \frac{T_L \times N}{9549}$ (kW)

P_M : Rated output of motor (kW)
N : Rated speed of motor (min^{-1})
T_L : Load torque $\times \frac{N_L}{N_M}$ (N·m)

N_L : Speed at load side
N_M : Speed at motor side

Load torque at a motor shaft $(T_L) < \frac{975 \times P_M}{N}$ (kgf·m)

Temporarily selected motor capacity $(P_M) > \frac{T_L \times N}{975}$ (kW) ······MKS system of units

P_M : Rated output of motor (kW)
N : Rated speed of motor (rpm)
T_L : Load torque $\times \frac{N_L}{N_M}$ (kgf·m)

N_L : Speed at load side
N_M : Speed at motor side

*** If the equation is not satisfied, the motor capacity is insufficient.**

1.2.2 Confirming the inertia

The inertia can be obtained by “the inertia of motor (J_M) + the inertia of load at the motor shaft (J_L).”
Note: If a load device is directly connected to the motor shaft, the conversion into the value on the shaft is not required.

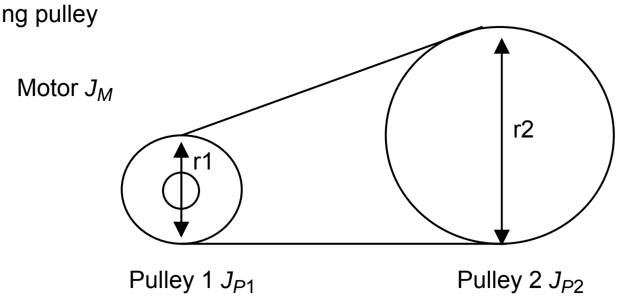
If the motor is driven through commercial power supply, it is generally necessary that “all moments of inertia < motor allowance J (see appendix 1).” However, in the case of the inverter driven, acceleration and deceleration is enabled by setting the acceleration and deceleration times considerably long.

Method of conversion into a value at motor shaft:

Conversion into a value at motor shaft $J = \left(\frac{N_L}{N_M}\right)^2 \times J_L = \left(\frac{r1}{r2}\right)^2 \times J_L$ [kg·m²]

J_L : Load J
N_L : Speed on the load side
N_M : Speed on the motor
r1 : Diameter of pulley on the motor side
r2 : Diameter of pulley on the load side

Ex. in case of using pulley



$$\text{Inertia} = J_M + J_{P1} + \left(\frac{N_L}{N_M}\right)^2 \times J_{P2}$$

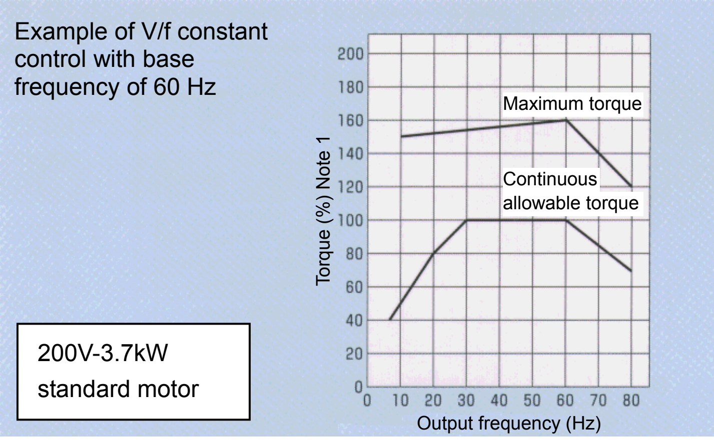
$$= J_M + J_{P1} + \left(\frac{r1}{r2}\right)^2 \times J_{P2} \quad [\text{kg·m}^2]$$

1.2.3 Confirming the acceleration torque

In the case of inverter driven, a maximum momentary torque should be as follows:

- V/f constant control: approx. 120 to 150%
- Vector control without sensor: approx. 150 to 200%············Note 1)

Note 1:
The maximum momentary torque varies depending on the series and capacity of the inverter.



Therefore, **if the acceleration time is specified**, the result of the equation below should be the rated torque of the motor or less.

Rated torque of motor $(N \cdot m) \geq \left(\frac{\Sigma J \times N}{9.549 \times ta} + T_L \right) \times \frac{1}{\alpha}$ SI system of units

ΣJ : Inertia (conversion into value at motor shaft) ($kg \cdot m^2$)
N : Speed (min^{-1})
ta : Acceleration time (sec)
T_L : Load torque at the motor shaft (N·m)
α : Coefficient (1.2 to 1.5 for V/f constant control, 1.5 to 2.0 for vector control)

Rated torque of motor $(kgf \cdot m) \geq \left(\frac{\Sigma GD^2 \times N}{375 \times ta} + T_L \right) \times \frac{1}{\alpha}$

ΣGD^2 : Inertia (conversion into value at motor shaft) ($kgf \cdot m^2$)
N : Speed (rpm)
ta : Acceleration time (sec)
T_L : Load torque at the motor shaft (kgf·m)
α : Coefficient (1.2 to 1.5 for V/f constant control, 1.5 to 2.0 for vector control)

······ MKS system of units

*** If the equation above is not satisfied, the motor capacity is insufficient or the acceleration time is too short.**

1.2.4 Confirming the deceleration torque

The deceleration (braking) torque driven by the inverter is as follows:

- In case of only inverter used……

inverter capacity	braking torque
0.1~3.7kW	30%~20%
5.5~55kW	15%~10%
75kW~	10%

- In case of using a standard optional braking resistor: 80% of torque
- In case of using a resistor with a minimum allowable resistance: 80 to 150% of torque (For the information on the maximum deceleration torque (β coefficient), see appendix 4.)

Therefore, **if the deceleration time is specified**, the result of the equation below should be the rated torque of the motor or less.

Rated torque of motor $(N\cdot m) \geq \left(\frac{\Sigma J \times N}{9.549 \times tb} - T_L \right) \times \frac{1}{\beta}$ SI system of units

ΣJ : Inertia (conversion into value at motor shaft) ($kg\cdot m^2$)
N : Speed (min^{-1})
tb : Acceleration time (sec)
T_L : Load torque at the motor shaft (N·m)
β : coefficient
Only inverter: 0.1 to 0.3
Standard optional braking resistor: 0.8
Resistor with minimum allowable resistance: 0.8 to 1.5

Rated torque of motor $(kgf\cdot m) \geq \left(\frac{\Sigma GD^2 \times N}{375 \times tb} - T_L \right) \times \frac{1}{\beta}$

ΣJ : Inertia (conversion into value at motor shaft) ($kgf\cdot m^2$)
N : Speed (rpm)
tb : Acceleration time (sec)
T_L : Load torque at the motor shaft (kgf·m)
Only inverter: 0.1 to 0.3
Standard optional braking resistor: 0.8
Resistor with minimum allowable resistance: 0.8 to 1.5

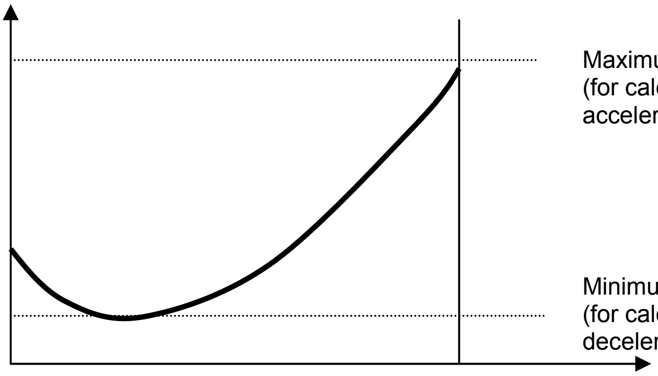
……MKS system of units

* If the braking resistor is used, follow paragraph 1.1.2 to calculate the capacity of the braking resistor.

*** If the equation above is not satisfied, the motor capacity is insufficient or the deceleration time is too short.**

Matters to be attended

For a lower load torque, refer to the torque characteristics graphic chart below to use the minimum load torque for T_L and calculate it.



* If only the maximum load torque at 100% speed is known, use the load torque calculated by the equation below:

$$T_L acc = N^X \times T_L$$

$T_L$acc : Load torque to calculate the acceleration time (if J exceeds the motor allowable J, $T_L acc = T_L$)
N : Ratio of speed for actual usage (Ex.: 30Hz/60Hz=0.5 for 30Hz)
X : Decrease ratio (2 for the square reduction torque load)

$$T_L dec = N^X \times T_L$$

$T_L$dec : Load torque to calculate the acceleration time
N : Ratio of speed for actual usage (Ex.: 30Hz/60Hz=0.5 for 30Hz)
X : Decrease ratio (2 for the square reduction torque load)

1.2.5 In case of the short-time acceleration/deceleration or starting torque of 150 % or more

If the short-time acceleration torque or starting torque of 150% or more is required, there is a case where only the capacity of the inverter is increased to meet the requirement.
In paragraph 1.2.3 or 1.2.4, increase only the rated torque of motor by one frame (in the inverter capacity group, large capacity by one) and confirm each item.

Ex.:
In case of that the motor decided in paragraph 1.2.1 and 1.2.2 is 2.2 kW
↓
Use the rated torque of the 3.7 kW motor for the left side (motor rated torque) of paragraph 1.2.3 and 1.2.4.

$$T_M up = T_M \times \frac{P_R up}{P_R} \quad (N{\cdot}m)$$

T_M up : Motor rated torque upper by one frame
P_R up : Motor capacity upper by one frame
However, the load torque in a regular operation should be within the rated torques of the motor actually used.

1.2.6 Calculation of the minimum acceleration/deceleration times

The minimum acceleration/deceleration times will be obtained with the below used in the previous paragraph:

- Motor J (J_M, $GD^2{}_M$)
- Load J at the motor shaft (J_L, $GD^2{}_L$)
- Motor rated torque (T_M)
- Difference between revolutions (ΔN)
- Load torque at the motor shaft (T_L)

(Use the value or more calculated by the equation below for the setting of acceleration/deceleration times of the inverter.)

