



Electromagnetically Compatible Installation Guidebook

Hitachi WJ Series C1 Inverter

Hitachi Europe GmbH

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Chapter 1 – Warnings and Instructions

- ⚠ WARNING The motor cable should be kept **as short as possible** in order to avoid electromagnetic emissions as well as capacitive currents. The rapid voltage changes of the Hitachi WJ Series C1 Inverter cause capacitive currents through the motor cable to stray capacitances. (Afterward “Hitachi WJ Series C1 Inverter” referred to as WJ-C1.)
The cable length increases the capacitive current and electromagnetic emission.
It is recommended that the motor cable length does not exceed 50m.
It is always recommended to install output AC reactors (motor chokes) if the cable length exceeds 50 m.
- ⚠ WARNING The filters contain capacitors between the phases and the phases to ground as well as suitable discharging resistors. But after switching off the line voltage you should wait a minimum of 60 seconds before removing protective covers or touching terminals etc. Ignore this and you may get an **electric shock!**
- ⚠ WARNING The protective conductor connection between the filter and drive must be designed as a solid and permanent installation. Plug-in connections are **not permissible**.
- ⚠ WARNING The use of ground fault monitoring devices is not recommended. Should they be compulsory in certain applications for safety reasons, you should choose monitoring devices which are suited for DC-, AC- and HF-ground currents.
- ⚠ WARNING The thermal capacity of the line filter is guaranteed up to a **maximum motor cable length of 50 m**.
- ⚠ WARNING The line filters have been developed for use in grounded systems. **Use in ungrounded systems is not recommended.**
- ⚠ WARNING WJ-C1 is not intended for sale to the public but a professional equipment to be used in trades, professions, and industries.

If installed according to the following directions, the frequency inverter complies with the following standards:

Emissions:	EN 61800-3 (EN 55011 group 1, Category C1/C2/C3[Class B/A])
Immunity:	EN 61800-3, industrial environments

Chapter 2 – Electromagnetically Compatible Installation of Drives and Drive Systems

Introduction

This brochure describes the electromagnetically compatible setup of your drive or your drive system. (EMC: Electro Magnetic Compatibility)

Read this information carefully and follow the instructions. **If necessary, provide this information to third parties.**

HF interference results from rapid switching of electric currents and voltages. All AC, DC and servo drives very rapidly switch large currents and voltages to optimally supply connected electric motors. They are thus major sources of interference, generating both line-conducted and radiated interference.

The additional use of line filters, also called interference suppression filters, and installation in a metal housing or a switch cabinet further improve the existing interference immunity. For the best possible damping of interference, special line filters have been developed which guarantee you easy assembly and installation along with the necessary electrical reliability.

However, effective EMC is only ensured if the suitable filter is selected for the particular drive and installed in accordance with these EMC recommendations.

Selection of line filter to reduce line-conducted interference

To reduce line-conducted interference, use the appropriate line filter for each frequency inverter. The table below shows you a list of the available line filters for your Hitachi frequency inverter.

The all line filters are built in the so-called footprint style, are fitted behind the respective frequency inverter, and thus require no additional space for installation. These filters are intended for installation in switch cabinets as standard.

Vertical mounting next to the frequency inverter is also possible.

Frequency Inverter	Rated input AC voltage	Line Filter
C1-002, 004SFE(X) *)	Single phase 200 V -15% to 240 V +10% 50/ 60 Hz \pm 5%	FPF-9120-10-SW
C1-007SFE(X) *)		FPF-9120-14-SW
C1-015, 022SFE(X) *)		FPF-9120-24-SW
C1-004, 007HFE(X) *)	Three phases 380 V -15% to 480 V +10% 50/ 60 Hz \pm 5%	FPF-9340-05-SW
C1-015, 022, 030HFE(X) *)		FPF-9340-10-SW
C1-040HFE(X) *)		FPF-9340-14-SW
C1-055, 075HFE(X) *)		FPF-9340-30-SW
C1-110, 150HFE(X) *)		FPF-9340-50-SW

*) : The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Filter installation

The connecting cable between filter and frequency inverter must be as short as possible and **laid separate from other cables/ lines**.

As user you must ensure that the HF impedance between frequency inverter, filter and ground is as small as possible:

- Remove paint and insulating material between the individual mounting points.
- See to it that the connections are metallic and have the largest possible areas.
- Use conductive contact grease as anticorrosive.

Anodized and yellow-chromated surfaces, e.g. cable/standard-section rail, screws, etc., have a large HF-impedance.

This paint must thus be removed at mounting points.

Ensure that the protective conductor terminal (PE) of the filter is properly connected with the protective conductor terminal of the frequency inverter. An **HF ground connection** via metal contact between the housings of the filter and the frequency inverter, or solely via cable shield, **is not permitted as a protective conductor connection**. The **filter must be solidly and permanently connected with the ground potential** so as to preclude the danger of electric shock upon touching the filter if a fault occurs. You can achieve this by:

- connecting it with a grounding conductor of at least 10 mm².
- connecting a second grounding conductor, connected with a separate grounding terminal, parallel to the protective conductor.

The cross-section of each single protective conductor terminal must be designed for the required nominal load.

Conductor loops act like antennas, especially when they encompass large areas. Consequently:

- Avoid unnecessary conductor loops.
- Avoid parallel arrangement of “clean” and interference-prone conductors over longer distances.

The line filters have been developed for use in grounded systems. Use of the line filters in ungrounded systems is not recommended, because in these applications

- loss current to ground increases.
- the effect of the filter is reduced.

The amount of line-conducted and radiated interference increases in proportion to an elementary frequency in frequency inverter.

The amount of line-conducted interference also increases as motor cable length increases.
Adherence to the interference limits for line-conducted interference is shown as follows:

Filter: FPF-9120-10-SW, FPF-9120-14-SW (Switch position 1: High leakage current)

EN61800-3	Cable length	Inverter carrier frequency	Frequency inverter
Category C1*1)	25 m Max.	9 kHz	C1-002, 004, 007SFE(X) *2)
Category C2	50 m Max.	9 kHz	

*1): The inverter needs to be installed in a metal cabinet to meet category C1. Otherwise category C2.

