TOSHIBA

E6581181⑫a

Inverter Application Manual

Leakage Current

– Contents –

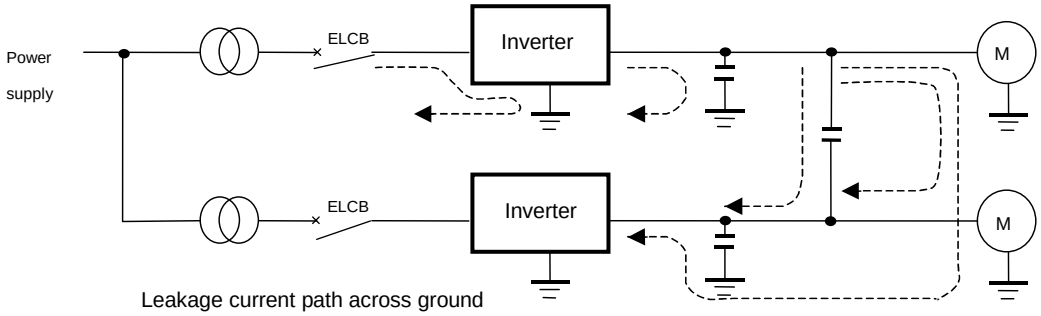
1. What is leakage current?

Leakage current flows through the inverter, its input and output wiring and electrostatic capacity of the motor, and it badly affects peripheral equipment. Leakage current depends on the inverter's carrier frequency, its input and output wiring system and length.

1.1 Influence of ground leakage current

1.1.1 Influence to other circuit

Leakage current may flow not only in the inverter's system but to other systems through its earth wire. Such the ground leakage current may cause malfunction of the Earth leakage circuit breaker (ELCB), ground-fault relay, fire alarm, and various sensors. Moreover, it may cause multiplex noise on the CRT screen and wrong indication of current detection by a CT.



Leakage current path across ground

Countermeasures:

1. Set the PWM carrier frequency lower.
   Setting of the PWM carrier frequency can be done by F300(CF). (Note 1)
2. Use an ELCB with low pass.
   If such a device is adopted, it is not required to lower the PWM carrier frequency.
3. If some influence on the sensor and CRT occurs, it can be eliminated by the measures mentioned in the item 1. However, if it is hard to take such the countermeasure due to increase of motor's magnetic noise, etc., contact your Toshiba distributor.

Note 1: The parameter's title depends on kind of inverter series.

1.1.2 Malfunction of over current function

The leakage current through the input/output power cables of inverter and capacitance of motor can affect to peripheral devices.

The value of leakage current is increased under the condition of the PWM carrier frequency and the length of the input/output power cables. In case the total cable length (total of length between an inverter and motors) is more than 100m, overcurrent trip can occur even the motor no-load current. Make enough space among each phase cable or install the rector or filter as countermeasure.

Single-phase 100V, Single-phase 200V, Three-phase 200V input class

Reactor type	VF-AS1	VF-PS1	VF-S15	VF-nC3
PFL-2001S	-	-	-	0.1-0.2kW
PFL-2005S	0.4kW	0.4kW	0.2-0.4kW	0.4-0.75kW
PFL-2011S	0.75-1.5kW	0.75-1.5kW	0.75-1.5kW	1.5kW
PFL-2018S	2.2kW	2.2kW	2.2kW	2.2kW
PFL-2025S	3.7kW	3.7kW	3.7kW	3.7kW

Note: Setting of carrier frequency: 2 kHz or lower, operating frequency: 60Hz or lower

Filter type	VF-AS1	VF-PS1	VF-S15	VF-FS1	VF-nC3
MSF-4015Z	0.4kW	0.4kW	0.2-0.4kW	0.4kW	0.1-0.4kW
MSF-4037Z	0.75-1.5kW	0.75-1.5kW	0.75-1.5kW	0.75-1.5kW	0.75-1.5kW
MSF-4075Z	2.2kW	2.2kW	2.2kW	2.2kW	2.2-3.7kW

Note: Setting of carrier frequency: 0.5 to 15 kHz, operating frequency: 60Hz or lower

Three-phase 400V input class

Reactor type	VF-AS1	VF-PS1	VF-S15
PFL-4012S	0.75-3.7kW	0.75-3.7kW	0.4-3.7kW

Note: Setting of carrier frequency: 2 kHz or lower, operating frequency: 60Hz or lower

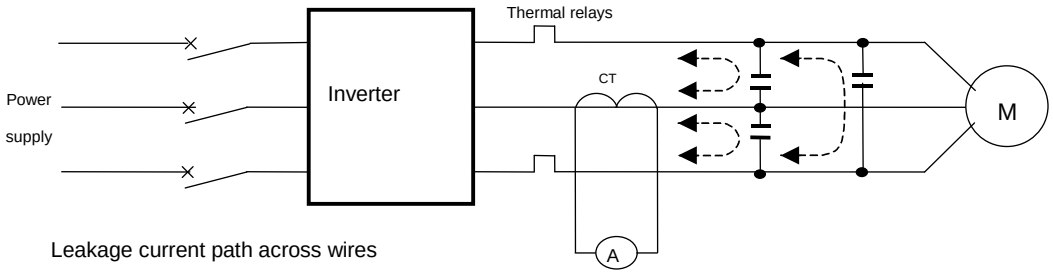
Filter type	VF-AS1	VF-PS1	VF-S15	VF-FS1
MSF-4015Z	0.75-1.5kW	0.75-1.5kW	0.4-1.5kW	0.4-1.5kW
MSF-4037Z	2.2-3.7kW	2.2-3.7kW	2.2-3.7kW	2.2-3.7kW

Note: Setting of carrier frequency: 0.5 to 15 kHz, operating frequency: 60Hz or lower

1.2 Influence of interline leakage current

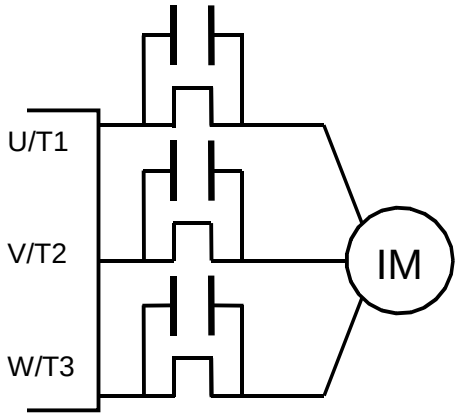
1.2.1 Thermal relay

The thermal relay externally connected with the inverter occasionally malfunctions, because the effective value of current is increased by high frequency component of leakage current flowing in the electrostatic capacity of the inverter output wiring. In case of long wiring of 50 m or more, or the model whose motor has a low rated current less than several amperes, particularly the 400 V class low capacity models as like under 3.7 kW, the externally connected thermal relay is apt to malfunction because the ratio of the leakage current to the rating of the motor is high.



Countermeasures:

1. Use the electronic thermal incorporated in the inverter.
   Setting of the electronic thermal can be done by OLN, F600 (tHr) (Note 1).
2. Lower the PWM carrier frequency of the inverter. In this case, the motor's magnetic noise increases.
   Setting of the PWM carrier frequency can be done by F300 (CF) (Note 1).
3. Connect a film capacity of 0.1 µF to 0.5 µF/1000 V approx. to the input and output terminal of each phase of the thermal relay. Influence by leakage current will be improved by the capacitors.