Setting of acceleration time:

If a smaller value than the calculated minimum acceleration time is set, an over-current protection or over-current stall prevention may operate.

Setting of deceleration time:

If a smaller value than the calculated minimum deceleration time is set, an over-voltage protection or over-voltage stall protection may operate.

Minimum acceleration time $t_a = \dfrac{(J_M + J_L) \times \Delta N}{9.549 \times (a \times T_M - T_L)}$ SI system of units

a : Coefficient

V/f constant control: 1.2 to 1.5

Vector control: 1.5 to 2.0

(Minimum acceleration time $ta = \dfrac{(GD^2{}_M + GD^2{}_L) \times \Delta N}{375 \times (a \times T_M - T_L)}$) ··· MKS system of units

Minimum deceleration time $t_a = \dfrac{(J_M + J_L) \times \Delta N}{9.549 \times (b \times T_M + T_L)}$ SI system of units

b : Coefficient

Only inverter: 0.1 to 0.3

Standard optional braking resistor: 0.8

Resistor with minimum allowable resistance: 0.8 to 1.5

(Minimum deceleration time $ta = \dfrac{(GD^2{}_M + GD^2{}_L) \times \Delta N}{375 \times (b \times T_M + T_L)}$) ··· MKS system of units

* If only the capacity of the inverter is increased by one frame, use the rated torque of the motor increased by one frame for T_M.

1.2.7 Selecting the inverter

After confirming all the paragraphs 1.2.1 to 1.2.5, select the inverter.

Items necessary for selecting the inverter:

Input voltage of inverter
Number of input phases of inverter
Voltage driving motor
Motor capacity (used for the calculation in paragraphs 1.2.1 to 1.2.5)

Inverter type:

Ex. VFS15S-2022PL

VF	S15	S	-	2	022	P	L
	Series names AS1: For high-performance PS1: For fan and pump A7: For high-performance P7: For fan and pump S15:For general-purpose or small size S11:For general-purpose or small size S9: For general-purpose or small size nC3, nC1: Ultra small size FS1: for HVAC	**Number of input phases** -: Three-phase S:Single-phase Note 1:		**Input voltage** 1: 100V input 2: 200V input 4: 400V input Note 1:	**Inverter capacity** 001: 0.1kW 002: 0.2 kW 004: 0.4 kW 005: 0.55 kW 007: 0.75 kW 015: 1.5 kW 022: 2.2 kW 037: 3.7kW 055: 5.5 kW 075: 7.5 kW 110: 11 kW 150: 15 kW 185: 18.5 kW 220: 22 kW 300: 30 kW 370: 37 kW 450: 45 kW 550: 55 kW 750: 75 kW 900: 90 kW 110K: 110 kW 132K: 132 kW 160K: 160 kW 200K: 200 kW 220K: 220 kW 250K: 250kW 280K: 280 kW 315K: 315kW 400K: 400kW 500K: 500kW 630K: 630kW Note 1:	**Operation panel** P: with panel P1: with panel * VFA7-37kW or more	**Additional function** -: M: Built-in standard filter L: Built-in EMC filter C: Built-in EMC filter Note 1:

Matters to be attended

- Some inverter series may not have a part of classes.
- If the braking resistor is required, select it in paragraph 1.1.2.
- The braking resistor cannot be used with VF-FS1, VF-nC3, and VF-nC1.

1.3 Example of calculating the capacity (fans)

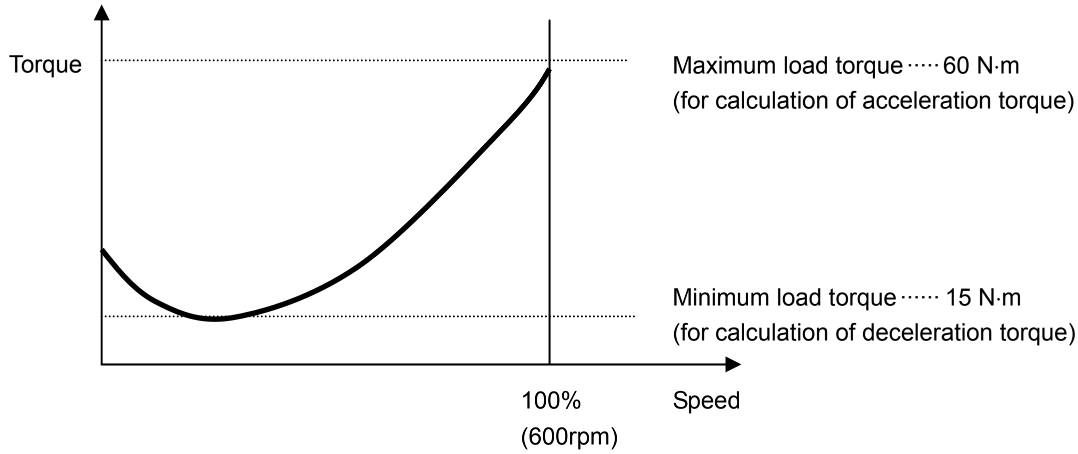
The acceleration/deceleration times are calculated for the case where the fan is driven under the conditions below. (The example uses SI system of units for calculation.)

Fan specification:

Motor capacity: 400V-3, 7kW-4P-60Hz

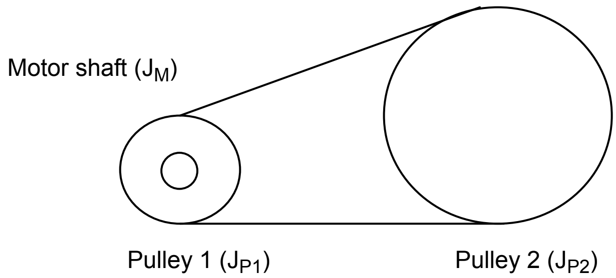
Synchronized speed: 120 × 60Hz / 4 = 1800 [min^{-1}]
Motor J: 0.015 kg·m^2
Rated torque of motor: 3.7kW ∗ 9549 / 1710 min^{-1} = 20.7 [N・m]

Fan torque characteristics:



Inertia:

Inertia of load: 15 kg·m^2
Pulley 1: 0.5 kg·m^2
Pulley 2: 2.5 kg·m^2



Each item will be calculated based on the conditions on the previous page.

1. Torque at the motor shaft (maximum) $= 60N \cdot m \times \frac{600\,min^{-1}}{1800\,min^{-1}} = 20[N \cdot m] < 20.7$

2. Torque at the motor shaft (minimum) $= 15N \cdot m \times \frac{600\,min^{-1}}{1800\,min^{-1}} = 5[N \cdot m] < 20.7$

3. Inertia $0.015kg \cdot m^2 + 0.5kg \cdot m^2 + \left(\frac{600min^{-1}}{1800min^{-1}}\right) \times (2.5kg \cdot m^2 + 15kg \cdot m^2) = 2.46[kg \cdot m^2]$

The minimum acceleration/deceleration times are as follows:

Minimum acceleration time $= \frac{2.46kg \cdot m^2 \times 1800\,min^{-1}}{9.549 \times (1.2 \times 20.7N \cdot m - 20N \cdot m)} = 95.8[sec]$ for V/f constant control

Minimum acceleration time $= \frac{2.46kg \cdot m^2 \times 1800\,min^{-1}}{9.549 \times (1.5 \times 20.7N \cdot m - 20N \cdot m)} = 42.0[sec]$ for vector control

Minimum deceleration time $= \frac{2.46kg \cdot m^2 \times 1800\,min^{-1}}{9.549 \times (0.2 \times 20.7N \cdot m + 5N \cdot m)} = 50.7[sec]$ for only inverter

Minimum deceleration time $= \frac{2.46kg \cdot m^2 \times 1800\,min^{-1}}{9.549 \times (0.8 \times 20.7N \cdot m + 5N \cdot m)} = 21.5[sec]$ for standard optional braking resistor

Minimum deceleration time $= \frac{2.46kg \cdot m^2 \times 1800\,min^{-1}}{9.549 \times (0.2 \times 20.7N \cdot m + 5N \cdot m)} = 18.0[sec]$ for resistor with minimum allowable resistance

In case of using the braking resistor (resistor with minimum allowable resistance):

Deceleration torque $= \left(\frac{J \times N}{9.549 \times tb}\right) = \frac{2.46kg \cdot m^2 \times 1800\,min^{-1}}{9.549 \times 18\,sec} = 25.7[N \cdot m]$

Deceleration torque required $T_B = T_b - \eta \times T_L = 25.7N \cdot m - 0.95 \times 5N \cdot m = 20.95[N \cdot m]$

Regenerative electric power $P_B = \frac{T_B \times (N_1 + N_2)}{9549} \times \frac{1}{2} = \frac{20.95N \cdot m \times 1800\,min^{-1}}{9549} \times \frac{1}{2} = 1.975(kW)$

Average regenerative electric power $\overline{P_B} = P_B \times \%ED = 1.975 \times 0.1 = 0.198[kW]$

$\left(\%ED = \frac{tb}{ts} = 0.1\right)$ · If the operation cycle is long enough

Capacity of selected braking resistor $> \overline{P_B} = 0.198[kW]$

and

Capacity of selected braking resistor $> P_B/5 = 0.395[kW]$

Resistance $\leq \frac{(720)^2}{0.105 \times T_B * N} \times \frac{1}{1.2} = 109.1[\Omega]$

Using above, the braking resistor below is selected:

- Capacity of braking resistor: 0.395 kW or more
- Resistance: minimum allowable resistance or more，109.1 Ω or less
  Minimum allowable resistance of VFAS1 – 4037PL : 40Ω
  Minimum allowable resistance of VFS15 – 4037PL : 54Ω

2. Selecting the capacity of motor

This chapter describes various equations used for “selecting the capacity of motor” which is the base for selecting the capacity of the inverter.

