

## The dimensioning of the protective conductor

### 1 Applicable Standard

DIN EN 61800-5-1 Adjustable speed electrical power drive systems - Part 5-1: Safety requirements - Electrical, thermal and energy (IEC 61800-5-1:2007); German version EN 61800-5-1:2007

### 2 Definition of terms

The design of the protective conductor applies for the following drive modules:

- BDM** Drive module which consists of a power converter module and a control and regulating device for speed, torque, current or voltage.  
(Basic Drive Module)
- CDM** Drive system without the motor and without the measuring sensors which are mechanically connected to the motor shaft, which consists of, but is not restricted to the BDM and extensions such as the feed module and auxiliary equipment.  
(Complete Drive Module)
- PDS** Speed control system for an electric motor, including the CDM and motor, but without the equipment which it powers.  
(Power Drive System)

Technical Information / Datasheet	The dimensioning of the protective conductor			
Frequency inverters	TI 80-0019	V 1.5	3517	en

### 3 Requirements and operating conditions



#### 3.1 Operating conditions

A protective conductor (PE) **must** be connected as soon as the PDS/CDM/BDM is supplied with power. (Exception: the PDS/CDM/BDM fulfils the requirements of Protection Class II –DIN EN 61800-5-1 Section 4.3.5.6)

In addition to the connected power, the strength of the leakage current (earth current) is the definitive criterion for the dimensioning of the protective conductor.

The limiting values for the leakage current are **AC 3.5 mA** or **DC 10 mA**

It must be assumed that in normal operation of the frequency inverter (CDM) leakage currents of  $\geq$  **AC 3.5 mA** will occur. Therefore the protective conductor must be installed so that the following requirements for systems with high leakage currents are fulfilled.

 <b>Information</b>	<b>Identification</b>
 <p>Warning symbol ISO 7000-04034 (2004-01)</p>	<p>The fact that the touch current in the protective conductor exceeds the limiting value of <b>AC 3.5 mA</b> or <b>DC 10 mA</b> must also be stated in the installation and operating manuals. In addition, the warning symbol SO 7000-04034 (2004-01) must be affixed to the product and the installation manual must contain an instruction for the user that the minimum cross-section of the protective conductor must comply with the local safety regulations for protective conductors for equipment with high leakage currents.</p>

#### 3.2 Requirements for equipment with high leakage currents

##### 3.2.1 Connection via plug connector and socket

1. If the protective conductor is connected so that it can be disconnected via a plug connector, the power supply to the component which is to be protected must be interrupted simultaneously.
2. The minimum cross-section of the protective conductor is 2.5 mm<sup>2</sup>.
3. The protective conductor must form part of a multi-conductor power supply cable.
4. Appropriate strain relief must be provided.
5. The protective conductor must be connected so that in case of failure of the strain relief device, the earth lead is the last conductor which is interrupted. This is normally ensured by installing the protective conductor in the plug so that it is longer than the other conductors.
6. Plugs for industrial applications in accordance with IEC 60309 are used:



CEE AC plug connector  
16 A, 230 V, L+N+PE, 6h, IP44



CEE three-phase plug connector  
16 A, 400 V, 3L+PE, 6h, IP44

- If a plug connector for industrial applications in accordance with IEC 60309 is not used in the case of a single-phase connection, e.g. a so-called earthed plug, the touch current (measured according to DIN EN 61800-5-1 Section 4.3.5.6) must not exceed a value of AC 3.5 mA or DC 10 mA.

In association with the operation of frequency inverters, it should be noted that without additional special measures, these values are normally exceeded in normal operation.

- Adapter leads from an earthed plug connector to an AC CEE blue L+N+PE coupling do not comply with the standard.

### 3.2.2 Permanent connection

- Use of a protective earthing conductor of at least 10 mm<sup>2</sup> Cu or 16 mm<sup>2</sup> Al or
- Automatic mains switch-off if the protective earthing conductor is interrupted or
- Connect a second protective earthing conductor with the same cross-section as the original protective earthing conductor." or
- The minimum cross-section of the protective conductor is 2.5 mm<sup>2</sup>. The protective conductor must form part of a multi-conductor power supply cable. Appropriate strain relief must be implemented. The protective conductor must be connected so that in case of failure of the strain relief device, the earth lead is the last conductor which is interrupted.

### 3.2.3 General requirements

All of the cross-sections stated above are minimum requirements. In the case of larger connected powers, the cross-section of the earth lead is oriented to the cross-section of the external cable of the PDS/CDM/BDM. Unless otherwise stated in the local wiring regulations, the cross-section of the earth lead must be determined according to the following table or by calculation according to IEC 60364-5-54, 543.1.