*2): The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Filter: FPF9120-24-SW (Switch position 1: High leakage current)

EN61800-3	Cable length	Inverter carrier frequency	Frequency inverter
Category C1*1)	20 m Max.	9 kHz	C1-015, 022SFE(X) *2)
Category C2	50 m Max.	9 kHz	

*1): The inverter needs to be installed in a metal cabinet to meet category C1. Otherwise category C2.

*2): The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Filter: FPF-9340-05-SW, FPF-9340-50-SW (Switch position 1: High leakage current)

EN61800-3	Cable length	Inverter carrier frequency	Frequency inverter
Category C1 *1)	25 m Max.	10 kHz	C1-004, 007, 110, 150HFE(X) *2)
Category C2	50 m Max.	10 kHz	

*1): The inverter needs to be installed in a metal cabinet to meet category C1. Otherwise category C2.

*2): The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Filter: FPF-9340-10-SW (Switch position 1: High leakage current)

EN61800-3	Cable length	Inverter carrier frequency	Frequency inverter
Category C1 *1)	10 m Max.	9 kHz	C1-015, 022, 030HFE(X) *2)
Category C2	50 m Max.	10 kHz	

*1): The inverter needs to be installed in a metal cabinet to meet category C1. Otherwise category C2.

*2): The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Filter: FPF-9340-14-SW, FPF-9340-30-SW (Switch position 1: High leakage current)

EN61800-3	Cable length	Inverter carrier frequency	Frequency inverter
Category C1 *1)	20 m Max.	10 kHz	C1-040, 055, 075HFE(X) *2)
Category C2	50 m Max.	10 kHz	

*1): The inverter needs to be installed in a metal cabinet to meet category C1. Otherwise category C2.

*2): The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Filter: FPF-9120-10-SW, FPF-9120-14-SW, FPF-9120-24-SW (Switch position 0: Low leakage current)

EN61800-3	Cable length	Inverter carrier frequency	Frequency inverter
Category C1*1)	5 m Max.	9 kHz	C1-002, 004, 007, 015, 022SFE(X) *2)
Category C2	10 m Max.	9 kHz	

*1): The inverter needs to be installed in a metal cabinet to meet category C1. Otherwise category C2.

*2): The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Filter: FPF-9340-05-SW, FPF-9340-10-SW, FPF-9340-14-SW, FPF-9340-30-SW, FPF-9340-50-SW (Switch position 0: Low leakage current)

EN61800-3	Cable length	Inverter carrier frequency	Frequency inverter
Category C1*1)	5 m Max.	10 kHz	C1-004, 007, 015, 022, 030, 040, 055, 075, 110, 150HFE(X) *2)
Category C2	10 m Max.	10 kHz	

*1): The inverter needs to be installed in a metal cabinet to meet category C1. Otherwise category C2.

*2): The version ("X" is number 2, 3, ...) is added to the end of the inverter model code.

Minimizing radiated interference

The frequency inverter of series WJ-C1 meet the limits of EN61800-3, C1/ C2/ C3, for radiated interference, if the specified line filter is used and installation is performed according to our instructions.

The prerequisite is that all analog and digital control lines are laid shielded.

With compact systems, if for example the frequency inverter is communicating with the steering unit, in the same control cabinet connected at the same PE-Potential, the screen should be put on, on both sides with PE.

With branch systems, if for example the communicating steering unit is not in the same control cabinet and there is a distance between the systems, we recommend to put on the screen only on the side of the frequency inverter. If it is possible, direct in the cable entry section of the steering unit. This is very important if there is a long distance between the systems and you expect there can be different PE-Potential between the systems.

You should allow the effective shield area of these lines to remain as large as possible; i.e., do not move the shield further away than absolutely necessary. The distance between an interference source and an interference sink (interference-threatened device) essentially determines the effects of the emitted interference on the interference sink. The interference field emitted by the frequency inverter falls sharply with increasing distance. Please note that the emitted interference field (frequency range 30 MHz - 1 GHz) of a drive (drive system) is measured at a distance of 10 m in accordance with EN61800-3. Every device placed closer than 10 m to a source of interference will thus be impacted by appreciably higher interference amplitudes. For this reason, you should use only interference-free devices and maintain a minimum distance of 0.25 m from the drive. Devices which react sensitively to interference from electric and magnetic fields should be kept at least a distance of 0.25 m from the following components:

- Frequency inverter
- EMC input/ output filters
- Input or output reactors/transformers
- Motor cable (even if shielded)
- External rheostat and its wiring (even if shielded)
- AC/ DC commutator motors, including any attached separate fans
- DC intermediate circuit coupling/wiring (even if shielded)
- Connected inductors like relays, contactors, solenoid valves, and brakes (even if shielded)