2.1 Formulas for motor

1. Calculation of speed of motor

   Synchronized speed $N_S = \frac{120 \times f}{P}$ (min^{-1}), (rpm)

   f : Frequency of power supply (Hz)

   p : Pole pair number

   Speed for full load $N = N_S$ (1-S) (min^{-1}), (rpm)

   S : Slip (%)

2. Calculation of torque

   Torque for full load $T = \frac{9549 \times P_{IM}}{N}$ (N·m)·SI system of units

   Torque for full load $T = \frac{975 \times P_{IM}}{N}$ (kg·m)··MKS system of units

   P_{IM} : Motor capacity (kW)

3. Calculation of output

   Output $PIM = \frac{T \times N}{9549}$ (kW)···· SI system of units

   Output $PIM = \frac{T \times N}{975}$ (kW)···· MKS system of units

4. Calculation of stating time

   Starting time $t = \frac{\sum J \times N}{9.549 \times T_a}$ (second)·SI system of units

   T_a : Acceleration torque = (Motor-generated torque) – (load torque) (N·m)

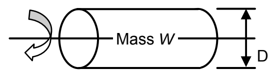
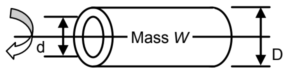
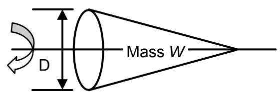
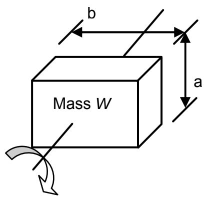
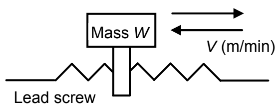
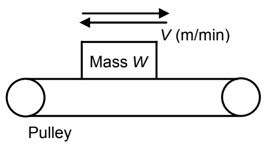
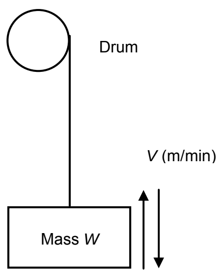
   $\sum J$: Inertia (motor J + load J (converted into the value at motor shaft))

   Starting time $t = \frac{\sum GD^2 \times N}{375}$ (second)····MKS system of units

   T_a : Acceleration torque = (Motor-generated torque) – (load torque) (kgf·m)

   $\sum GD^2$: Inertia (motor GD^2 + load GD^2 (converted into the value at motor shaft))

2.2 J equations

Shapes		Equations	Remarks
Column		$J = \frac{WD^2}{8}$ $(kg \cdot m^2)$	(1) W = Mass of object (kg) The unit of each dimension of A, b, d, and D is metric (m). (2) J is the value at the rotation shaft shown in figure. If it is converted into the value at the motor shaft, use below: $J_L = \left(\frac{N_L}{N_M}\right)^2 \times J$ $(kg \cdot m^2)$
Hollow column		$J = \frac{W(D^2 + d^2)}{8}$ $(kg \cdot m^2)$	
Cone		$J = \frac{3WD^2}{40}$ $(kg \cdot m^2)$	
Cube		$J = \frac{W(a^2 + b^2)}{12}$ $(kg \cdot m^2)$	
Straight-line motion, general	When an object with a mass of W moves in a straight line at a speed of V (m/min), the rotating speed of the motor to move it shall be N_M (min^{-1}).	$J = \frac{W}{4}\left(\frac{V}{\pi N_M}\right)^2$ $(kg \cdot m^2)$	(1) W = Mass of object (kg) V = Speed of straight-line motion (m/min) N_M = Speed of motor (min^{-1}) π = Ratio of the circumference of a circle to its diameter (3.14) (2) J is the value at the motor shaft. (3) The objects such as lead screw, pulley, belt, and drum do not include J other than W.
Straight-line motion, lead screw			
Straight-line motion, belt conveyer			
Straight-line motion, crane or winch			

2.3 Equations of kW necessary for motor

Crane

a. Wind up

$$\text{Necessary kW} = \frac{W \cdot V}{6.12 \times \eta}$$

W : Total mass of winding-up part (load + mass of hook rope) (ton)
V : Winding-up speed (m/min)
η : Machine efficiency
Rough estimate:
Speed reduction by one stage of gear: 0.95 to 0.85
Speed reduction by two stages of gear: 0.9 to 0.7
Speed reduction by one stage of worm gear: 0.5

b. Sliding or traveling

$$\text{Necessary kW} = \frac{K \cdot (W + W_1) \cdot V}{6.12 \times \eta \times 1000}$$

W : Total mass of winding-up part (ton)
W_1 : Trolley mass for sliding, Own weight of crane for traveling (ton)
V : Speed (m/min)
K : Traveling resistance
In a ceiling crane
For roller bearing: 7kg/ton
For sleeve bearing: 12kg/ton
η : Machine efficiency (Same for wind up)

Winding machine

$$\text{Necessary kW} = \frac{(W + W_t + W_r) \cdot (\sin\alpha + \mu\cos\alpha) \cdot 2\pi nR}{6120 \times \eta}$$

W : Load (kg)
Wt : Mass of truck (kg)
Wr : Unbalanced mass of rope itself (kg)
R : Rotating radius of winding drum (m)
n : Rotating speed per minute of winding drum (min^{-1}), (rpm)
α : Angle of horizontal line with winding-up direction
μ : Friction coefficient (0.015 ~ 0.03)
η : Machine efficiency

Elevator

$$\text{Necessary kW} = \frac{K \cdot V \cdot W \cdot F}{6.12 \times \eta \times 1000}$$

V : Elevation speed (m/min)
W : Maximum load mass (kg)
F : Balanced load ratio (0.5 ~ 0.6)
K : Coefficient concerning torque required for acceleration/deceleration of elevator (1.3 ~ 1.5)
η : Efficiency of winding-up equipment
For gear wheel type: 0.45 ~ 0.55
For non-gear wheel type: 0.75 ~ 0.8

Pump

$$\text{Necessary kW} = (1.1 \sim 1.2)\frac{Q \cdot H}{6.12 \times \eta}$$

Q : Pumping-up quantity (m^3/min)
H : Total head of pump (m)
η : Pump efficiency

Air compressor

$$\text{Necessary kW} = \frac{5.83Q\left(P^{0.286} - 1\right)}{9.80665 \times 10^{-2}} \times \frac{1}{\eta}$$

P : Discharge absolute pressure (MPa)
Q : Quantity of air discharged (m^3/min)
η : Efficiency

	Efficiency
Small-size air cooled	0.5~0.8
Middle-size water cooled	0.7~0.85

(For discharge pressure of 0.69 Mpa)

Blower

$$\text{Necessary kW} = \frac{Q \cdot H \cdot K}{6120 \times \eta \times 9.81}$$

Q : Air quantity (m^3/min)
H : Air pressure (Pa)
η : Blower efficiency
K : Coefficient

Values of blower efficiency (η) and coefficient (K)

Types	η	K
Propeller fan	0.5~0.75	1.3
Desk fan	0.3~0.5	1.5
Sirocco fan	0.45~0.55	1.20~1.30
Turbo fan, 500 HP or more	0.65~0.75	1.15~1.25
Turbo fan, less than 500 HP	0.6~0.7	1.15~1.25
Plate fan	0.5~0.6	1.15~1.25
Turbo blower, single stage	0.6~0.75	1.10~1.20
Turbo blower, multiple stages	0.55~0.7	1.10~1.20

2.4 Other equations concerning motor

Voltage drop at electric service wire (copper wire)
The inner wiring rules prescribes that the thickness and length of the electric wire to supply power to the motor should be selected so that its voltage drop is 2% or less of the standard voltage (in operation).

Single-phase $e = \dfrac{35.6 \times L \times I}{1000 \times A}$

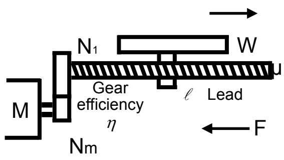
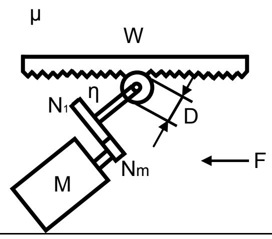
Three-phase $e = \dfrac{30.8 \times L \times I}{1000 \times A}$

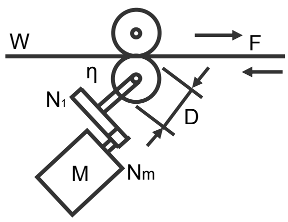
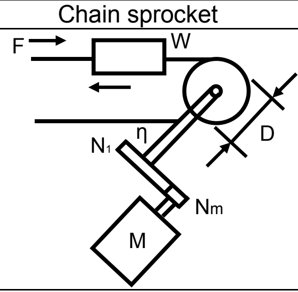
e : Voltage drop between wires
A : Section area of electric wire (mm^2)
L : Length of electric wire (m)
I : Current (A)

2.5 Equation for capacity of adjustable speed motor

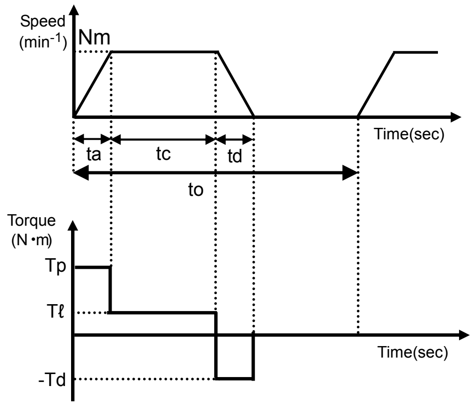
Use the equations on next page to calculate the capacity of adjustable speed motors below:

1. Ball screw
2. Rack and pinion
3. Roll feed
4. Chain sprocket

Driving methods		Ball screw	Rack and pinion
Mechanism			
Gear ratio $\frac{1}{R}$		$\frac{1}{R}=\frac{N_1}{Nm}$	$\frac{1}{R}=\frac{N_1}{Nm}$
Load torque at motor shaft $T\ell$ [N·m]		$T\ell = 9.8\left\{\frac{1}{R}\cdot\left(\frac{F+\mu W}{2\pi\eta}\right)\cdot \ell\right\}$	$T\ell = 9.8\left\{\frac{1}{R}\cdot\left(\frac{F+\mu W}{2\pi\eta}\right)\cdot \pi D\right\}$
Inertia of load converted into the value at motor shaft	Work J_W [kgm^2]	$J_w = \frac{1}{4}\left\{W\cdot\left(\frac{\ell}{\pi}\cdot\frac{1}{R}\right)^2\right\}$	$J_w = \frac{1}{4}\left\{W\cdot\left(D\frac{1}{R}\right)^2\right\}$
	Others (1) J_1 [kgm^2]	Ball screw J_S, Reduction gear J_G $J_1 = (J_S + J_G)\left(\frac{1}{R}\right)^2$	Reduction gear J_G $J_1 = J_G\left(\frac{1}{R}\right)^2$
	Others (2) J_2 [kgm^2]	Pinion gear coupling J_2	Pinion gear coupling J_2
	Entire J $\sum J$ [kgm^2]	$\sum J = J_w + J_1 + J_2$	$\sum J = J_w + J_1 + J_2$

Driving methods		Roll feed	Chain sprocket
Mechanism			
Gear ratio $\frac{1}{R}$		$\frac{1}{R}=\frac{N_1}{Nm}$	$\frac{1}{R}=\frac{N_1}{Nm}$
Load torque at motor shaft $T\ell$ [N·m]		$T\ell = 9.8\left\{\frac{1}{R}\cdot\frac{FD}{2\eta}\right\}$	$T\ell = 9.8\left\{\frac{1}{R}\cdot\left(\frac{F+\mu W}{2\pi\eta}\right)\cdot \pi D\right\}$
Inertia of load converted into the value at motor shaft	Work J_W [kgm^2]	$J_w = \frac{1}{4}\left\{W\cdot\left(D\frac{1}{R}\right)^2\right\}$	$J_w = \frac{1}{4}\left\{W\cdot\left(D\frac{1}{R}\right)^2\right\}$
	Others (1) J_1 [kgm^2]	Roll J_R, reduction gear J_G $J_1 = (J_R + J_G)\left(\frac{1}{R}\right)^2$	Chain (W_C), reduction gear GD^2_G $J_1 = \left(W_C D^2 + J_G\right)\left(\frac{1}{R}\right)^2$
	Others (2) J_2 [kgm^2]	Pinion gear coupling J_2	Pinion gear coupling J_2
	Entire J ΣJ [kgm^2]	$\sum J = J_w + J_1 + J_2$	$\sum J = J_w + J_1 + J_2$

Remarks						
	π	: Ratio of the circumference of a circle to its diameter	F	: Outer force (kg)	ℓ	: Lead of ball screw (m)
	D	: Outer diameter of roll (m)	μ	: Friction coefficient	ta	: Acceleration time (Sec)
	W	: Mass of straight-line motion part (kg)	η	: Efficiency	tc	: Constant speed time (Sec)
	Nm	: Speed of motor (min^{-1})	J_M	: Inertia of motor ($kg\cdot m^2$)	td	: Deceleration time (Sec)
	N_l	: Speed of load (min^{-1})			to	: One-cycle time (Sec)

Driving methods	Ball screw	Rack and pinion	Roll feed	Chain sprocket
Acceleration torque requirement Tp [N·m]	$Tp = \frac{(\sum J + J_M) \times Nm}{9.549 \times ta} + T\ell$			
Deceleration torque requirement Td [N·m]	$Tp = \frac{(\sum J + J_M) \times Nm}{9.549 \times tb} - T\ell$			
Effective average torque Trms [N·m]	 $Trms = \sqrt{\frac{T_p^2 \times ta + T_\ell^2 \times tc + T_d^2 \times td}{to}}$			
Remarks	π : Ratio of the circumference of a circle to its diameter D : Outer diameter of roll (m) W : Mass of straight-line motion part (kg) Nm : Speed of motor (min^{-1}) N_l : Speed of load (min^{-1}) F : Outer force (kg) μ : Friction coefficient η : Efficiency J_M : Inertia of motor ($kg·m^2$) ℓ : Lead of ball screw (m) ta : Acceleration time (Sec) tc : Constant speed time (Sec) td : Deceleration time (Sec) to : One-cycle time (Sec)			

Appendix 1: List of motor data

Motor data of FCK8/FBK8 and FCK21/FBK21 (full-closed outer fan-shaped, 60Hz base) from Toshiba Industrial Products Manufacturing Corporation and TM21-FII (full-closed outer fan-shaped, 60Hz base) from Toshiba Mitsubishi-Electric Industrial System Corp.

200V, 2-pole

Types	Voltage [V]	Capacity [kW]	Rated current [A]	Rated speed [rpm] [min^{-1}]	Rated torque [N•m]	J at shaft [kg•m^2]	Allowable J [kg•m^2]	Rated torque [kgf•m]	GD^2 at shaft [kgf•m^2]	Allowable GD^2 [kgf•m^2]	Efficiency [%]	Power factor [%]
IK-FCKK8	200	0.4	1.8	3350	1.14	0.00057	0.25	0.12	0.00228	1	72.4	89.6
IK-FCKK8	200	0.75	3.2	3420	2.09	0.0011	0.35	0.21	0.0044	1.4	76.7	90.5
IK-FCKA21	200	1.5	5.8	3380	4.24	0.0015	0.43	0.43	0.006	1.72	79.6	92.5
IK-FCKA21	200	2.2	8.4	3390	6.20	0.0021	0.6	0.63	0.0084	2.4	82.5	92.4
IK-FCKA21	200	3.7	13.8	3400	10.4	0.0038	0.9	1.06	0.0152	3.6	83.4	93.2
IKK-FCKA21	200	5.5	20	3460	15.2	0.008	1.2	1.55	0.032	4.8	85.2	93.8
IKK-FCKA21	200	7.5	26.6	3470	20.6	0.0105	1.6	2.11	0.042	6.4	87.1	94.8
IKK-FCKA21	200	11	40	3480	30.2	0.0228	1.9	3.08	0.0912	7.6	87.8	93.1
TIKK-FCKA21	200	15	52	3480	41.2	0.03	2.5	4.20	0.12	10	90	93.6
TIKK-FCKA21	200	18.5	64	3470	50.9	0.0373	2.8	5.19	0.1492	11.2	91.1	94.1
TIKK-FCK21A	200	22	78	3525	59.6	0.0825	4	6.08	0.33	16	89.7	91.1
TIKK-FCK21A	200	30	105	3525	81.3	0.1	4.3	8.29	0.4	17.2	90.6	91.4
TIKK-FCK21A	200	37	127	3525	100.2	0.17	5	10.2	0.68	20	90.5	92.9
TIKK-FCK21A	200	45	154	3510	122.4	0.193	5.3	12.5	0.772	21.2	90.5	92.9
TIKK-FCK21A	200	55	188	3530	148.8	0.283	5.6	15.2	1.132	22.4	90.5	92.9

200V, 4-pole

Types	Voltage [V]	Capacity [kW]	Rated current [A]	Rated speed [rpm] [min^{-1}]	Rated torque [N•m]	J at shaft [kg•m^2]	Allowable J [kg•m^2]	Rated torque [kgf•m]	GD^2 at shaft [kgf•m^2]	Allowable GD^2 [kgf•m^2]	Efficiency [%]	Power factor [%]
IK-FBKK8	200	0.2	1.2	1690	1.13	0.00079	0.75	0.12	0.00316	3	70	73.2
IK-FBKK8	200	0.4	2	1680	2.27	0.0012	1.2	0.23	0.0048	4.8	75.7	78.6
IK-FBKK8	200	0.75	3.4	1690	4.24	0.0027	1.5	0.43	0.0108	6	79	81.7
IK-FBKA21	200	1.5	6.2	1690	8.48	0.004	1.8	0.86	0.016	7.2	80.7	85.9
IK-FBKA21	200	2.2	8.9	1680	12.5	0.006	2.2	1.28	0.024	8.8	82.1	87.4
IK-FBKA21	200	3.7	14.8	1690	20.9	0.0078	3.4	2.13	0.0312	13.6	83.5	88.4
IKK-FBKA21	200	5.5	21	1730	30.4	0.0202	5.2	3.10	0.0808	20.8	87.7	87.4
IKK-FBKA21	200	7.5	28.2	1730	41.4	0.0267	6.8	4.22	0.1068	27.2	88.4	87.7
IKK-FBKA21	200	11	40.6	1730	60.7	0.0453	9.8	6.20	0.1812	39.2	90.1	88.2
TIKK-FBKA21	200	15	54.6	1730	82.8	0.0603	13	8.45	0.2412	52	90.8	88.5
TIKK-FBK21A	200	18.5	68	1750	100.9	0.11	16	10.3	0.44	64	90.5	87.9
TIKK-FBK21A	200	22	80	1750	120.0	0.133	18	12.2	0.532	72	91.3	88
TIKK-FBK21A	200	30	108	1745	164.2	0.165	22	16.8	0.66	88	91.6	88.8
TIKK-FBK21A	200	37	134	1750	201.9	0.253	25	20.6	1.012	100	91.6	88.4
TIKK-FBK21A	200	45	160	1750	245.5	0.293	28	25.1	1.172	112	91.9	88.7
TIKK-FBK21A	200	55	196	1755	299.3	0.483	31	30.5	1.932	124	92.3	89.4