Note 1: The parameter's title depends on kind of inverter series.

1.2.2 CT, ammeter

When a CT and ammeter are externally connected with the inverter for detecting its output current, the CT and ammeter may burn out due to high frequency component of leakage current. In case of long wiring of 50 m or more, or the model whose motor has a low rated current less than several amperes, particularly the 400 V class low capacity 3.7 kW models, the externally connected ammeter is apt to burn because the ammeter is multiplexed by the high frequency component through the externally connected CT.

Countermeasures:

1. Use the meter output terminal of the inverter's control circuit.
   Output current can be outputted from the meter output terminal, FM or AM. When connecting a meter, use a 1 mA dc full-scale ammeter or 7.5 V-1 mA full-scale voltmeter.
2. Use the monitor function incorporated in the inverter.
   Use the monitor function of the built-in panel of the inverter to show the amperage.

1.3 General countermeasures

1. Wire the circuit cables apart from the ground as possible as the circumstances permit to increase the floating capacitor to ground.
2. Decrease the length of circuit cables, particularly the cables between the inverter and motor, in order to control increase of leakage current owing to higher harmonic.
3. Use cables whose floating capacity to ground is low.
   Example: 50 mm^2 cable's floating capacity to ground
   IV cable : 1.16 μF
   RB cable : 0.772 μF
   CV cable : 0.486 μF
4. Install the ELCB between the inverter and power supply. If it is installed in the output side of the inverter, it may occasionally malfunction due to high frequency current contained in the inverter output.
5. Set the carrier frequency of the inverter low, however, note that the motor's magnetic noise increases in this case.
6. Don't use a shielded cable and metal distributing tube.
   Install a zero-phase reactor between the inverter and power supply.
7. Separate the earth capacitor built-in the filter from the ground. However, it declines noise control effect.

2. Rough estimate of leakage current

2.1 Rough estimate of ground leakage current

Since there is electrostatic capacity to ground between the electric wire and ground, some leakage current always flows in the electric line even if insulation resistance (megohm) is normal. Such the leakage current can be roughly estimated by calculation if the type and size of the electric wire, the total length of the electric line between the ELCB and load equipment, and so on are known. Therefore, it is required to fix the rated sensitivity current to prevent the ELCB from malfunction caused by leakage current.

Leakage current $I_g = I_{g1} + \kappa * \times (I_{g2} + I_{g3}) + I_{g4}$

I_{g1} : Leakage current between ELCB and inverter

κ : Coefficient depending the type of ELCB

1 for Compact NJ series, NJV, ESPAR mighty series, LEH and etc.

3 for the old-type ELCB which doesn't have the low pass filter.

Note) Leakage current between inverter and motor is 3 times as much as that in commercial use because of including higher harmonic in case of the old-type ELCB.

I_{g2} : Leakage current between inverter and motor

I_{g3} : Leakage current from motor

I_{g4} : Leakage current from inverter's noise filter (power supply side)

Rated sensitivity current of ELCB > ΣI_gX10

ΣI_g : Amperage of total leakage current*

* Total leakage current when multiple inverters are connected with one ELCB

Estimate of leakage current from electric wire ... I_{g1}, I_{g2}

Leakage current can be estimated from the length of electric line of the load side of ELCB, type and size of electric wire. (Refer to 2.2, 2.3)

Estimate of leakage current from motor ... I_{g3}

If two or more motors are simultaneously started, check the capacity of each motor and number of motors first, and then estimate the leakage current referring to values of leakage current at start time shown in the separate table. (Refer to 2.4.)

Note on the models with built-in noise filter

The models with built-in noise filter use the capacitor in the circuit, therefore, leakage current in/from them are a little more than those without noise filter. When multiple inverters (with built-in noise filter) are connected with one ELCB, there is a fear that the ELCB may be activated. Therefore, take measures such as to increase the sensitivity current of the ELCB.

Applicable models:

All VF-AS1 models
All VF-PS1 models
All VF-FS1 models
VFA7-2004PL to -2075PL, -4007PL to -4150PL
All VF-S15 models
VF-S11 models except 600Vclass
All VF-S9 models
VFS7-4015PL to -4150PL
VFNC3S-2001 ~ 2022PL
All VF-MB1 models
VFNC1S-2002 ~ 2022PL

2.2 Estimate of leakage current in electric line

2.2.1 Leakage current by wire size (3-phase, 3-wire delta connection, 200 V)

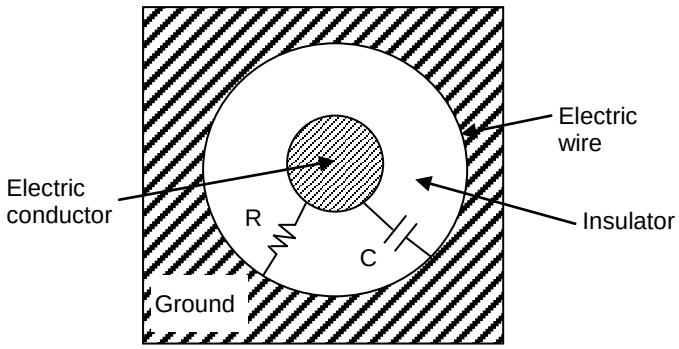
In case of 600 V vinyl-insulated wire (IV)

Leakage current per 1 km when IV wire is laid in contact with ground

Wire size [mm^2]	Electrostatic capacity [μF]	Insulation resistance [MΩ]	Leakage current by C [mA]	Leakage current by R [mA]	Leakage current [mA]
5.5	0.763	40	99.6	0.009	99.6
8	0.763	40	99.6	0.009	99.6
14	0.845	40	110.4	0.009	110.4
22	0.915	30	119.5	0.012	119.5
30	1.02	30	133.2	0.012	133.2
38	1.03	30	134.5	0.012	134.5
50	1.16	30	151.5	0.012	151.5
60	1.26	20	164.5	0.017	164.5
80	1.30	20	169.8	0.017	169.8
100	1.45	20	189.4	0.017	189.4
150	1.60	20	208.9	0.017	208.9
200	1.65	10	215.5	0.035	215.5
250	1.86	10	242.9	0.035	242.9
325	1.94	10	253.4	0.035	253.4
400	2.13	10	278.2	0.035	278.2
500	2.18	10	284.7	0.035	284.7

Remarks

1. Values of electrostatic capacity C and insulation resistance R are as shown in the figure on the right hand.
2. The values of the above table are based on reference materials of electric wire manufacturers.
3. Leakage current is estimated on condition that V = 200 V, f = 60 Hz.
   For estimate at 50 Hz, multiply the value by 0.84.
4. Theoretical equation of electrostatic current C:
   $C = 0.02413\ \varepsilon/\log_{10}(d2/d1)(\mu F/km)$



In case of rubber-insulated wire (RB) and 3-core 600 V bridge-type polyethylene-insulated wire (CV)