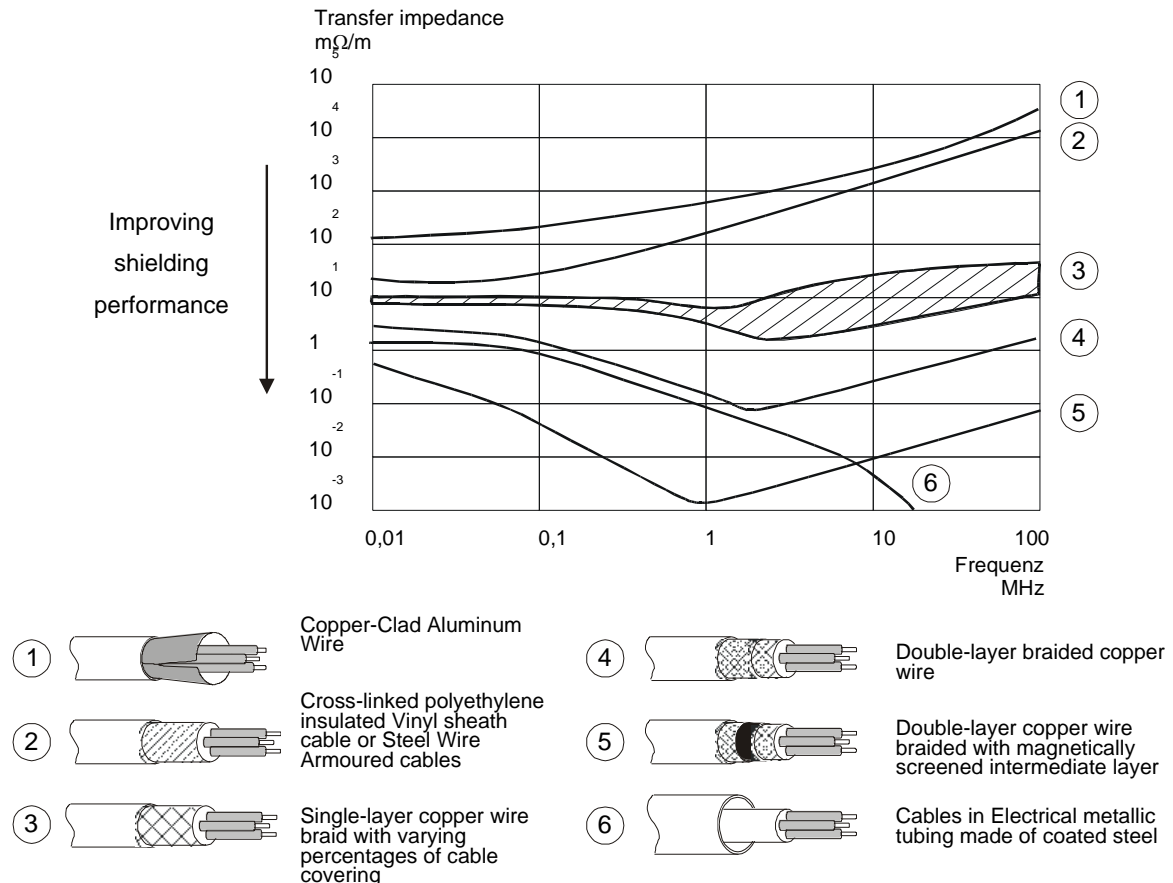
Very frequently, interference is coupled in through installation cables. You can minimize this influence by laying interfering cables separately, a minimum of 0.25 m from cables susceptible to interference. A particularly critical point is laying cables parallel over larger distances. If two cables intersect, the interference is smallest if they intersect at an angle of 90 °C. Cables susceptible to interference should therefore only intersect motor cables, intermediate circuit cables, or the wiring of a rheostat at right angles and never be laid parallel to them over larger distances.

Using EMC compliant cables

In order to reduce electromagnetic emission caused by motor cables and to increase EMI immunity for control cables, shielded cables have to be used. Using this shielding can reduce the interference coupled into and out of the cable (please also refer to the previous chapter „Minimizing radiated interference“). The effectiveness of the shielding heavily depends on the construction and the material of the shielding. The screening effectiveness can be characterized by the so called transfer impedance. This effectiveness or performance can be improved by keeping the transfer impedance as low as possible. The transfer impedance is mainly affected by the following variables:

- The cable covering, which is the cable area actually covered by the shielding. It is normally indicated as a percentage value and should be at least 85 %.
- The shielding’s design. Possible design alternatives are braided cables or shieldings made of metal conduit. These two types should be preferred when shielding is to be implemented.
- The contact (or transition) resistance between the individual stranded conductors of the shielding. The performance of the shielding improves if this resistance is kept as low as possible.

The following diagram shows the transfer impedance for various cable types. By comparing the cables' individual designs, the shielding effectiveness can be estimated and a suitable cable be chosen.



Installing the motor cable

If you use an EMC line filter or would like to observe certain limits of line-conducted interference, the motor cable which you use must be shielded. **The shield is to be grounded on both sides, over a large area.** For this purpose, turn the shield through 180 °C, for instance, and make large-area contact (360 °C) with the metal PG screw connections. The illustration on the following page shows you the electromagnetically compatible motor wiring.

- **Use only copper mesh cable (CY) with 85 % coverage. Foil shields often have a higher coupling impedance than mesh shields and are therefore unsuitable.**
- Some motors have terminal boxes and PG screw connections of plastic. In these cases, the shield should be connected on the motor side to the motor housing, with as large an area as possible, by means of a cable clamp.
- Some motors have a rubber gasket between the terminal box and motor housing. Very often, the terminal boxes, and particularly the threads for the metal PG screw connections, are painted. Make sure there is always a good metallic connection between the shielding of the motor cable, the metal PG screw connection, the terminal box and the motor housing, and carefully remove this paint if necessary.
- The shielding should not be interrupted at any point in the cable. If the use of reactors, contactors, terminals or safety switches in the motor output is necessary, i.e., if the shield must be interrupted, then the unshielded section should be kept as small as possible. It is better to install the reactor, contactor, terminal or safety switch in a metal housing with as much HF damping as possible. The shield connection to the metal housing should again be made with the smallest possible HF impedance, as already described.