200V, 6-pole

Types	Voltage [V]	Capacity [kW]	Rated current [A]	Rated speed [rpm] [min^{-1}]	Rated torque [N·m]	J at shaft [kg·m^2]	Allowable J [kg·m^2]	Rated torque [kgf·m]	GD^2 at shaft [kgf·m^2]	Allowable GD^2 [kgf·m^2]	Efficiency [%]	Power factor [%]
IK-FBKK8	200	0.4	2.3	1110	3.44	0.0031	3.1	0.35	0.0124	12.4	74.4	73.4
IK-FBKA21	200	0.75	3.6	1110	6.45	0.0043	3.3	0.66	0.0172	13.2	75.4	80
IK-FBKA21	200	1.5	7.2	1090	13.1	0.0067	6	1.34	0.0268	24	77	79.2
IK-FBKA21	200	2.2	9.6	1110	18.9	0.0105	7.2	1.93	0.042	28.8	79.9	82.6
IK-FBKA21	200	3.7	15.6	1120	31.5	0.0265	11	3.22	0.106	44	83.1	83.8
IKK-FBKA21	200	5.5	22.4	1140	46.1	0.033	14	4.70	0.132	56	86.2	84.9
IKK-FBKA21	200	7.5	30	1150	62.3	0.0595	20	6.35	0.238	80	88.7	83.1
IKK-FBKA21	200	11	43	1150	91.3	0.0823	30	9.32	0.3292	120	89.1	84
TIKK-FBK21A	200	15	57	1170	122.4	0.198	43	12.5	0.792	172	91	85.1
TIKK-FBK21A	200	18.5	69	1170	151.0	0.223	46	15.4	0.892	184	90.4	85.8
TIKK-FBK21A	200	22	83	1165	180.3	0.268	50	18.4	1.072	200	91	86
TIKK-FBK21A	200	30	113	1165	245.9	0.343	66	25.1	1.372	264	91	86.1
TIKK-FBK21A	200	37	137	1165	303.3	0.42	66	30.9	1.68	264	91.1	86.5
TIKK-FBK21A	200	45	164	1170	367.3	0.658	75	37.5	2.632	300	92	88

400V, 2-pole

Types	Voltage [V]	Capacity [kW]	Rated current [A]	Rated speed [rpm] [min^{-1}]	Rated torque [N·m]	J at shaft [kg·m^2]	Allowable J [kg·m^2]	Rated torque [kgf·m]	GD^2 at shaft [kgf·m^2]	Allowable GD^2 [kgf·m^2]	Efficiency [%]	Power factor [%]
IK-FCKK8	400	0.2	0.5	3380	0.57	0.00037	0.19	0.06	0.00148	0.76	68.7	85.4
IK-FCKK8	400	0.4	0.9	3350	1.14	0.00057	0.25	0.12	0.00228	1	72.5	89.4
IK-FCKK8	400	0.75	1.6	3420	2.09	0.0011	0.35	0.21	0.0044	1.4	76.4	90.4
IK-FCKA21	400	1.5	2.9	3380	4.24	0.0015	0.43	0.43	0.006	1.72	78.7	92.7
IK-FCKA21	400	2.2	4.2	3390	6.20	0.0021	0.6	0.63	0.0084	2.4	81.7	92.5
IK-FCKA21	400	3.7	6.9	3400	10.4	0.0038	0.9	1.06	0.0152	3.6	82.7	93.3
IKK-FCKA21	400	5.5	10	3460	15.2	0.008	1.2	1.55	0.032	4.8	85.2	93.8
IKK-FCKA21	400	7.5	13.3	3470	20.6	0.0105	1.6	2.11	0.042	6.4	86.6	94.8
IKK-FCKA21	400	11	20	3480	30.2	0.0228	1.9	3.08	0.0912	7.6	87.8	93.1
TIKK-FCKA21	400	15	26	3480	41.2	0.03	2.5	4.20	0.12	10	89.7	93.7
TIKK-FCKA21	400	18.5	32	3470	50.9	0.0373	2.8	5.19	0.1492	11.2	90.8	94.2
TIKK-FCK21A	400	22	39	3525	59.6	0.0825	4	6.08	0.33	16	89.7	91.1
TIKK-FCK21A	400	30	52.5	3525	81.3	0.1	4.3	8.29	0.4	17.2	90.6	91.4
TIKK-FCK21A	400	37	63.5	3525	100.2	0.17	5	10.2	0.68	20	90.5	92.9
TIKK-FCK21A	400	45	77	3510	122.4	0.193	5.3	12.5	0.772	21.2	90.5	92.9
TIKK-FCK21A	400	55	94	3530	148.8	0.283	5.6	15.2	1.132	22.4	90.5	92.9
TM21-FII	440	75	117	3570	200.6	0.45	14.75	20.5	1.8	59	93.6	90.2
TM21-FII	440	90	138	3570	240.7	0.5	15.75	24.6	2	63	94	90.8
TM21-FII	440	110	169	3565	294.6	0.725	17.5	30.1	2.9	70	94.1	91
TM21-FII	440	132	199	3565	353.6	0.875	19.75	36.1	3.5	79	94.6	91.9
TM21-FII	440	150	229	3575	400.7	1.125	20.25	40.9	4.5	81	95	90.6
TM21-FII	440	160	243	3570	428.0	1.125	21.5	43.7	4.5	86	95	90.9
TM21-FII	440	185	281	3570	494.8	1.2	23	50.5	4.8	92	95.3	90.8
TM21-FII	440	200	304	3575	534.2	1.325	23.75	54.5	5.3	95	95.4	90.5
TM21-FII	440	220	337	3570	588.5	1.1	24.25	60.0	4.4	97	94.9	90.4
TM21-FII	440	250	379	3570	668.7	1.25	27.25	68.2	5	109	95.1	91
TM21-FII	440	280	423	3570	748.9	1.425	30	76.4	5.7	120	95.4	91
TM21-FII	440	300	449	3575	801.3	1.775	31.25	81.8	7.1	125	95.7	91.6
TM21-FII	440	315	471	3570	842.6	1.775	32.5	86.0	7.1	130	95.7	91.7
TM21-FII	440	355	535	3570	949.6	2.25	35	96.9	9	140	95.8	90.9
TM21-FII	440	400	598	3575	1068.4	3	38.75	109.0	12	155	96.1	91.3

400V, 4-pole

Types	Voltage [V]	Capacity [kW]	Rated current [A]	Rated speed [rpm] [min^{-1}]	Rated torque [N•m]	J at shaft [$kg•m^2$]	Allowable J [$kg•m^2$]	Rated torque [kgf•m]	GD^2 at shaft [$kgf•m^2$]	Allowable GD^2 [$kgf•m^2$]	Efficiency [%]	Power factor [%]
IK-FBKK8	400	0.2	0.55	1690	1.13	0.00079	0.75	0.12	0.00316	3	68.9	79.9
IK-FBKK8	400	0.4	1	1680	2.27	0.0012	1.2	0.23	0.0048	4.8	76.6	78.2
IK-FBKK8	400	0.75	1.7	1690	4.24	0.0027	1.5	0.43	0.0108	6	79.1	81.9
IK-FBKA21	400	1.5	3.1	1690	8.48	0.004	1.8	0.86	0.016	7.2	79.7	86.3
IK-FBKA21	400	2.2	4.5	1680	12.5	0.006	2.2	1.28	0.024	8.8	81.2	87.7
IK-FBKA21	400	3.7	7.4	1690	20.9	0.0078	3.4	2.13	0.0312	13.6	82.7	88.5
IKK-FBKA21	400	5.5	10.5	1730	30.4	0.0202	5.2	3.10	0.0808	20.8	87.7	87.4
IKK-FBKA21	400	7.5	14.1	1730	41.4	0.0267	6.8	4.22	0.1068	27.2	88.4	87.7
IKK-FBKA21	400	11	20.3	1730	60.7	0.0453	9.8	6.20	0.1812	39.2	90.1	88.2
TIKK-FBKA21	400	15	27.3	1730	82.8	0.0603	13	8.45	0.2412	52	90.4	88.5
TIKK-FBK21A	400	18.5	34	1750	100.9	0.11	16	10.3	0.44	64	90.1	88
TIKK-FBK21A	400	22	40	1750	120.0	0.133	18	12.2	0.532	72	90.9	88.1
TIKK-FBK21A	400	30	54	1745	164.2	0.165	22	16.8	0.66	88	91.6	88.8
TIKK-FBK21A	400	37	67	1750	201.9	0.253	25	20.6	1.012	100	91.6	88.4
TIKK-FBK21A	400	45	80	1750	245.5	0.293	28	25.1	1.172	112	91.9	88.7
TIKK-FBK21A	400	55	98	1755	299.3	0.483	31	30.5	1.932	124	92.3	89.4
TM21-FII	440	75	118	1780	402.3	0.6	43.75	41.1	2.4	175	92.9	89.3
TM21-FII	440	90	140	1780	482.8	0.7	48.75	49.3	2.8	195	93.5	89.9
TM21-FII	440	110	172	1775	591.8	1	67.5	60.4	4	270	93.6	89.2
TM21-FII	440	132	203	1775	710.1	1.15	77.5	72.5	4.6	310	94.4	90
TM21-FII	440	150	235	1780	804.7	2.225	98.75	82.1	8.9	395	94.3	89.1
TM21-FII	440	160	246	1785	855.9	2.75	101.25	87.3	11	405	94.6	90.4
TM21-FII	440	185	281	1780	992.5	2.75	105	101.3	11	420	94.7	91.2
TM21-FII	440	200	305	1780	1072.9	3	107.5	109.5	12	430	95	90.5
TM21-FII	440	220	337	1780	1180.2	3	112.5	120.4	12	450	95.2	90.2
TM21-FII	440	250	378	1780	1341.2	3.5	120	136.9	14	480	94.9	91.6
TM21-FII	440	280	422	1780	1502.1	4	128.75	153.3	16	515	95.1	91.6
TM21-FII	440	300	452	1780	1609.4	4.25	138.75	164.2	17	555	95.4	91.3
TM21-FII	440	315	473	1780	1689.9	4.25	142.5	172.4	17	570	95.4	91.5
TM21-FII	440	355	558	1780	1904.4	4.25	157.5	194.3	17	630	95.7	87.3
TM21-FII	440	400	628	1780	2145.8	5	170	219.0	20	680	95.9	87.1