Leakage current per 1 km when RB or CV wire is laid in contact with ground

Wire type	RB			CV		
Wire size [mm^2]	Electrostatic capacity [μF]	Insulation resistance [MΩ]	Leakage current by C [mA]	Electrostatic capacity [μF]	Insulation resistance [MΩ]	Leakage current by C [mA]
5.5	0.400	60	52.2	0.251	2500	32.8
8	0.467	60	61.0	0.289	2500	37.7
14	0.573	60	74.8	0.368	2500	48.1
22	0.582	50	76.0	0.380	2500	49.6
30	0.654	50	85.4	0.426	2500	55.6
38	0.722	50	94.3	0.486	2000	63.5
50	0.722	40	94.3	0.486	2000	63.5
60	0.722	40	94.3	0.486	2000	63.5
80	0.812	30	106.0	0.535	2000	69.9
100	0.812	30	106.0	0.535	1500	69.9
150	0.885	30	115.6	0.563	1500	73.5
200	0.885	30	115.6	0.563	1500	73.5
250	0.900	30	117.5	0.573	1500	74.8
325	0.997	30	130.2	0.649	1000	84.8
400	1.030	30	134.5	0.718	1000	93.8
500	1.030	30	134.5	0.718	900	93.8

Remarks

1. Values of electrostatic capacity C and insulation resistance R are those at installation mentioned in the preceding page.
2. The values of the above table are based on reference materials of electric wire manufacturers.
3. Leakage current is estimated on condition that V = 200 V, f = 60 Hz.
   For estimate at 50 Hz, multiply the value by 0.84.
4. The values of 3-core 600 V bridge-type polyethylene-insulated wire (CV) are those of three phases in one lump sum.

2.2.2 Estimate of leakage current in other wiring systems

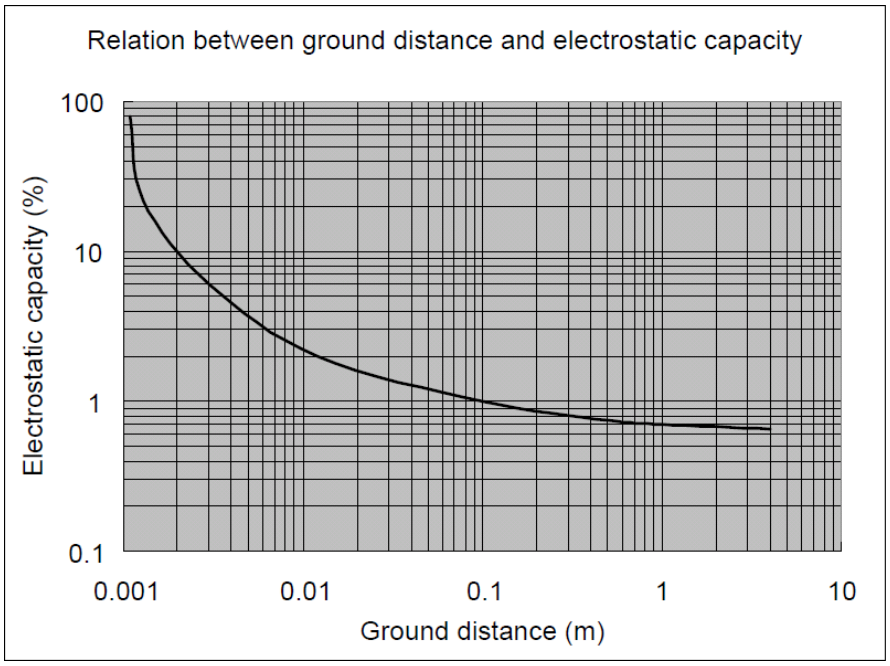
Leakage current in other wiring systems can be found by multiplying the value found by the above-mentioned method by the conversion value shown in the table below.

Type of wiring system	Magnification
Single-phase 100 V line	0.3
Single-phase 200 V line	0.3
Three-phase 400 V line (star connection)	0.7

2.3 Wiring work method and leakage current

2.3.1 Relation between ground distance and electrostatic capacity

When wire is installed apart from ground, electrostatic capacity decreases as shown in the figure below.



2.3.2 In the case wire is installed 4 m or more apart from ground

When the wire is installed 4 m or more apart from ground, iron reinforcing rod or steel frame such as wiring on the first floor ceiling of a wooden house, wiring in the second and higher floors, aerial wiring with utility pole, and so on, electrostatic capacity of the wire to ground is about 0.6 % of the value shown in the section 2.2. Therefore, leakage current is as shown in the following table.

Leakage current per 1 km line when wire is 4 m or more apart from ground

Unit: mA

Type of wire / Wire size mm^2	IV	RB	CV
5.5	0.60	0.31	0.20
8	0.60	0.37	0.23
14	0.66	0.45	0.29
22	0.72	0.46	0.30
30	0.80	0.51	0.,33
38	0.81	0.57	0.38
50	0.91	0.57	0.38
60	0.99	0.57	0.38
80	1.02	0.64	0.42
100	1.14	0.64	0.42
150	1.25	0.69	0.44
200	1.29	0.69	0.44
250	1.46	0.71	0.45
325	1.52	0.78	0.51
400	1.67	0.81	0.56
500	1.71	0.81	0.56

2.3.3 In the case wire is installed 10 cm or more apart from ground

Unit: mA

Type of wire / Wire size mm^2	IV	RB	CV
5.5	1.29	0.68	0.43
8	1.29	0.79	0.49
14	1.44	0.97	0.63
22	1.55	0.99	0.64
30	1.73	1.11	0.72
38	1.75	1.22	0.83
50	1.97	1.22	0.83
60	2.14	1.22	0.83
80	2.21	1.38	0.91
100	2.46	1.38	0.91
150	2.72	1.50	0.96
200	2.80	1.50	0.96
250	3.16	1.53	0.97
325	3.29	1.69	1.10
400	3.62	1.75	1.22
500	3.70	1.75	1.22

Leakage current decreases to 1.3 % approx.

2.3.4 In the case wire is installed 1.5 mm or more apart from ground

Unit: mA

Type of wire / Wire size mm^2	IV	RB	CV
5.5	19.9	10.4	6.6
8	19.9	12.2	7.5
14	22.1	15.0	9.6
22	23.9	15.2	9.9
30	26.6	17.1	11.1
38	26.9	18.9	12.7
50	30.3	18.9	12.7
60	32.9	18.9	12.7
80	34.0	21.2	14.0
100	37.9	21.2	14.0
150	41.8	23.1	14.7
200	43.1	23.1	14.7
250	48.6	23.5	15.0
325	50.7	26.0	17.0
400	55.6	26.9	18.8
500	56.8	26.9	18.8

Leakage current decreases to 20 % approx.

2.3.5 In the case wire is installed in contact with ground

There is no decrease in leakage current (same as the result of estimate in the section 2.1).

2.4 Leakage current from motor

In case of the motor, it is necessary to take leakage current during operation and at starting into consideration.
Leakage current during motor operation flows through electrostatic capacity to ground and insulation resistance to ground. At starting, leakage current is the same as that in operation because only load current increases at that time. However, since magnetic flux generated in zero-phase current transformer slightly differs due to each primary conductor current caused by the arrangement of the primary conductor of the zero-phase current transformer of the ELCB, there is a little output in the secondary side of the zero-phase current transformer even if there is no actual leakage current. Therefore, it is required to pay careful attention to estimate leakage current at motor starting, because considerable load current flows and the secondary output of the zero-phase current transformer increases by the balance characteristic at starting.