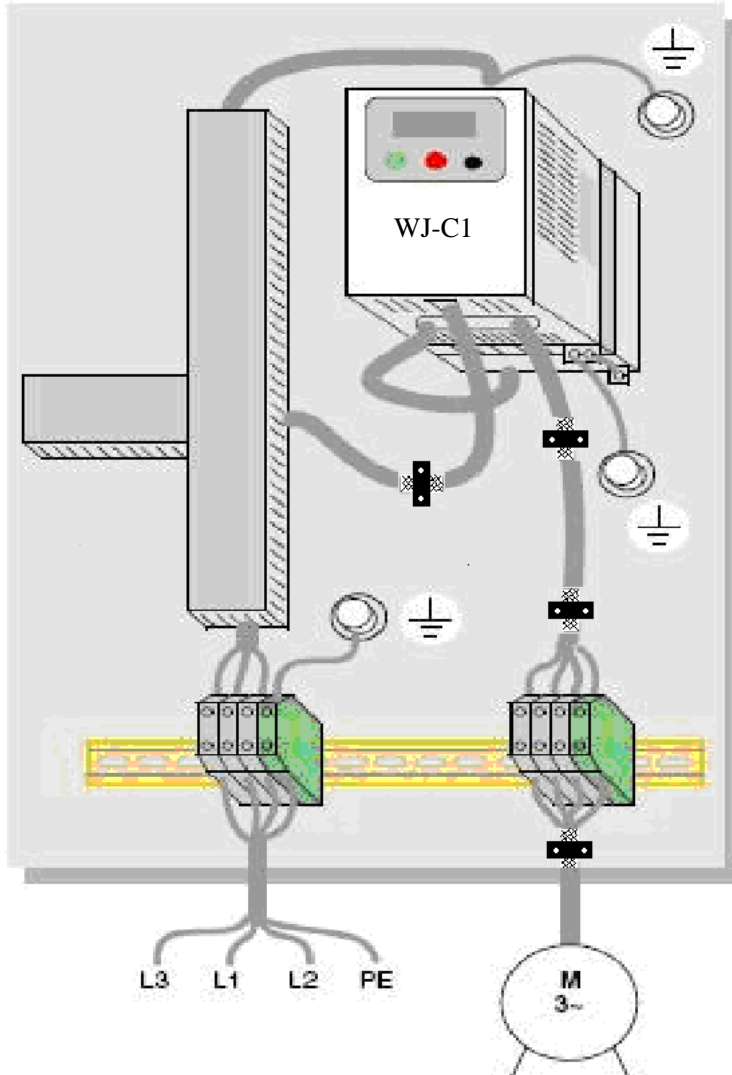
Should no shielded motor cable be available, lay the unshielded cable in a metal tube having the best possible shielding effect, for example. The metal tube should have good HF contact with the frequency inverter and the motor housing, e.g., by means of copper gauze tape. **Safety grounding always takes precedence over HF grounding.** If, for example, a braking chopper/ rheostat is to be connected to the DC intermediate circuit, then this connecting line, too, must be shielded. The shield is to be connected on both sides, with a large area (e.g. to the protective ground terminal of the rheostat).

Installing control and signal lines

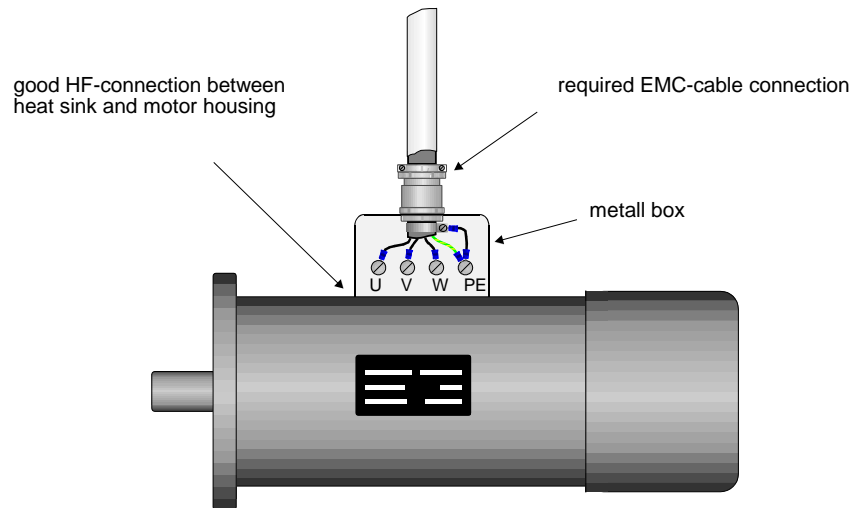
To ensure reliable operation of the frequency inverter, analogue and digital control lines (angular momentum pulser connection, all analogue inputs, serial interfaces, etc.) should be shielded. You should allow the effective shielding surface to remain as large as possible, i.e., do not move the shield further away than necessary. The shield must be applied on both sides to PE. As a matter of principle, the shielding of these lines should not be interrupted.

Shielding and grounding for installation in switch cabinets

Observe the requirements of European standard EN60204-1, "Electrical Equipment of Industrial Machinery." You get optimum EMC only if you properly arrange and mount the Hitachi frequency inverter, the appropriate line filter, and the other equipment which might be necessary, on a metal mounting plate in accordance with the following mounting instructions. The following figure shows a Hitachi inverter using a footprint filter:



The following figure shows the required EMC compliant connection to the motor:



Chapter 3 – Influence of the Motor Cable Length

Shielded motor cables have quite a high cable capacity towards ground, which increases linearly as cable length increases. A typical rule-of-thumb figure is 200 pF per meter of cable. But these figures vary among different types of cables and are also dependent on the current-carrying capacity. Long motor cables can give rise to the following:

- Frequency inverter and servo amplifiers give a pulse-width-modulated square-wave output voltage with quite steep slopes, which causes high reverse-charging currents in the cable capacities towards ground. This reverse-charging current must be additionally supplied by the device. Unwanted switch-off due to overload may occur.
- Long motor cables produce more line-conducted interference.
- Long motor cables lead to the triggering of a ground fault monitoring device that may be present.
- Long motor cables lead to thermal overload of the line filter due to the higher line-conducted interference.

If a motor choke of appropriate size is used, you have the following advantages:

- It can counteract unwanted shut-off due to overload, as described above.
- The thermal load on the EMC line filter is reduced.

In multiple motor applications, i.e., a frequency inverter feeds several motors connected in parallel, you should try to minimize the effective cable capacity and/or the effective length of the shielded cable. You can achieve this by creating a neutral cross-connecting point from which you can supply all motors.

See to it that the shielding is maintained over the entire length of the cable, if possible, or is only very briefly interrupted. It is better to install this neutral cross-connecting point in a metal housing with as much HF damping as possible. The shield connection from/ to the metal housing should again be made with the smallest possible HF impedance, as already described.