400V, 6-pole

Types	Voltage [V]	Capacity [kW]	Rated current [A]	Rated speed [rpm] [min^{-1}]	Rated torque [N•m]	J at shaft [$kg•m^2$]	Allowable J [$kg•m^2$]	Rated torque [kgf•m]	GD^2 at shaft [$kgf•m^2$]	Allowable GD^2 [$kgf•m^2$]	Efficiency [%]	Power factor [%]
IK-FBKK8	400	0.4	1.2	920	4.15	0.0031	4.5	0.42	0.0124	18	71.4	68.4
IK-FBKA21	400	0.75	1.8	1110	6.45	0.0043	3.3	0.66	0.0172	13.2	76.3	80.1
IK-FBKA21	400	1.5	3.6	1090	13.1	0.0067	6	1.34	0.0268	24	76.9	78.1
IK-FBKA21	400	2.2	4.8	1110	18.9	0.0105	7.2	1.93	0.042	28.8	79.9	82.6
IK-FBKA21	400	3.7	7.8	1120	31.5	0.0265	11	3.22	0.106	44	83.1	83.7
IKK-FBKA21	400	5.5	11.2	1140	46.1	0.033	14	4.70	0.132	56	86.2	84.9
IKK-FBKA21	400	7.5	15	1150	62.3	0.0595	20	6.35	0.238	80	88.7	83.1
IKK-FBKA21	400	11	21.5	1150	91.3	0.0823	30	9.32	0.3292	120	88.8	85.1
TIKK-FBK21A	400	15	28.5	1170	122.4	0.198	43	12.5	0.792	172	91	85.1
TIKK-FBK21A	400	18.5	34.5	1170	151.0	0.223	46	15.4	0.892	184	90.4	85.8
TIKK-FBK21A	400	22	41.5	1165	180.3	0.268	50	18.4	1.072	200	91	86
TIKK-FBK21A	400	30	56.5	1165	245.9	0.343	66	25.1	1.372	264	91	86.1
TIKK-FBK21A	400	37	68.5	1165	303.3	0.42	66	30.9	1.68	264	91.1	86.5
TIKK-FBK21A	400	45	82	1170	367.3	0.658	75	37.5	2.632	300	92	88
TM21-FII	440	55	90	1180	445.1	0.65	107.5	45.4	2.6	430	93.2	85.9
TM21-FII	440	75	122	1180	606.9	0.875	145	61.9	3.5	580	93.9	86
TM21-FII	440	90	145	1180	728.3	1.4	166.25	74.3	5.6	665	94.2	86.7
TM21-FII	440	110	173	1180	890.2	1.725	192.5	90.8	6.9	770	94.4	88.2
TM21-FII	440	132	215	1185	1063.7	2.75	238.75	108.5	11	955	94.6	85.3
TM21-FII	440	150	243	1185	1208.7	3.25	262.5	123.3	13	1050	94.8	85.4
TM21-FII	440	160	257	1185	1289.3	3.25	275	131.6	13	1100	94.8	86.2
TM21-FII	440	185	296	1185	1490.8	3.25	287.5	152.1	13	1150	95	86.4
TM21-FII	440	200	314	1185	1611.6	4	300	164.5	16	1200	95	88.1
TM21-FII	440	220	346	1185	1772.8	4.25	337.5	180.9	17	1350	95.1	87.8
TM21-FII	440	250	409	1185	2014.6	4.25	375	205.6	17	1500	95.1	84.3
TM21-FII	440	280	441	1185	2256.3	6	400	230.2	24	1600	95.4	87.4
TM21-FII	440	300	470	1185	2417.5	6.75	425	246.7	27	1700	95.7	87.5
TM21-FII	440	315	493	1185	2538.3	6.75	437.5	259.0	27	1750	95.6	87.7

Appendix 2: List of braking resistors

Model	Capacity (W)	Resistance (ohm)	Continuous regenerative capacity (W)	Configuration
PBR-2007	120	200	90	120W-200Ω
PBR-2022	120	75	90	120W-75Ω
PBR-2037	120	40	90	120W-40Ω
PBR-4037	120	160	90	120W-160Ω
PBR7-004W060	440	60	130	440W-60Ω
PBR7-004W015	440	15	130	440W-15Ω
PBR7-008W060	880	60	270	880W-60Ω
PBR7-008W040	880	40	270	880W-40Ω
PBR7-008W030	880	30	270	880W-30Ω
PBR7-008W015	880	15	270	880W-15Ω
PBR7-008W010	880	10	270	880W-10Ω
PBR7-008W7R5	880	7.5	270	880W-7.5Ω
PBR7-017W060	1760	60	540	1760W-60Ω
PBR7-017W040	1760	40	540	1760W-40Ω
PBR7-017W030	1760	30	540	1760W-30Ω
PBR7-017W020	1760	20	540	1760W-20Ω
PBR7-017W015	1760	15	540	1760W-15Ω
PBR7-017W010	1760	10	540	1760W-10Ω
PBR7-017W7R5	1760	7.5	540	1760W-7.5Ω
PBR7-017W005	1760	5	540	1760W-5Ω
PBR7-017W3R7	1760	3.75	540	1760W-3.75Ω
PBR7-035W060	3520	60	1080	3520W-60Ω
PBR7-035W040	3520	40	1080	3520W-40Ω
PBR7-035W030	3520	30	1080	3520W-30Ω
PBR7-035W020	3520	20	1080	3520W-20Ω
PBR7-035W015	3520	15	1080	3520W-15Ω
PBR7-035W010	3520	10	1080	3520W-10Ω
PBR7-035W7R5	3520	7.5	1080	3520W-7.5Ω
PBR7-035W005	3520	5	1080	3520W-5Ω
PBR7-035W3R7	3520	3.75	1080	3520W-3.75Ω
PBR7-035W2R5	3520	2.5	1080	3520W-2.5Ω
PBR7-035W1R8	3520	1.87	1080	3520W-1.87Ω
PBR7-052W060	5280	60	1620	5280W-60Ω
PBR7-052W040	5280	40	1620	5280W-40Ω
PBR7-052W030	5280	30	1620	5280W-30Ω
PBR7-052W020	5280	20	1620	5280W-20Ω
PBR7-052W015	5280	15	1620	5280W-15Ω
PBR7-052W010	5280	10	1620	5280W-10Ω
PBR7-052W7R5	5280	7.5	1620	5280W-7.5Ω
PBR7-052W005	5280	5	1620	5280W-5Ω
PBR7-052W3R7	5280	3.75	1620	5280W-3.75Ω
PBR7-052W2R5	5280	2.5	1620	5280W-2.5Ω
PBR7-052W1R8	5280	1.87	1620	5280W-1.87Ω
PBR7-052W1R2	5280	1.25	1620	5280W-1.25Ω
PBR3-2055	240	20	96	120W-40Ω×2P
PBR3-2075	440	15	130	220W-30Ω×2P
PBR3-2110	660	10	200	220W-30Ω×3P
PBR3-2150	880	7.5	270	220W-30Ω×4P
PBR3-2220	1760	3.3	610	220W-27Ω×8P
PBR3-4037	120	160	50	120W-160Ω
PBR3-4055	240	80	96	120W-160Ω×2P
PBR3-4075	440	60	130	220W-120Ω×2P
PBR3-4110	660	40	190	220W-120Ω×3P
PBR3-4150	880	30	270	220W-120Ω×4P
PBR3-4220	1760	15	540	220W-30Ω×4P2S

Model	Capacity (W)	Resistance (ohm)	Continuous regenerative capacity (W)	Configuration
PBR233W010	3300	10	1760	220W-150Ω×15P
PBR233W7R5	3300	7.5	1380	220W-113Ω×15P
PBR233W3R3	3300	3.3	610	220W-50Ω×15P
PBR233W002	3300	2	1000	220W-30Ω×15P
PBR235W040	3520	40	2250	220W-160Ω×8P2S
PBR235W020	3520	20	2330	220W-80Ω×8P2S
PBR235W015	3520	15	2080	220W-60Ω×8P2S
PBR235W010	3520	10	1960	220W-40Ω×8P2S
PBR235W7R5	3520	7.5	1660	220W-30Ω×8P2S
PBR235W3R3	3520	3.3	610	220W-53Ω×16P
PBR252W015	5280	15	3330	220W-90Ω×12P2S
PBR252W010	5280	10	3200	220W-60Ω×12P2S
PBR252W7R5	5280	7.5	3210	220W-45Ω×12P2S
PBR252W3R3	5280	3.3	1760	220W-20Ω×12P2S
PBR252W002	5280	2	1000	220W-12Ω×12P2S
PBR402W160	240	160	50	120W-80Ω×2S
PBR408W160	880	160	570	220W-160Ω×2P2S
PBR408W080	880	80	270	220W-80Ω×2P2S
PBR408W060	880	60	130	220W-60Ω×2P2S
PBR408W040	880	40	190	220W-40Ω×2P2S
PBR408W030	880	30	270	220W-30Ω×2P2S
PBR417W080	1760	80	1090	220W-160Ω×4P2S
PBR417W060	1760	60	1000	220W-120Ω×4P2S
PBR417W040	1760	40	490	220W-80Ω×4P2S
PBR417W030	1760	30	270	220W-80Ω×4P2S
PBR417W015	1760	15	540	220W-30Ω×4P2S
PBR417W008	1760	8	1000	220W-16Ω×4P2S
PBR422W040	2200	40	810	220W-400Ω×10P
PBR422W030	2200	30	550	220W-300Ω×10P
PBR422W015	2200	15	540	220W-150Ω×10P
PBR426W040	2640	40	1250	220W-120Ω×6P2S
PBR426W030	2640	30	870	220W-90Ω×6P2S
PBR426W015	2640	15	540	220W-45Ω×6P2S
PBR426W008	2640	8	1000	220W-24Ω×6P2S
PBR435W040	3520	40	1900	220W-160Ω×8P2S
PBR435W030	3520	30	1680	220W-120Ω×8P2S
PBR435W015	3520	15	540	220W-60Ω×8P2S
PBR452W040	5280	40	2250	220W-240Ω×12P2S
PBR452W030	5280	30	2700	220W-180Ω×12P2S
PBR452W015	5280	15	1740	220W-90Ω×12P2S
PBR452W008	5280	8	1000	220W-48Ω×12P2S

Note：

PBR***：Braking resistor with built-in thermal fuse

PBR7** : Braking resistor with thermal relay and built-in thermal fuse

PBR3** : Braking resistor installed inside the box. This type has a thermal relay and over heat relay to protect resistor.

PBR2** : High frequency braking resistor for 200V-class inverters.
This type has a thermal relay and over heat relay to protect resistor.