Example of leakage current from totally-enclosed-fan-cooled type motor (200 V)

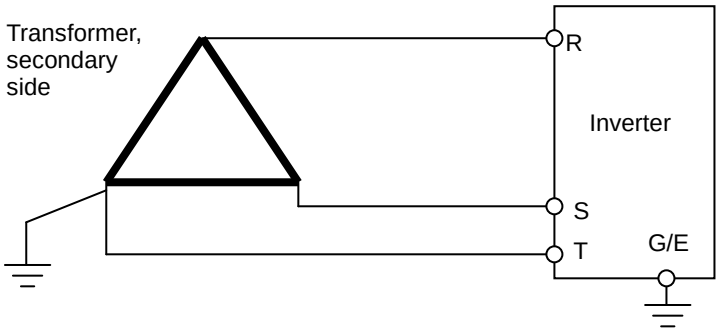
Capacity [kW]	Motor			Estimate of leakage current			
	Full-load current [A] / Starting current [A]	Electrostatic capacity to ground per phase C[μF]	Insulation resistance to ground per phase R [MΩ]	Leakage current by C I_C [mA]	Leakage current by R I_R [mA]	Influence of zero-phase current at starting I_M [mA]	Leakage current $I_{gM}=I_C+I_R+I_M$ [mA]
0.2	1.1	0.0004	10	0.05	0.04	-	0.06
	7.7					0.08	0.14
0.4	1.9	0.0006		0.08		-	0.09
	13.3					0.14	0.23
0.75	3.2	0.0008		0.11		-	0.12
	22.4					0.23	0.35
1.5	6.0	0.0011		0.14		-	0.15
	42.0					0.43	0.58
2.2	8.4	0.0014		0.18		-	0.18
	58.8					0.61	0.79
3.7	14.0	0.0020		0.26		-	0.26
	98.0					1.01	1.27
5.5	20.5	0.0022		0.29		-	0.29
	143.5					1.28	1.57
7.5	27.5	0.0029		0.38		-	0.38
	192.5					1.67	2.05
11	41.0	0.0040		0.52		-	0.50
	287.0					1.89	2.39
15	52.0	0.0044		0.57		-	0.57
	364.0					2.06	2.63
18.5	66.0	0.0050		0.65		-	0.65
	462.0					2.38	3.03
22	76.5	0.0055		0.72		-	0.72
	535.5					2.76	3.48
30	103	0.0067		0.87		-	0.87
	721.0					3.71	4.58
37	127	0.0077		1.00		-	1.00
	889.0					4.57	5.57
45	153	0.0084		1.09		-	1.09
	1071					5.51	6.60
55	188	0.0094		1.22		-	1.22
	1316					6.77	7.99
75	252	0.0114		1.48		-	1.48
	1764					9.07	10.54
90	300	0.0127		1.65		-	1.65
	2100					10.80	12.45
110	374	0.0150		1.95		-	1.95
	2618					13.50	15.45

3. Leakage current from inverter

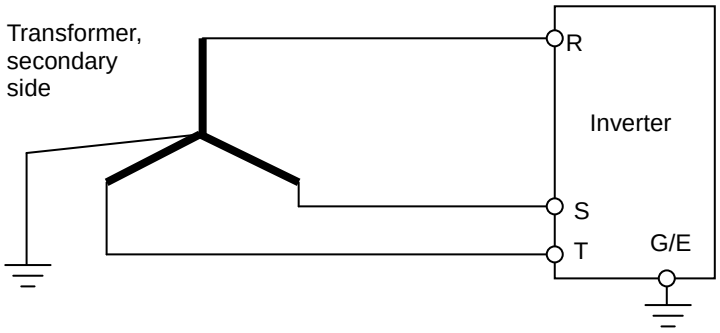
Leakage current from the general-purpose inverter depends on the ground capacitor for preventing noise generated by the inverter from leaking out in general. Such being the case, leakage current occurs whenever the power supply to inverter is turned on (as the motor is still stopped).
In case of inverter models with the built-in noise filter, note that leakage current at the one-phase grounding power source may be higher than that of general inverters.

3.1 Cause of large leakage current depending on input power source connection method

Regarding some 200 V class inverters, the input power supply line is in delta-connection with one-phase grounding. In case of one-phase grounding power supply, the supply voltage impressed to the ground capacitor of each phase on the noise filter board becomes unbalanced and leakage current flows through the ground terminal.

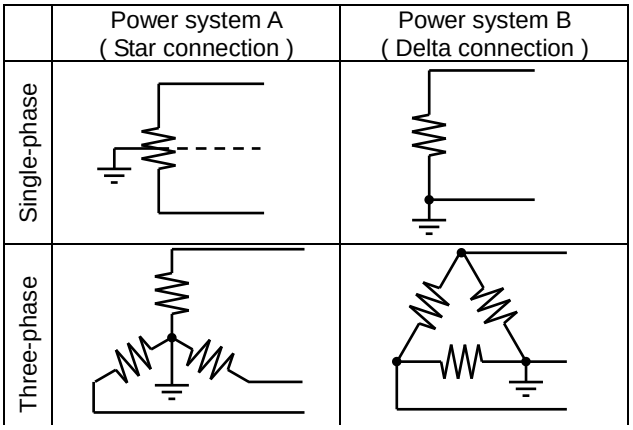


In the case the input power supply line is in star connection and neutral grounding, there is no leakage current because of unbalanced supply voltage, however, a slight leakage current actually occurs because of unbalanced original power source.
Generally, 400 V class inverters have the input power supply of star-connection and neutral grounding.



3.2 Leakage current from the built-in filter inside inverter

Amperage of leakage current differs depending on balanced/unbalanced power supply and wiring condition. Maximum amperage of estimate is shown below as the standard value.



■TOSVERT VF-S15series

Inverter type-form	Approximate leakage current [mA] note1)			
	Standard note2)		Small capacitors note2)	
	Power system A	Power system B	Power system A	Power system B
	Max.	Max.	Max.	Max.
VFS15S-2002PL	1.2	6.1	0.0	0.0
VFS15S-2004PL	1.2	6.1	0.0	0.0
VFS15S-2007PL	1.2	6.1	0.0	0.0
VFS15S-2015PL	1.7	8.9	0.0	0.0
VFS15S-2022PL	1.7	8.9	0.0	0.0
VFS15-2002PM	0.1	0.9	-	-
VFS15-2004PM	0.1	0.9	-	-
VFS15-2007PM	0.1	0.9	-	-
VFS15-2015PM	0.1	0.9	-	-
VFS15-2022PM	0.1	0.9	-	-
VFS15-2037PM	0.1	0.9	-	-
VFS15-2055PM	0.1	0.9	-	-
VFS15-2075PM	0.1	0.9	-	-
VFS15-2110PM	0.1	0.9	-	-
VFS15-2150PM	0.1	0.9	-	-
VFS15-4004PL	6.2	44.4	0.0	0.0
VFS15-4007PL	6.2	44.4	0.0	0.0
VFS15-4015PL	6.2	44.4	0.0	0.0
VFS15-4022PL	7.9	57.2	0.0	0.0
VFS15-4037PL	7.9	57.2	0.0	0.0
VFS15-4055PL	6.6	80.9	0.0	0.0
VFS15-4075PL	6.6	80.9	0.0	0.0
VFS15-4110PL	6.8	83.2	0.0	0.0
VFS15-4150PL	6.8	83.2	0.0	0.0

Note 1) The value of leakage current is estimated in the condition below.
Frequency of power supply:
60 Hz
Voltage of power supply:
240V for 200V class,
500V for 400V class
Note2) “Standard” means the grounding capacitor disconnecting switch ON, and “Small capacitors” means the switch OFF.