Chapter 4 – Further Notes

Influence of ground fault monitoring devices

In the line filter, capacitors are placed between the phases and ground, which can cause larger charge currents to flow to ground when the filter is first switched on. The amount of this flow has already been minimized by constructional circuit details. Nevertheless, ground fault monitoring devices possibly present may be triggered. Ground currents with high-frequency components and DC components may also flow under normal operating conditions. If faults occur, large DC-carrying ground currents may flow, possibly preventing the ground fault monitoring device from responding. For this reason, the use of ground fault monitoring devices is not recommended.

But should they be prescribed in certain applications for safety reasons, you should choose monitoring devices which are suited for DC, AC and HF ground currents. In addition, you should ensure that their responsiveness and time characteristics are adjustable so that a disturbance is not immediately caused the first time the frequency inverter is switched on.

Components susceptible to interference

The following components must be classified as particularly susceptible to interference from electromagnetic fields. Special attention should therefore be paid to them during installation:

- Sensors with analog output voltages (< 1 volt)
- Load cells
- Tractive force meters
- Torque measuring hubs
- Resistance thermometer PT100
- Thermoelements
- Anemometers
- Piezoelectric sensors
- AM radios (only long and medium wave)
- Video cameras and TV sets
- Office PCs
- Capacitive proximity switches and filling level sensors
- Inductive proximity switches and metal detectors
- Ripple control transmitters, baby talkers, etc., i.e. all communication devices which use low-voltage systems as transmission medium
- Devices which do not comply with the pertinent EMC requirements

Chapter 5 – Technical Specifications and Dimensions of WJ-C1 Filters

Type: FPF- Specification	FPF-9120-10-SW	FPF-9120-14-SW	FPF-9120-24-SW
Voltage in V	240 +5 %	240 +5 %	240 +5 %
Current in A at 40°C	8	14	24
Leakage current in mA/ phase/ 50Hz worst case ^{1) 3)}	36 (6.1)	55 (4.1)	55 (6.1)
Leakage current in mA/ phase/ 50Hz Un ^{2) 3)}	< 20 (3.1)	< 31 (2.1)	< 31 (3.1)
Test voltage in V DC for 1s ph./ ground	1770	1770	1770
Dimensions Single wire/ litze in mm ²	6	6	6
Output cable in mm ²	2 x 2.5	2 x 2.5	3 x 4
Weight in kg (approx.)	0.5	1.0	0.9
Heat dissipation in W (approx.)	2	5	10

Type: FPF- Specification	FPF-9340-05-SW	FPF-9340-10-SW	FPF-9340-14-SW	FPF-9340-30-SW	FPF-9340-50-SW
Voltage in V	460 +5 %	460 +5 %	460 +5 %	460 +5 %	460 +5 %
Current in A at 40°C	5	11	14	25	44
Leakage current in mA/ phase/ 50Hz worst case ^{1) 3)}	40 (24)	46 (3.4)	59 (23)	73 (25)	69 (24)
Leakage current in mA/ phase/ 50Hz Un ^{2) 3)}	< 2.4 (1.3)	< 3.8 (0.2)	< 2.3 (1.3)	< 4.8 (1.3)	< 4.7 (1.3)
Test voltage in V DC for 1s ph./ ground	1770	1770	1770	1770	1770
Dimensions Single wire/ litze mm ²	6	6	6	10	25
Output cable mm ²	3 x 2.5	3 x 2.5	3 x 2.5	3 x 6	3 x 10
Weight in kg (approx.)	0.7	1.2	1.0	2.5	3.0
Heat dissipation in W (approx.)	4	7	16	19	31

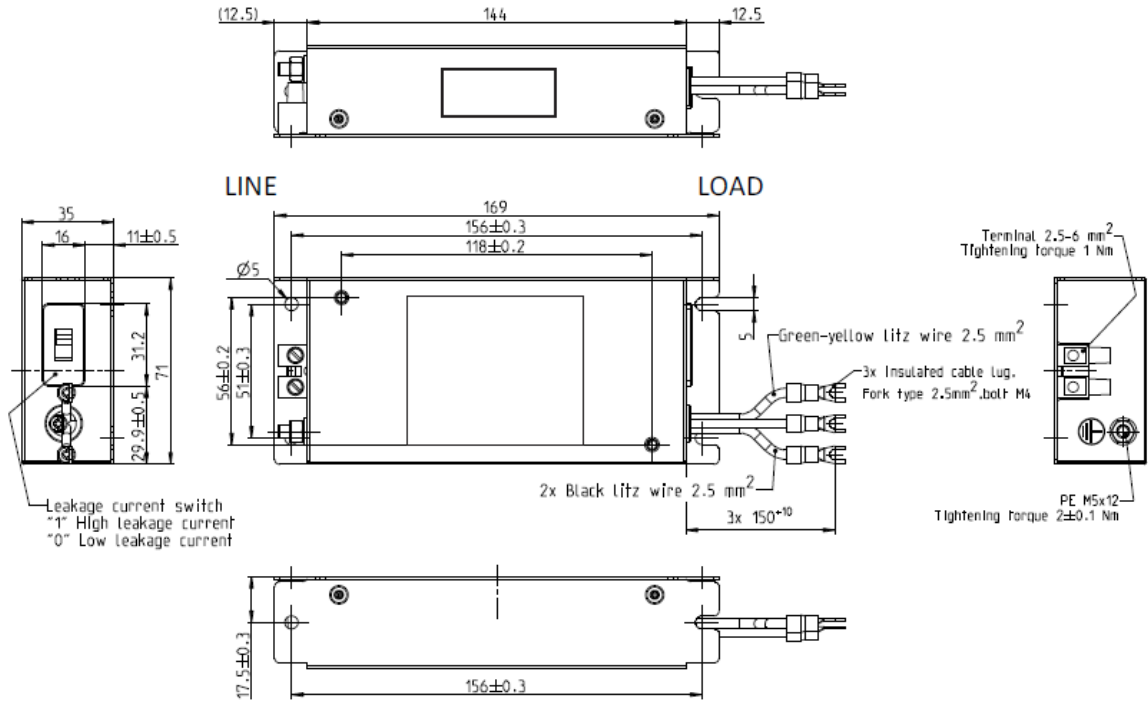
1). “Worst case” states the leakage current for three-phase filters in the worst of cases. That means one phase is live and two phases of the feed-line lead-in are interrupted. These maximum values are based on an operating voltage of 460 V (ph./ ph.).