PBR4** : High frequency braking resistor for 400V-class inverters.
This type has a thermal relay and over heat relay to protect resistor.

Appendix 3: List of minimum allowable resistances

Type	Input phase	Input voltage [V]	Capacity [kW]	Minimum allowable resistance [Ω]	Standard optional braking resistor (β coefficient = 0.8)	β coefficient
VFAS1-2004PL	3	200	0.4	50	PBR-2007	1.5
VFAS1-2007PL	3	200	0.75	50	PBR-2007	1.5
VFAS1-2015PL	3	200	1.5	35	PBR-2022	1.4
VFAS1-2022PL	3	200	2.2	20	PBR-2022	1.4
VFAS1-2037PL	3	200	3.7	16	PBR-2037	1.4
VFAS1-2055PL	3	200	5.5	11	PBR7-004W015	1.3
VFAS1-2075PL	3	200	7.5	8	PBR7-004W015	1.4
VFAS1-2110PM	3	200	11	5	PBR7-008W7R5	1.4
VFAS1-2150PM	3	200	15	5	PBR7-008W7R5	1.1
VFAS1-2185PM	3	200	18.5	3.3	PBR7-008W7R5	1.0
VFAS1-2220PM	3	200	22	3.3	PBR7-017W3R7	1.3
VFAS1-2300PM	3	200	30	2.5	PBR7-017W3R7	1.3
VFAS1-2370PM	3	200	37	1.7	PBR7-035W1R8	1.5
VFAS1-2450PM	3	200	45	1.7	PBR7-035W1R8	1.3
VFAS1-2550P	3	200	55	1.7	PBR7-035W1R8	1.0
VFAS1-2750P	3	200	75	1.3	DGP600W-B1	1.0
VFAS1-2900P	3	200	90	1	PB7-4200K+ transformer (200/400V)+ DGP600W-B1	1.1
VFAS1-2110KP	3	200	110	1	PB7-4200K + transformer (200/400V)+ DGP600W-B1	0.9
VFAS1-2132KP	3	200	132	1	PB7-4200K + transformer (200/400V)+ DGP600W-B3	0.8
VFAS1-4007PL	3	400	0.75	60	PBR-2007	1.5
VFAS1-4015PL	3	400	1.5	60	PBR-2007	1.5
VFAS1-4022PL	3	400	2.2	60	PBR-2007	1.5
VFAS1-4037PL	3	400	3.7	40	PBR-4037	1.5
VFAS1-4055PL	3	400	5.5	30	PBR7-004W060	1.5
VFAS1-4075PL	3	400	7.5	20	PBR7-004W060	1.4
VFAS1-4110PL	3	400	11	20	PBR7-008W030	1.4
VFAS1-4150PL	3	400	15	13.3	PBR7-008W030	1.1
VFAS1-4185PL	3	400	18.5	13.3	PBR7-008W030	1.2
VFAS1-4220PL	3	400	22	13.3	PBR7-017W015	1.2
VFAS1-4300PL	3	400	30	10	PBR7-017W015	1.1
VFAS1-4370PL	3	400	37	6.7	PBR7-017W7R5	1.4
VFAS1-4450PL	3	400	45	5	PBR7-017W7R5	1.5
VFAS1-4550PL	3	400	55	5	PBR7-017W7R5	1.3
VFAS1-4750PL	3	400	75	3.3	PBR7-017W3R7	1.4
VFAS1-4900PC	3	400	90	2.5	DGP600W-B2	1.5
VFAS1-4110KPC	3	400	110	1.9	DGP600W-B2	1.5
VFAS1-4132KPC	3	400	132	1.9	DGP600W-B2	1.5
VFAS1-4160KPC	3	400	160	1.9	DGP600W-B2	1.3
VFAS1-4200KPC	3	400	200	1	PB7-4200K + DGP600W-B3	1.5
VFAS1-4220KPC	3	400	220	1	PB7-4200K + DGP600W-B3	1.5
VFAS1-4280KPC	3	400	280	1	PB7-4200K + DGP600W-B4	1.4
VFAS1-4355KPC	3	400	355	0.7	PB7-4400K + DGP600W-B3 X 2 parallel	1.5
VFAS1-4400KPC	3	400	400	0.7	PB7-4400K + DGP600W-B3 X 2 parallel	1.4
VFAS1-4500KPC	3	400	500	0.7	PB7-4400K + DGP600W-B4 X 2 parallel	1.2

Type	Input phase	Input voltage [V]	Capacity [kW]	Minimum allowable resistance [Ω]	Standard optional braking resistor (β coefficient = 0.8)	β coefficient
VFPS1-2004PL	3	200	0.4	50	PBR-2007	1.2
VFPS1-2007PL	3	200	0.75	50	PBR-2007	1.2
VFPS1-2015PL	3	200	1.5	35	PBR-2022	1.2
VFPS1-2022PL	3	200	2.2	20	PBR-2022	1.2
VFPS1-2037PL	3	200	3.7	16	PBR-2037	1.2
VFPS1-2055PL	3	200	5.5	11	PBR7-004W015	1.2
VFPS1-2075PL	3	200	7.5	8	PBR7-004W015	1.2
VFPS1-2110PM	3	200	11	5	PBR7-008W7R5	1.2
VFPS1-2150PM	3	200	15	5	PBR7-008W7R5	1.1
VFPS1-2185PM	3	200	18.5	3.3	PBR7-008W7R5	1.2
VFPS1-2220PM	3	200	22	3.3	PBR7-017W3R7	1.2
VFPS1-2300PM	3	200	30	2.5	PBR7-017W3R7	1.2
VFPS1-2370PM	3	200	37	1.7	PBR7-035W1R8	1.2
VFPS1-2450PM	3	200	45	1.7	PBR7-035W1R8	1.2
VFPS1-2550P	3	200	55	1.7	PBR7-035W1R8	1.0
VFPS1-2750P	3	200	75	1.3	DGP600W-B1	1.0
VFPS1-2900P	3	200	90	1	DGP600W-B1	1.1
VFPS1-4007PL	3	400	0.75	60	PBR-2007	1.2
VFPS1-4015PL	3	400	1.5	60	PBR-2007	1.2
VFPS1-4022PL	3	400	2.2	60	PBR-2007	1.2
VFPS1-4037PL	3	400	3.7	40	PBR-4037	1.2
VFPS1-4055PL	3	400	5.5	30	PBR7-004W060	1.2
VFPS1-4075PL	3	400	7.5	20	PBR7-004W060	1.2
VFPS1-4110PL	3	400	11	20	PBR7-008W030	1.2
VFPS1-4150PL	3	400	15	13.3	PBR7-008W030	1.2
VFPS1-4185PL	3	400	18.5	13.3	PBR7-008W030	1.2
VFPS1-4220PL	3	400	22	13.3	PBR7-007W015	1.2
VFPS1-4300PL	3	400	30	10	PBR7-007W015	1.1
VFPS1-4370PL	3	400	37	6.7	PBR7-017W7R5	1.2
VFPS1-4450PL	3	400	45	5	PBR7-017W7R5	1.2
VFPS1-4550PL	3	400	55	5	PBR7-017W7R5	1.2
VFPS1-4750PL	3	400	75	3.3	PBR7-017W3R7	1.2
VFPS1-4900PC	3	400	90	2.5	DGP600W-B2	1.2
VFPS1-4110KPC	3	400	110	1.9	DGP600W-B2	1.2
VFPS1-4132KPC	3	400	132	1.9	DGP600W-B2	1.2
VFPS1-4160KPC	3	400	160	1.9	DGP600W-B2	1.2
VFPS1-4220KPC	3	400	220	1.9	DGP600W-B3	1.0
VFPS1-4250KPC	3	400	250	1	PB7-4200K + DGP600W-B4	1.2
VFPS1-4280KPC	3	400	280	1	PB7-4200K + DGP600W-B4	1.2
VFPS1-4315KPC	3	400	315	1	PB7-4200K + DGP600W-B4	1.2
VFPS1-4400KPC	3	400	400	0.7	PB7-4400K + DGP600W-B3 X 2 parallel	1.2
VFPS1-4500KPC	3	400	500	0.7	PB7-4400K + DGP600W-B4 X 2 parallel	1.2
VFPS1-4630KPC	3	400	630	0.7	PB7-4400K + DGP600W-B4 X 2 parallel	1.0

Type	Input phase	Input voltage [V]	Capacity [kW]	Minimum allowable resistance [Ω]	Standard optional braking resistor (β coefficient = 0.8)	β coefficient
VFA7-2004PL	3	200	0.4	63	Built-in	1.5
VFA7-2007PL	3	200	0.75	63	Built-in	1.2
VFA7-2015PL	3	200	1.5	35	Built-in	1.3
VFA7-2022PL	3	200	2.2	25	Built-in	1.4
VFA7-2037PL	3	200	3.7	17	Built-in	1.3
VFA7-2055PL	3	200	5.5	10	PBR3-2055	1.5
VFA7-2075PL	3	200	7.5	10	PBR3-2075	1.1
VFA7-2110P	3	200	11	10	PBR3-2110	1.0
VFA7-2150P	3	200	15	7.5	PBR3-2150	1.0
VFA7-2185P	3	200	18.5	5	PBR3-2150	1.0
VFA7-2220P	3	200	22	3.3	PBR3-2220	1.3
VFA7-2300P	3	200	30	3.3	PBR3-2220	1.0
VFA7-2370P1	3	200	37	1.7	PBR-222W002	1.5
VFA7-2450P1	3	200	45	1.7	PBR-222W002	1.2
VFA7-2550P1	3	200	55	1.7	PBR-222W002	1.0
VFA7-2750P1	3	200	75	1.3	DGP600W-B1	1.0
VFA7-2900P1	3	200	90	1	DGP600W-B1	1.1
VFA7-4007PL	3	400	0.75	100	Built-in	1.5
VFA7-4015PL	3	400	1.5	100	Built-in	1.5
VFA7-4022PL	3	400	2.2	67	Built-in	1.5
VFA7-4037PL	3	400	3.7	40	Built-in	1.5
VFA7-4055PL	3	400	5.5	40	PBR3-4055	1.4
VFA7-4075PL	3	400	7.5	40	PBR3-4075	1.1
VFA7-4110PL	3	400	11	40	PBR3-4110	1.0
VFA7-4150PL	3	400	15	30	PBR3-4150	1.0
VFA7-4185P	3	400	18.5	20	PBR3-4150	1.0
VFA7-4220P	3	400	22	13.3	PBR3-4220	1.3
VFA7-4300P	3	400	30	13.3	PBR3-4220	1.0
VFA7-4370P1	3	400	37	6.7	PBR-417W008	1.5
VFA7-4450P1	3	400	45	6.7	PBR-417W008	1.2
VFA7-4550P1	3	400	55	5	PBR-417W008	1.3
VFA7-4750P1	3	400	75	3.3	PBR-417W008	1.5
VFA7-4110KP1	3	400	110	2.5	DGP600W-B2	1.4
VFA7-4132KP1	3	400	132	2.5	DGP600W-B2	1.2
VFA7-4160KP1	3	400	160	1.3	DGP600W-B2	1.5
VFA7-4220KP1	3	400	220	1	DGP600W-B3	1.5
VFA7-4280KP1	3	400	280	1	DGP600W-B4	1.4