■TOSVERT VF-S11series

Inverter type-form	Approximate leakage current [mA] note1)			
	Standard note2)		Small capacitors note2)	
	Power system A	Power system B	Power system A	Power system B
	Max.	Max.	Max.	Max.
VFS11S-2002PL / PLE	0.4	3.6	0.0	0.0
VFS11S-2004PL / PLE	0.4	3.6	0.0	0.0
VFS11S-2007PL / PLE	0.4	3.6	0.0	0.0
VFS11S-2015PL / PLE	0.9	7.6	0.0	0.0
VFS11S-2022PL / PLE	0.9	7.6	0.0	0.0
VFS11-2002PM	0.1	0.8	-	-
VFS11-2004PM / PME	0.1	0.8	-	-
VFS11-2007PM / PME	0.1	0.8	-	-
VFS11-2015PM / PME	0.1	0.8	-	-
VFS11-2022PM / PME	0.1	0.8	-	-
VFS11-2037PM / PME	0.1	0.8	-	-
VFS11-2055PM	0.1	0.8	-	-
VFS11-2075PM	0.1	0.8	-	-
VFS11-2110PM	0.1	0.8	-	-
VFS11-2150PM	0.1	0.8	-	-
VFS11-4004PL / PLE	5.0	35.6	0.0	0.0
VFS11-4007PL / PLE	5.0	35.6	0.0	0.0
VFS11-4015PL / PLE	5.0	35.6	0.0	0.0
VFS11-4022PL / PLE	6.4	45.7	0.0	0.0
VFS11-4037PL / PLE	6.4	45.7	0.0	0.0
VFS11-4055PL / PLU	3.1	22.7	0.0	0.0
VFS11-4075PL / PLU	3.1	22.7	0.0	0.0
VFS11-4110PL / PLU	5.3	37.8	0.0	0.0
VFS11-4150PL / PLU	5.3	37.8	0.0	0.0

Note 1) The value of leakage current is estimated in the condition below.
Frequency of power supply: 60 Hz
Voltage of power supply: 200V for 200V class,
400V for 400V class

Note2) “Standard” means the grounding capacitor disconnecting switch ON, and “Small capacitors” means the switch OFF.

■TOSVERT VF-nC3 series

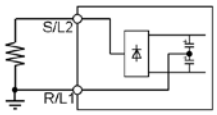
Inverter type-form	Approximate leakage current [mA] note1)			
	Standard note2)		Small capacitors note2)	
	Power system A	Power system B	Power system A	Power system B
VFNC3S-1001P	0.85	1.88	-	-
VFNC3S-1002P	0.85	1.88	-	-
VFNC3S-1004P	0.85	1.88	-	-
VFNC3S-1007P	0.26	0.26	-	-
VFNC3S-2001PL	1.63	9.77	0.89	2.64
VFNC3S-2002PL	1.63	9.77	0.89	2.64
VFNC3S-2004PL	1.63	9.77	0.89	2.64
VFNC3S-2007PL	1.63	9.77	0.89	2.64
VFNC3S-2015PL	4.63	25.5	0.27	1.63
VFNC3S-2022PL	4.63	25.5	0.27	1.63
VFNC3-2001P	0.1	0.88	-	-
VFNC3-2002P	0.1	0.88	-	-
VFNC3-2004P	0.1	0.88	-	-
VFNC3-2007P	0.1	0.88	-	-
VFNC3-2015P	0.1	0.88	-	-
VFNC3-2022P	0.1	0.88	-	-
VFNC3-2037P	0.2	1.07	-	-

Note 1) The value of leakage current is estimated in the condition below.
Frequency of power supply: 60 Hz
Voltage of power supply: 120V for 100V class, 240V for 200V class

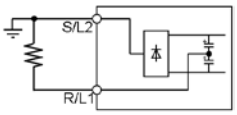
Note2) “Standard” means the grounding capacitor disconnecting switch ON, and “Small capacitors” means the switch OFF.

Note 3)
In case of single phase 100V input model, the power system A and B are the followings;

Power system A



Power system B



■TOSVERT VF-MB1 series

	Approximate leakage current [mA] note1)			
	Standard note2)		Small capacitors note2)	
	Power system A	Power system B	Power system A	Power system B
VFMB1S-2002PL	1.38	7.49	0.13	0.66
VFMB1S-2004PL	1.38	7.49	0.13	0.66
VFMB1S-2007PL	1.38	7.49	0.13	0.66
VFMB1S-2015PL	1.36	10.55	0.10	0.67
VFMB1S-2022PL	1.36	10.55	0.10	0.67
VFMB1-4004PL	3.54	31.86	0.04	0.38
VFMB1-4007PL	3.54	31.86	0.04	0.38
VFMB1-4015PL	3.54	31.86	0.04	0.38
VFMB1-4022PL	5.43	48.82	0.04	0.38
VFMB1-4037PL	5.43	48.82	0.04	0.38
VFMB1-4055PL	6.6	80.9	-	-
VFMB1-4075PL	6.6	80.9	-	-
VFMB1-4110PL	6.8	83.2	-	-
VFMB1-4150PL	6.8	83.2	-	-

Note 1) The value of leakage current is estimated in the condition below.
Frequency of power supply : 60 Hz
Voltage of power supply :
240V for 240V class
500V for 500V class

Note 2) “Standard” means the grounding capacitor disconnecting switch ON, and “Small capacitors” means the switch OFF.