2) The normal leakage current for three-phase filters is stated. This means the filter is operating on 460 V (ph./ ph.). The stated values are adhered to up to a neutral voltage of 5V to ground caused by line unbalance.

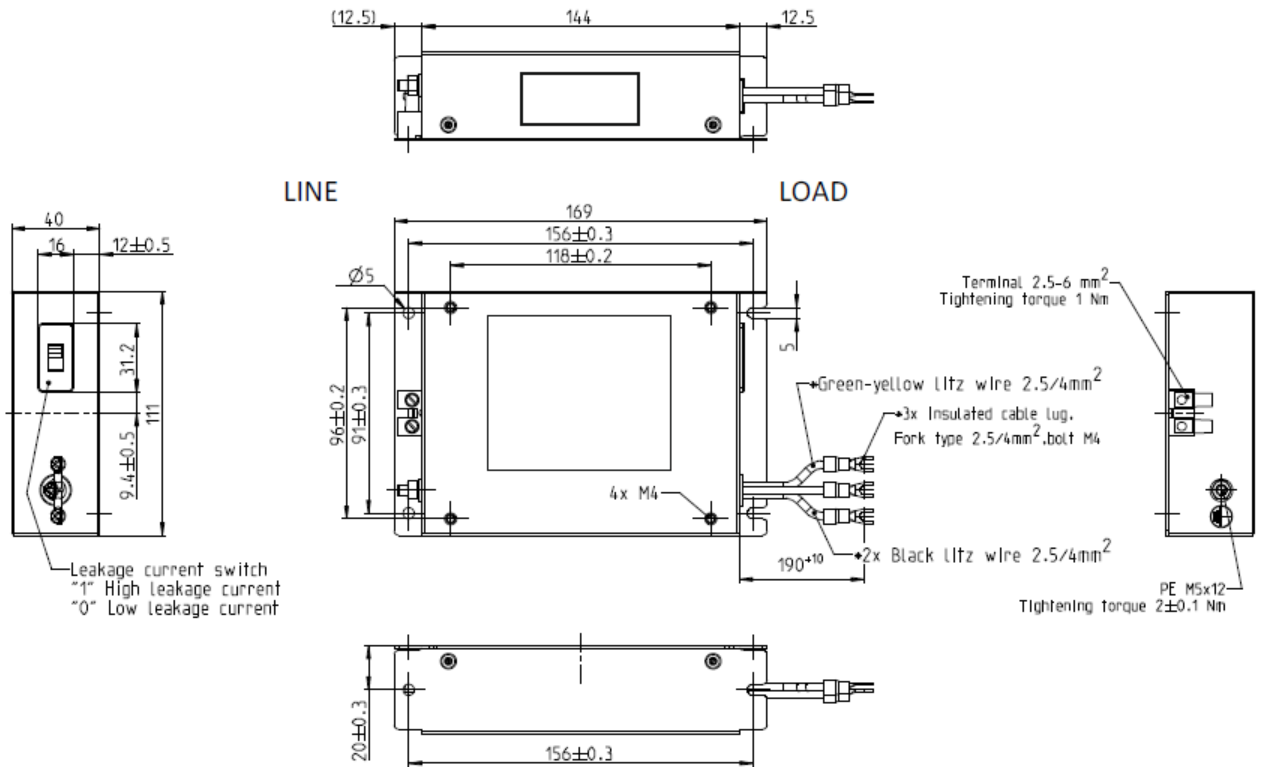
3) (): Values when switch position is 0 (low leakage current)

Current	at 40 °C ambient temperature
Overload	1.5 x I_N for 3 min
Frequency	50/ 60 Hz
Material	Metal housing
Humidity class	IEC-Climate-Category acc. to IEC60068-1: 25/100/21