Type	Input phase	Input voltage [V]	Capacity [kW]	Minimum allowable resistance [Ω]	Standard optional braking resistor (β coefficient = 0.8)	β coefficient
VFP7-2185P	3	200	18.5	5	PBR3-2150	1.0
VFP7-2220P	3	200	22	3.3	PBR3-2220	1.2
VFP7-2300P	3	200	30	3.3	PBR3-2220	1.0
VFP7-2370P	3	200	37	1.7	PBR-222W002	1.2
VFP7-2450P	3	200	45	1.7	PBR-222W002	1.2
VFP7-2550P	3	200	55	1.7	PBR-222W002	1.0
VFP7-2750P	3	200	75	1.3	DGP600W-B1	1.0
VFP7-2900P	3	200	90	1	DGP600W-B1	1.1
VFP7-2110KP	3	200	110	1	DGP600W-B1	1.0
VFP7-4185P	3	400	18.5	20	PBR3-4150	1.0
VFP7-4220P	3	400	22	13.3	PBR3-4220	1.2
VFP7-4300P	3	400	30	13.3	PBR3-4220	1.0
VFP7-4370P	3	400	37	13.3	PBR3-4220	1.0
VFP7-4450P	3	400	45	6.7	PBR-417W008	1.2
VFP7-4550P	3	400	55	5	PBR-417W008	1.2
VFP7-4750P	3	400	75	3.3	PBR-417W008	1.2
VFP7-4900P	3	400	90	3.3	PBR-417W008	1.2
VFP7-4110KP	3	400	110	2.5	DGP600W-B2	1.2
VFP7-4132KP	3	400	132	2.5	DGP600W-B2	1.2
VFP7-4160KP	3	400	160	2.5	DGP600W-B2	1.0
VFP7-4200KP	3	400	200	1	DGP600W-B3	1.2
VFP7-4220KP	3	400	220	1	DGP600W-B3	1.2
VFP7-4280KP	3	400	280	1	DGP600W-B4	1.2
VFP7-4315KP	3	400	315	1	DGP600W-B4	1.2

Type	Input phase	Input voltage [V]	Capacity [kW]	Minimum allowable resistance [Ω]	Standard optional braking resistor (β coefficient = 0.8)	β coefficient
VFS15-2002PM	3	200	0.2	55	PBR-2007	1.5
VFS15-2004PM	3	200	0.4	55	PBR-2007	1.5
VFS15-2007PM	3	200	0.75	55	PBR-2007	1.5
VFS15-2015PM	3	200	1.5	44	PBR-2022	1.1
VFS15-2022PM	3	200	2.2	33	PBR-2022	1.1
VFS15-2037PM	3	200	3.7	16	PBR-2037	1.4
VFS15-2055PM	3	200	5.5	12	PBR7-004W015	1.2
VFS15-2075PM	3	200	7.5	12	PBR7-004W015	1.0
VFS15-2110PM	3	200	11	5	PBR7-008W7R5	1.4
VFS15-2150PM	3	200	15	5	PBR7-008W7R5	1.2
VFS15-4004PL	3	400	0.4	114	PBR-2007	1.5
VFS15-4007PL	3	400	0.75	114	PBR-2007	1.5
VFS15-4015PL	3	400	1.5	67	PBR-2007	1.5
VFS15-4022PL	3	400	2.2	67	PBR-2007	1.5
VFS15-4037PL	3	400	3.7	54	PBR-4037	1.5
VFS15-4055PL	3	400	5.5	43	PBR7-004W060	1.3
VFS15-4075PL	3	400	7.5	28	PBR7-004W060	1.5
VFS15-4110PL	3	400	11	16	PBR7-008W030	1.5
VFS15-4150PL	3	400	15	16	PBR7-008W030	1.5
VFS15S-2002PL	1	200	0.2	55	PBR-2007	1.5
VFS15S-2004PL	1	200	0.4	55	PBR-2007	1.5
VFS15S-2007PL	1	200	0.75	55	PBR-2007	1.5
VFS15S-2015PL	1	200	1.5	44	PBR-2022	1.1
VFS15S-2022PL	1	200	2.2	33	PBR-2022	1.1

Type	Input phase	Input voltage [V]	Capacity [kW]	Minimum allowable resistance [Ω]	Standard optional braking resistor (β coefficient = 0.8)	β coefficient
VFS11-2002PM	3	200	0.2	55	PBR-2007	1.5
VFS11-2004PM	3	200	0.4	55	PBR-2007	1.5
VFS11-2007PM	3	200	0.75	55	PBR-2007	1.4
VFS11-2015PM	3	200	1.5	44	PBR-2022	1.1
VFS11-2022PM	3	200	2.2	33	PBR-2022	1.0
VFS11-2037PM	3	200	3.7	16	PBR-2037	1.4
VFS11-2055PM	3	200	5.5	12	PBR3-2055	1.1
VFS11-2075PM	3	200	7.5	12	PBR3-2075	1.0
VFS11-2110PM	3	200	11	5	PBR3-2110	1.4
VFS11-2150PM	3	200	15	5	PBR3-2150	1.1
VFS11-4004PL	3	400	0.4	114	PBR-2007	1.5
VFS11-4007PL	3	400	0.75	114	PBR-2007	1.5
VFS11-4015PL	3	400	1.5	67	PBR-2007	1.5
VFS11-4022PL	3	400	2.2	67	PBR-2007	1.5
VFS11-4037PL	3	400	3.7	54	PBR-4037	1.5
VFS11-4055PL	3	400	5.5	43	PBR3-4055	1.2
VFS11-4075PL	3	400	7.5	28	PBR3-4075	1.5
VFS11-4110PL	3	400	11	16	PBR3-4110	1.5
VFS11-4150PL	3	400	15	16	PBR3-4150	1.4
VFS11S-2002PL	1	200	0.2	55	PBR-2007	1.5
VFS11S-2004PL	1	200	0.4	55	PBR-2007	1.5
VFS11S-2007PL	1	200	0.75	55	PBR-2007	1.4
VFS11S-2015PL	1	200	1.5	44	PBR-2022	1.1
VFS11S-2022PL	1	200	2.2	33	PBR-2022	1.0

Type	Input phase	Input voltage [V]	Capacity [kW]	Minimum allowable resistance [Ω]	Standard optional braking resistor (β coefficient = 0.8)	β coefficient
VFS9-2002PM	3	200	0.2	63	PBR-2007	1.5
VFS9-2004PM	3	200	0.4	63	PBR-2007	1.5
VFS9-2007PM	3	200	0.75	42	PBR-2007	1.5
VFS9-2015PM	3	200	1.5	30	PBR-2022	1.5
VFS9-2022PM	3	200	2.2	30	PBR-2022	1.2
VFS9-2037PM	3	200	3.7	24	PBR-2037	1.0
VFS9-2055PL	3	200	5.5	10	PBR3-2055	1.4
VFS9-2075PL	3	200	7.5	10	PBR3-2075	1.2
VFS9-2110PM	3	200	11	7	PBR3-2110	1.0
VFS9-2150PM	3	200	15	7	PBR3-2150	1.0
VFS9-4007PL	3	400	0.75	99	PBR-2007	1.5
VFS9-4015PL	3	400	1.5	99	PBR-2007	1.5
VFS9-4022PL	3	400	2.2	73	PBR-2007	1.5
VFS9-4037PL	3	400	3.7	73	PBR-2007	1.1
VFS9-4055PL	3	400	5.5	44	PBR3-4055	1.3
VFS9-4075PL	3	400	7.5	44	PBR3-4075	1.1
VFS9-4110PL	3	400	11	22	PBR3-4110	1.3
VFS9-4150PL	3	400	15	22	PBR3-4150	1.1
VFS9S-2002PL	1	200	0.2	63	PBR-2007	1.5
VFS9S-2004PL	1	200	0.4	63	PBR-2007	1.5
VFS9S-2007PL	1	200	0.75	42	PBR-2007	1.5
VFS9S-2015PL	1	200	1.5	30	PBR-2022	1.5
VFS9S-2022PL	1	200	2.2	30	PBR-2022	1.2

Notice: VF-FS1, VF-nC3 and VF-nC1 can not connect the braking resistor.

Maximum value of β coefficient

Model	Maximum value of β coefficient
VF-AS1	1.5
VF-PS1	1.2
VF-A7	1.5
VF-P7	1.2
VF-S15, VF-S11, VF-S9	1.5
VF-nC3, VF-nC1	0.3 (for braking with only inverter)
VF-FS1	0.1 or less

β coefficient: Maximum reduction torque when using the braking resistor with a minimum allowable resistance (β x rated torque)

Matter to be attended:

If a reduction torque larger than a maximum reduction torque is loaded, the over-current trip or over-load trip for braking resistance may operate in the inverter.