■TOSVERT VF-FS1series

Inverter type-form	Approximate leakage current [mA] note1)			
	Standard note2)		Small capacitors note2)	
	Power system A	Power system B	Power system A	Power system B
	Max.	Max.	Max.	Max.
VFFS1-2004PM	0.1	0.8	-	-
VFFS1-2007PM	0.1	0.8	-	-
VFFS1-2015PM	0.1	0.8	-	-
VFFS1-2022PM	0.1	0.8	-	-
VFFS1-2037PM	0.1	0.8	-	-
VFFS1-2055PM	0.1	0.8	-	-
VFFS1-2075PM	0.1	0.8	-	-
VFFS1-2110PM	0.1	0.8	-	-
VFFS1-2150PM	0.1	0.8	-	-
VFFS1-2185PM	0.1	0.8	-	-
VFFS1-2220PM	0.1	0.6	-	-
VFFS1-2300PM	0.1	0.7	-	-
VFFS1-4004PL	5.0	35.6	0	0
VFFS1-4007PL / PLE	5.0	35.6	0	0
VFFS1-4015PL / PLE	5.0	35.6	0	0
VFFS1-4022PL / PLE	5.0	35.6	0	0
VFFS1-4037PL / PLE	6.4	45.7	0	0
VFFS1-4055PL / PLE	6.4	45.7	0	0
VFFS1-4075PL / PLE	3.1	22.7	0	0
VFFS1-4110PL	3.1	22.7	0	0
VFFS1-4110PLE	10.0	71.8	0	0
VFFS1-4150PL	5.3	37.8	0	0
VFFS1-4150PLE	10.0	71.8	0	0
VFFS1-4185PL	5.3	37.8	0	0
VFFS1-4185PLE	25.1	183.8	0	0
VFFS1-4220PL / PLE	17.5	126.8	0	0
VFFS1-4300PL / PLE	17.5	126.8	0	0
VFFS1-4370PL / PLE	10.1	72.4	0	0.3
VFFS1-4450PL / PLE	10.1	72.4	0	0.3
VFFS1-4550PL / PLE	10.1	72.4	0	0.3
VFFS1-4750PL / PLE	10.1	72.4	0	0.3
VFFS1-4004PDE	20.2	144.3	0	0
VFFS1-4007PDE	20.2	144.3	0	0
VFFS1-4015PDE	20.2	144.3	0	0
VFFS1-4022PDE	20.2	144.3	0	0
VFFS1-4037PDE	53.2	383.7	0	0
VFFS1-4055PDE	53.2	383.7	0	0
VFFS1-4075PDE	74.1	541.7	0	0
VFFS1-4110PDE	39.4	284.9	0	0
VFFS1-4150PDE	39.4	284.9	0	0
VFFS1-4185PDE	64.8	474.4	0	0
VFFS1-4220PDE	81.2	586.1	0.9	7.1
VFFS1-4300PDE	81.2	586.1	0.9	7.1
VFFS1-4370PDE	69.3	498.7	0.9	7.1
VFFS1-4450PDE	69.3	498.7	0.9	7.1
VFFS1-4550PDE	61.1	447.3	0.9	7.1
VFFS1-4750PDE	61.1	447.3	0.9	7.1

Note 1) The value of leakage current is estimated in the condition below.
Frequency of power supply: 60 Hz
Voltage of power supply: 200V for 200V class, 400V for 400V class
Note2) “Standard” means the grounding capacitor disconnecting switch ON, and “Small capacitors” means the switch OFF.

■TOSVERT VF-AS1/VF-PS1series

Inverter type-form		Approximate leakage current [mA] note1)			
		Standard note2)		Change capacitors switch note2)	
		Power system A	Power system B	Power system A	Power system B
VF-AS1	VF-PS1	Max.	Max.	Max.	Max.
VFAS1-2004PL	VFPS1-2004PL	1.6	13.2	0.0	0.0
VFAS1-2007PL	VFPS1-2007PL	1.6	13.2	0.0	0.0
VFAS1-2015PL	VFPS1-2015PL	1.6	13.2	0.0	0.0
VFAS1-2022PL	VFPS1-2022PL	2.4	19.4	0.0	0.0
VFAS1-2037PL	VFPS1-2037PL	2.4	19.4	0.0	0.0
VFAS1-2055PL	VFPS1-2055PL	1.6	13.2	0.0	0.0
VFAS1-2075PL	VFPS1-2075PL	2.4	19.4	0.0	0.0
VFAS1-2110PM	VFPS1-2110PM	1.1	7.7	0.1	0.7
VFAS1-2150PM	VFPS1-2150PM	1.1	7.7	0.1	0.7
VFAS1-2185PM	VFPS1-2185PM	0.1	1.1	0.05	0.3
VFAS1-2220PM	VFPS1-2220PM	0.1	1.1	0.05	0.3
VFAS1-2300PM	VFPS1-2300PM	0.1	0.9	0.02	0.2
VFAS1-2370PM	VFPS1-2370PM	0.1	0.9	0.02	0.2
VFAS1-2450PM	VFPS1-2450PM	0.1	0.9	0.02	0.2
VFAS1-2550P	VFPS1-2550P VFPS1-2750P	0.0	0.3	48.1	387.4
VFAS1-2750P	VFPS1-2900P	0.0	0.3	48.1	387.4
VFAS1-4007PL	VFPS1-4007PL / PLE	8.1	58.0	0.0	0.0
VFAS1-4015PL	VFPS1-4015PL / PLE	8.1	58.0	0.0	0.0
VFAS1-4022PL	VFPS1-4022PL / PLE	8.1	58.0	0.0	0.0
VFAS1-4037PL	VFPS1-4037PL / PLE	9.2	66.2	0.0	0.0
VFAS1-4055PL	VFPS1-4055PL / PLE	9.2	66.2	0.0	0.0
VFAS1-4075PL	VFPS1-4075PL / PLE	9.2	66.2	0.0	0.0
VFAS1-4110PL	VFPS1-4110PL / PLE	17.4	125.2	0.0	0.0
VFAS1-4150PL	VFPS1-4150PL / PLE	12.4	88.5	0.0	0.0
VFAS1-4185PL	VFPS1-4185PL / PLE	21.9	158.5	0.0	0.0
VFAS1-4220PL	VFPS1-4220PL / PLE	14.3	104.9	0.1	0.5
VFAS1-4300PL	VFPS1-4300PL / PLE	28.2	202.3	0.1	0.7
VFAS1-4370PL	VFPS1-4370PL / PLE	28.2	202.3	0.1	0.7
VFAS1-4450PL	VFPS1-4450PL / PLE	12.1	86.4	0.05	0.3
VFAS1-4550PL	VFPS1-4550PL / PLE	12.1	86.4	0.05	0.3
VFAS1-4750PL	VFPS1-4750PL / PLE VFPS1-4900PLE	12.1	86.4	0.05	0.3
VFAS1-4900PC	VFPS1-4900PC VFPS1-4110KPC	0.1	0.7	96.1	774.8
VFAS1-4110KPC	VFPS1-4132KPC	0.1	0.7	96.1	774.8
VFAS1-4132KPC	VFPS1-4160KPC	0.1	0.7	96.1	774.8
VFAS1-4160KPC	VFPS1-4220KPC	0.1	0.7	96.1	774.8
VFAS1-4200KPC	VFPS1-4250KPC	0.1	0.7	96.1	774.8
VFAS1-4220KPC	VFPS1-4280KPC	0.1	0.7	96.1	774.8
VFAS1-4280KPC	VFPS1-4315KPC	0.1	0.7	96.1	774.8
VFAS1-4355KPC	VFPS1-4400KPC	0.1	0.7	96.1	774.8
VFAS1-4400KPC	VFPS1-4500KPC	0.1	0.7	96.1	774.8
VFAS1-4500KPC	VFPS1-4630KPC	0.1	0.7	96.1	774.8

Note 1) The value of leakage current is estimated in the condition below;
Frequency of power supply: 60 Hz
Voltage of power supply: 240V for 200V class,
480V for 400V class

Note 2) Change capacitors switch:
"Standard" is in a condition of shipment. In case of changing capacitor switch, the leakage current is to be larger over 200V-55kW, 400V-90kW.