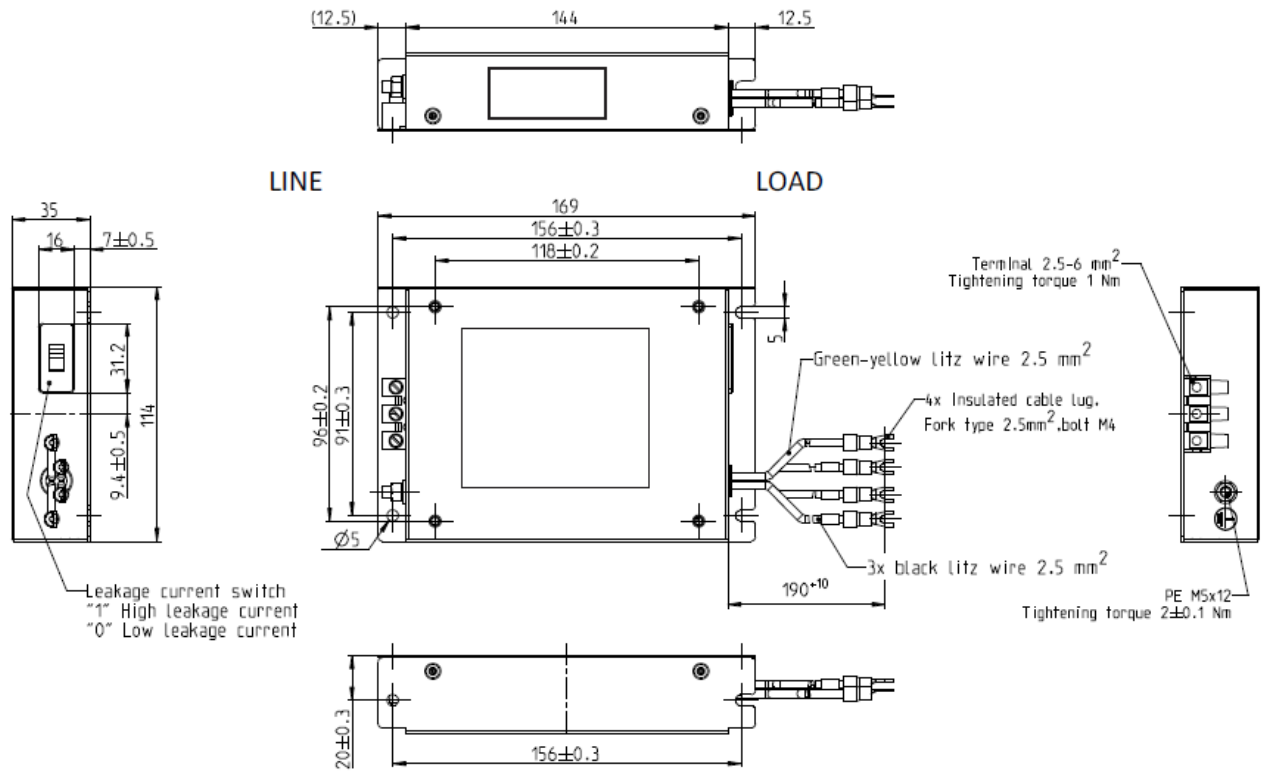
FPF-9120-10-SW



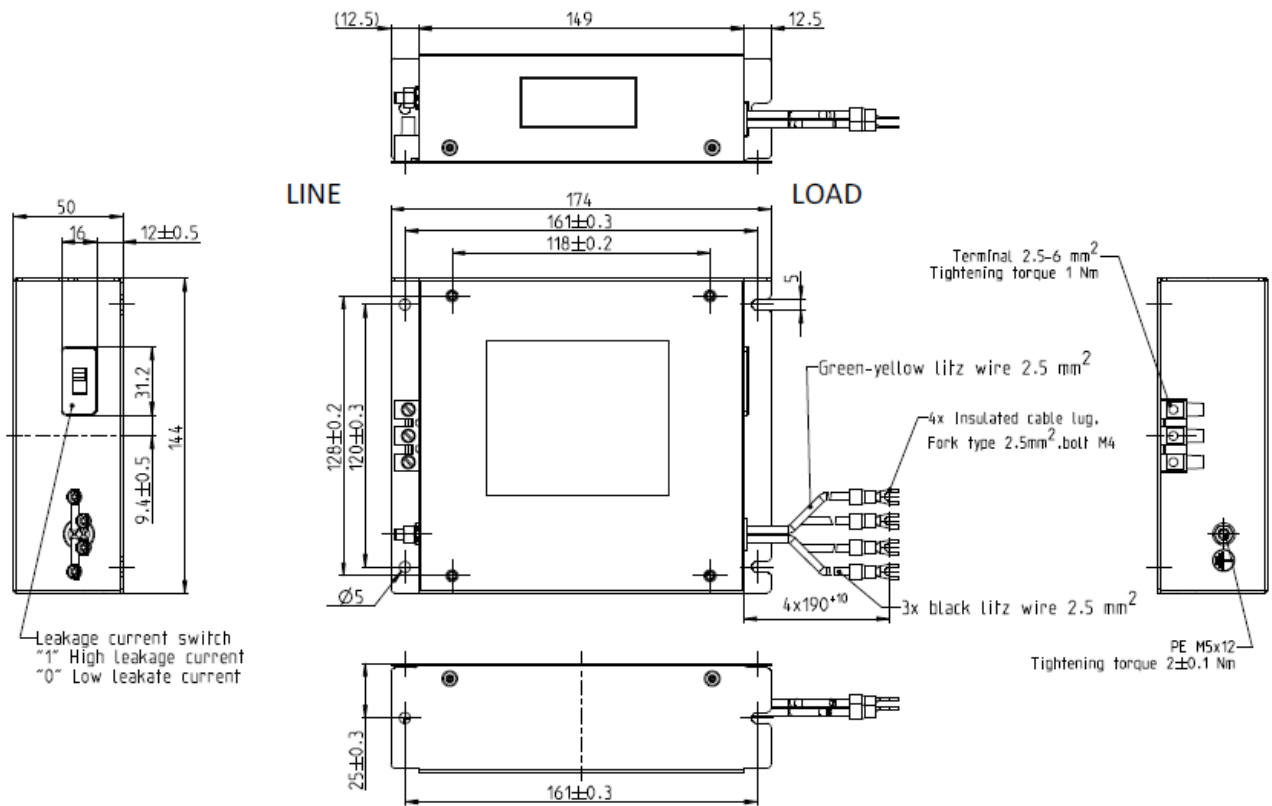
FPF-9120-14-SW/ FPF-9120-24-SW



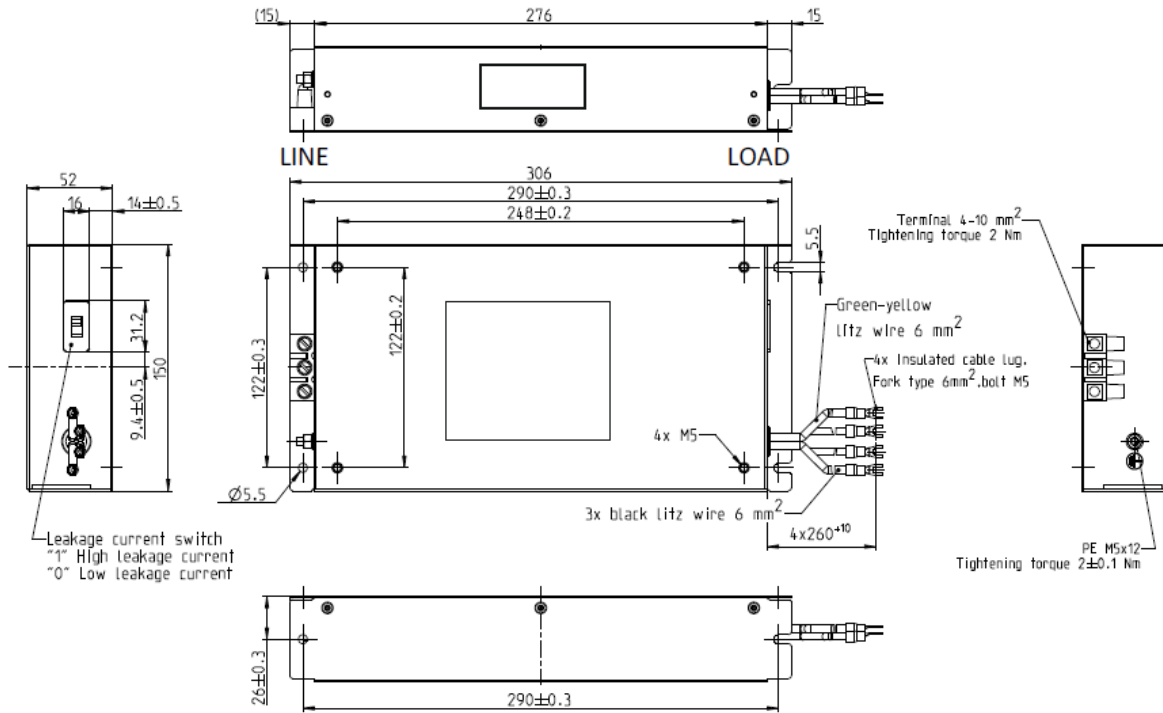
FPF-9340-05-SW/ FPF-9340-10-SW



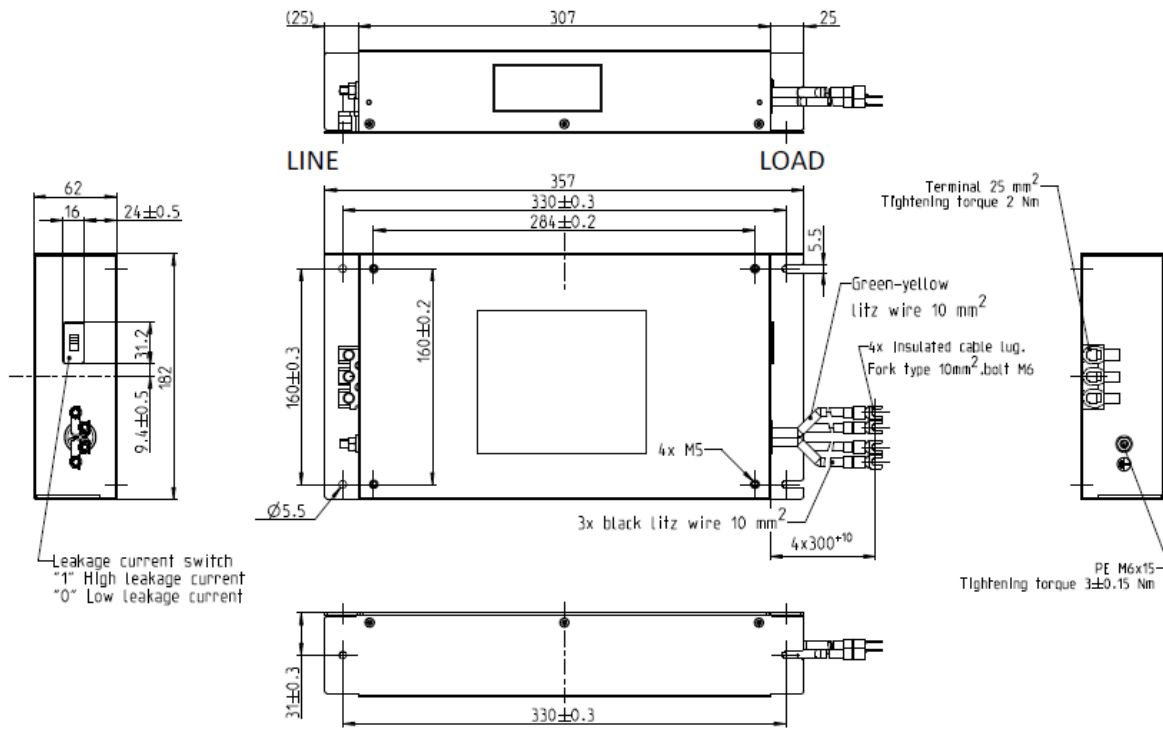
FPF-9340-14-SW



FPF-9340-30-SW



FPF-9340-50-SW



Chapter 6 – Harmonics “EN/ IEC 61000-3-2” and “EN/ IEC 61000-3-12”

Frequency converters, which are connected to the **public low voltage power supply** must comply with limits for harmonics currents. For equipment with input current ≤ 16 A per phase, the limits according to EN/ IEC 61000-3-2 are applied, and for equipment with input current > 16 A and ≤ 75 A, the limits according to EN/ IEC 61000-3-12 are applied. For professional equipment with a rated power > 1 kW, no limits are defined in EN/ IEC 61000-3-2.

This equipment complies with EN/ IEC61000-3-12 provided that the short-circuit power S_{sc} is greater than or equal to the value provided in the table below at the interface point between the user's supply and the public system. It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that the equipment is connected only to a supply with a short-circuit power S_{sc} greater than or equal to the value mentioned in the table below.

Inverter model	AC/DC reactor	Norm	S_{sc}	R_{sce}
C1-001/ 002SF	3 % AC choke or 4 % DC choke	EN/ IEC61000-3-2	---	---
C1-055HF		EN/ IEC61000-3-12	1663 kVA	> 120
C1-075HF			1996 kVA	> 120
C1-110HF			3160 kVA	> 120
C1-150HF			3659 kVA	> 120

If these devices are connected without an AC/ DC reactor to the public low-voltage power supply, they must obtain connection approval from the distribution network operator.