Amperage of leakage current differs depending on balanced/unbalanced power supply and wiring condition. Maximum amperage of estimate is shown below as the standard value.

VF-A7:	VFA7-2004PL to -2037PL	4 mA approx.
	VFA7-2055PL, -2075PL	13 mA approx.
VF-S9:	VFS9-2002PM to -2015PM	2 mA approx.
	VFS9-2022PM, -2073PM	9 mA approx.
	VFS9-2055PL to -2150PM	19 mA approx.
VF-S9S:	VFS9S-xxxxPL	6 to 8 mA approx.
VF-NC1:	VFNC1-2001P to -2022P	1 mA approx.
	VFNC1S-2002P to -2007P	6 mA approx.
	VFNC1S-2015P, -2022P	3 mA approx.
	VFNC1S-1001P to -1007P	3 mA approx.
	VFNC1S-2002PL to -2007PL	11 mA approx.
	VFNC1S-2015PL, -2022PL	17 mA approx.

*** This leakage current is generated whenever the power supply to inverter is turned on.**

3.3 Measures against power supply of delta-connection (one-phase grounding)

When multiple inverters are connected with one ELCB or the ELCB malfunctions because of leakage current mentioned above, it is required to increase the value of sensitivity current of the ELCB.

4. Leakage current from noise filter

Since the noise filter including simple type, high attenuation type, and EMC filter has a built-in ground capacitor, leakage current flows whenever the power supply to inverter is turned on. For using some optional noise filter, it is required to add the value of leakage current from the equipment to the value of leakage current estimated in the item 2.

4.1 Leakage current from simple type, high attenuation type noise filter

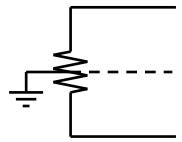
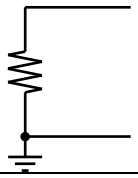
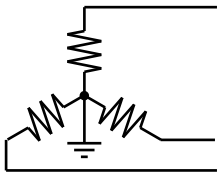
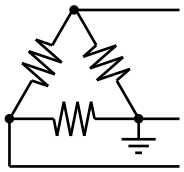
Filter type-form	Approximate leakage current [mA]
RCL-M2	6.7
RCL-M4	13.4
NF3005A-MJ (Single-phase 200 V)	0.98
NF3005A-MJ ~ NF3080A-MJ (Three-phase 200 V)	1.63

* The leakage current shown in the above table is of all phases of delta-connection (one-phase grounding) or star-connection (one phase missing).
(Reference standard: IEC-1000-2-4 ... capacitor's capacity deviation: ±20%, unbalanced supply voltage: ±3% included)

4.2 Leakage current from EMC command adaptable EMC filter for VF-S15/VF-S11/VF-FS1

Filter type- form	Inverter type-form VF-S15	Inverter type-form VF-S11	Inverter type-form VF-FS1	Leakage current (mA) Note)	
				Power system A	Power system B
EMFS11S-2009AZ	VFS15S-2002~2007PL	VFS11S-2002~2007PL	-	3	47
EMFS11-2007AZ	VFS15-2002~2007PM	VFS11-2002~2007PM	-	7	45
EMFS11S-2016BZ	VFS15S-2015PL	VFS11S-2015PL	-	3	47
EMFS11-4015BZ	VFS15-2015,2022PM	VFS11-2015,2022PM	VFFS1-2004~2022PM	8	48
	VFS15-4004~4015PL	VFS11-4004~4015PL	VFFS1-4004~4022PL	15	96
EMFS11S-2022CZ	VFS15S-2022PL	VFS11S-2022PL	-	6	103
EMFS11-4025CZ	VFS15-2037PM	VFS11-2037PM	VFFS1-2037PM	20	125
	VFS15-4022,4037PL	VFS11-4022,4037PL	VFFS1-4037,4055PL	40	249
EMFS11-4047DZ	VFS15-2055,2075PM	VFS11-2055,2075PM	VFFS1-2055,2075PM	23	147
	VFS15-4055,4075PL	VFS11-4055,4075PL	VFFS1-4075,4110PL	47	293
EMFS11-2083EZ	VFS15-2110,2150PM	VFS11-2110,2150PM	VFFS1-2110~2185PM	17	104
EMFS11-4049EZ	VFS15-4110,4150PL	VFS11-4110,4150PL	VFFS1-4150,4185PL	47	293
VW3A4406	-	-	VFFS1-2220PM	36	268
			VFFS1-4220,4300PL	70	535
VW3A4408	-	-	VFFS1-2300PM	70	537

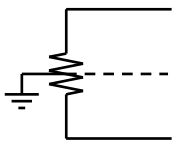
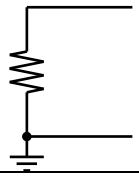
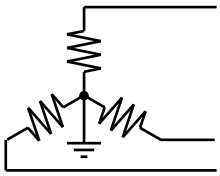
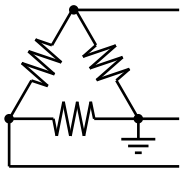
Note) These values are referential ones of EMC filter. For 200V class, 60Hz/200V power supply.
For 400V class, 60Hz/400V power supply. For power system A and B, refer to table below.
Select an earth leakage circuit breaker with consideration of leakage current above and leakage current from the inverter unit.

	Power system A	Power system B
1-phase		
3-phase		

4.3 Leakage current from EMC command adaptable EMC filter for VF-MB1

Filter Type-form	Inverter type-form VF-MB1	Leakage current (mA) Note)	
		Power system A	Power system B
EMF4S-2010A	VFMB1S-2002～2007PL	10	54
EMF4S-2018B	VFMB1S-2015PL	10	54
EMF4S-2024C	VFMB1S-2022PL	23	119
EMF4-4015B	VFMB1-4004～4037PL	17	125
EMF4-4047D	VFMB1-4055～4075PL	52	383
EMF4-4049E	VFMB1-4110～4150PL	52	383

Note) These values are referential ones of EMC filter. For 240V class, 60Hz/240V power supply.
For 500V class, 60Hz/500V power supply. For power system A and B, refer to table below.
Select an earth leakage circuit breaker with consideration of leakage current above and leakage current from the inverter unit.

	Power system A	Power system B
1-phase		
3-phase		

4.4 Leakage current from foot-mounted type filter for VF-nC3/nC1

Filter Type-form	Inverter type-form VF-nC3	Inverter type-form VF-nC1	Approximate leakage current [mA]
EMFAS2011Z	VFnC3S-1001P~1004P	VFnC1S-1001P~1004P	54
EMFAS2025Z	VFnC3S-1007P	VFnC1S-1007P	18
EMFAS2011Z	VFnC3S-2001~2007P	VFnC1S-2002~2007P	112
EMFAS2025Z	VFnC3S-2015, 2022P	VFnC1S-2015, 2022P	37
EMFA2006Z	VFnC3-2001~2007P	VFnC1-2001~2007P	117
EMFA2015Z	VFnC3-2015, 2022P	VFnC1-2015, 2022P	117
EMFS11-4025CZ	VFnC3-2037P	-	125

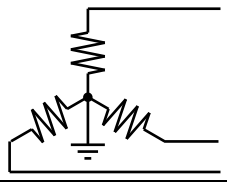
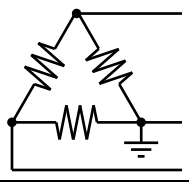
* The leakage current shown in the above table is of all phases of delta-connection (one-phase grounding). (Reference standard: IEC-1000-2-4 ... capacitor's capacity deviation: ±20%, unbalanced supply voltage: ±3% included)

4.5 Leakage current from EMC command adaptable EMC filter for VF-AS1/PS1

Filter type-form	Inverter type-form VF-AS1	Inverter type-form VF-PS1	Leakage current (mA) Note 1)	
			Power system A	Power system B
VW3A4401	VFAS1-2004~2015PL	VFPS1-2004~2015PL	5	35
	VFAS1-4007~4022PL	VFPS1-4007~4022PL	9	71
VW3A4402	VFAS1-2022~2037PL	VFPS1-2022~2037PL	6	42
	VFAS1-4037PL	VFPS1-4037PL	11	83
VW3A4403	VFAS1-2055PL	VFPS1-2055PL	4	25
	VFAS1-4055, 4075PL	VFPS1-4055, 4075PL	6	44
VW3A4404	VFAS1-2075PL	VFPS1-2075PL	12	91
	VFAS1-4110PL	VFPS1-4110PL	24	183
VW3A4405	VFAS1-2110, 2150PM	VFPS1-2110, 2150PM	25	195
	VFAS1-4150, 4185PL	VFPS1-4150, 4185PL	52	390
VW3A4406	VFAS1-2185, 2220PM	VFPS1-2185, 2220PM	36	268
	VFAS1-4220PL	VFPS1-4220PL	70	535
VW3A4407	VFAS1-4300, 4370PL	VFPS1-4300, 4370PL	70	535
VW3A4408	VFAS1-2300~2450PM	VFPS1-2300~2450PM	70	537
	VFAS1-4450~4750PL	VFPS1-4450~4750PL	142	1075
VW3A4410	VFAS1-2550, 2750P	VFPS1-2550, 2750P	3	180
	VFAS1-4900~4132KPC	VFPS1-4900~4132KPC	5	350
VW3A4411	VFAS1-4160~4280KPC VFAS1-4355KPC Note 2) VFAS1-4400KPC Note 2) VFAS1-4500KPC Note 2)	VFPS1-2900P, 4160~4315KPC VFPS1-4500KPC Note 2) VFPS1-4630KPC Note 2)	5	350
VW3A4412	-	VFPS1-4400KPC	5	350

Note 1) These values are referential ones of EMC filter. For 200V class, 60Hz/200V power supply. For 400V class, 60Hz/400V power supply. For power system A and B. refer to table below.
Select an earth leakage circuit breaker with consideration of leakage current above and leakage current from the inverter unit.

Note 2) Need to use 2 pieces parallel.

Power system A	Power system B
	

4.6 Leakage current from EMC command adaptable EMC filter for VF-A7/P7

Filter type-form	Approximate leakage current 2 [mA]
FN258-7/07	67
FN258-16/07	70
FN258-30/07	100
FN258-42/07	104
FN258-75/34	104
FN258-100/35	104
FN258-130/35	32.8
FN258-180/07	32.8
FN258-250/07	32.8
FN3258-75/52	33
FN3258-100/04	33
FN3258-180/04	33
FN359-250~900/99	39
FN359H-250~900/99	51
FN3359(HV)-250~900/99	< 6.0

* The leakage current shown in the above table is of all phases of delta-connection (one-phase grounding) or star-connection (one phase missing).
(Reference standard: IEC-1000-2-4 ... capacitor's capacity deviation: ±20%, unbalanced supply voltage: ±3% included)

4.7 Leakage current from foot-mounted type filter for VF-S9

Filter type-form	Inverter type-form	Approximate leakage current [mA]
EMFS2010AZ	VFS9S-2002PL~2007PL	90
EMF2011BZ	VFS9-2002PM~2015PM	112
EMFS2016CZ	VFS9S-2015PL	93
EMF4006CZ	VFS9-4007, 4015PL	243
EMFS2025DZ	VFS9S-2002PL	90
EMF4022DZ	VFS9-2002PM, 2037PM	223
	VFS9-4022PL, 4037PL	485
EMF4045EZ	VFS9-2055PL, 2075PL	223
	VFS9-4055PL, 4075PL	485
EMF4045FZ	VFS9-4110PL, 4150PL	485
EMF2080GZ	VFS9-2110PM, 2150PM	129

* The leakage current shown in the above table is of all phases of delta-connection (one-phase grounding) or star-connection (one phase missing).
  (Reference standard: IEC-1000-2-4 ... capacitor's capacity deviation: ±20%, unbalanced supply voltage: ±3% included)
* For models of 400V series, the above value is just for reference because their power supply line is generally in star-connection.

5. Method of leakage current measurement

Detection of leakage current from the ELCB is designed based on sine wave current, therefore, the higher the degree and content of higher harmonic is, the lower the current sensitivity is and the harder to activate the ELCB becomes. The ELCB is generally activated with much more leakage current than the sensitivity current in the frequency band of 120 Hz and higher. If frequency is 200 Hz or higher, the ELCB hardly operates. (Figure 4-1)
Therefore, it is advisable to use measuring instruments of different frequency characteristics or to use a spectrum analyzer for measuring leakage current.

Figure 4-1 Frequency characteristic of ELCB
(Type of 30 mA sensitivity current)

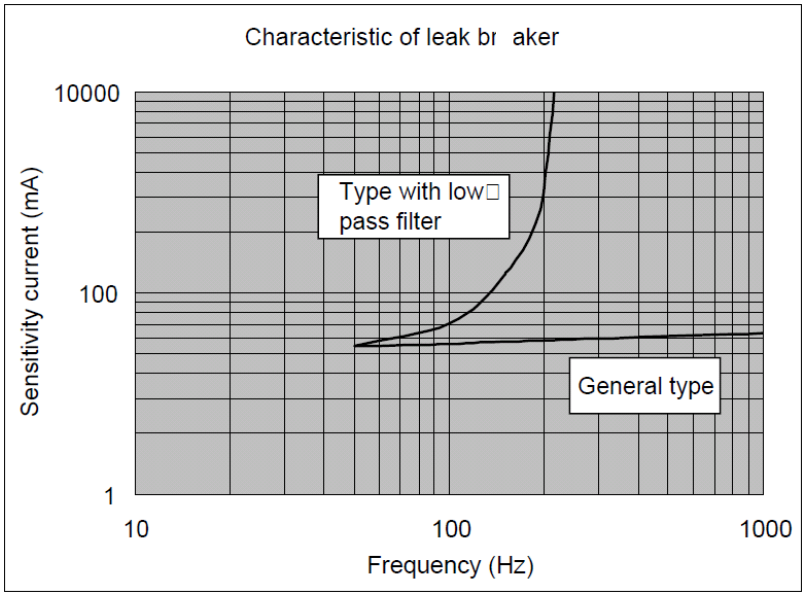


Figure 4-2 Leakage current measuring point