Cross-section of the external conductor of the PDS/CDM/BDM "S" [mm <sup>2</sup> ]	Minimum cross-section of the corresponding protective earthing conductor "S <sub>p</sub> " [mm <sup>2</sup> ]
S ≤ 16	S
16 < S ≤ 35	16
35 < S	S/2



#### Information

#### Materials for the protective earthing conductor

The values in the table only apply if the protective earthing conductor is made from the same material as the external conductor. If this is not the case, the cross-section of the protective earthing conductor must be determined so that a conductivity results, which is equivalent to the results for the application in the table.

The cross-section of each protective earthing conductor which is not a part of the power supply cable must not be less than

- 2.5 mm<sup>2</sup>, if mechanical protection is provided,  
or
- 4 mm<sup>2</sup>, if no mechanical protection is provided.

## 4 PE cable connection

### 4.1 SK 500E series – PE cable connection

The following fundamental conditions are relevant for the connection of the PE cable:

1. SK 500E series inverters are equipped with two PE connection terminals. Both terminals are connected to the central PE connection in the control cabinet in order to meet the requirement for a redundant earth connection (second earth connection). The possible alternative connection of a PE cable with a cross section  $\geq 10 \text{ mm}^2$  (Cu) is not practical for low power inverters.
2. A minimum cross-section of  $2.5 \text{ mm}^2$  is specified for wiring with individual conductors in the control cabinet if mechanical protection is provided.
3. Only **one** conductor may be connected to a PE connection terminal.

#### 4.1.1 Connection examples

##### 4.1.1.1 PE connection on the mains side



- Each PE connection terminal on the mains side must be earthed to the PE connection terminal on the snap-on rail with a single conductor.
- "Through connection" with a single PE conductor from inverter to inverter is not permissible.
- Due to the construction, the PE- terminals on the snap-on rail are electrically connected to it. The snap-on rails form a part of the central earthing system of the control cabinet and must also be earthed with PE conductors. The screw connection between the snap-on rail and the mounting plate is not considered to be an electrical connection!

##### 4.1.1.2 PE connection on the motor side

###### Version 1



- Each PE connection terminal on the motor side must be earthed to the PE connection terminal on the snap-on rail with a single conductor.
- The motor cable is connected to the connection terminals on the snap-on rail. Adequate strain relief must be provided for the motor cable.
- Due to the construction, the PE- terminals on the snap-on rail are electrically connected to it. The snap-on rails form a part of the central earthing system of the control cabinet and must also be earthed with PE conductors. The screw connection between the snap-on rail and the mounting plate is not considered to be an electrical connection!

### Version 2



- If the motor cable is connected directly to the motor terminal of the inverter without intermediate terminals, the PE conductor of the motor cable must be connected to the snap-on rail via the PE connection terminals.
- A large area of the motor cable shield is connected to the shield rail; the motor cable has strain relief. Adequate strain relief must be provided if an unshielded motor cable is used.
- Due to the construction, the PE- terminals on the snap-on rail are electrically connected to it. The snap-on rails form a part of the central earthing system of the control cabinet and must also be earthed with PE conductors. The screw connection between the snap-on rail and the mounting plate is not considered to be an electrical connection!


### Version 3



- On the motor side, the PE conductor can be guided with the aid of the optionally available shield bracket.
- A large area of the motor cable shield is connected to the shield bracket; the motor cable has strain relief. Adequate strain relief must be provided if an unshielded motor cable is used.
- Due to the construction, the PE- terminals on the snap-on rail are electrically connected to it. The snap-on rails form a part of the central earthing system of the control cabinet and must also be earthed with PE conductors. The screw connection between the snap-on rail and the mounting plate is not considered to be an electrical connection!

## 4.2 SK 200E series – PE cable connection

The following fundamental conditions are relevant for the connection of the PE cable:

1. SK 200E series inverters are equipped with two PE connection terminals inside the connection unit. The PE cable(s) of the mains input and (if present) the mains output cable and the PE conductor of the motor cable are connected to these internal PE connection terminals. If a second PE cable is required, see 3.2.2 – point 3, an additional PE connection can be attached. (Option: ANSCHLUSSERW SK TIE4-PE-M12-V2A, Part number: 275274034,  see TI 275274034). For the possible alternative connection of PE cable with a cross-section of  $\geq 10 \text{ mm}^2$  (Cu) the optional external PE connection must also be used.
2. A minimum cross-section of  $2.5 \text{ mm}^2$  is specified for wiring with individual conductors if mechanical protection is provided. If no mechanical protection is provided for the individual conductors, a minimum cross-section of  $4 \text{ mm}^2$  is prescribed.

## 4.2.1 Connection examples

### 4.2.1.1 PE connection on the mains side (within the connection unit)




- The PE conductor(s) of the mains cable(s) must be fastened to one of the two PE connection terminals inside the connection unit using ring cable lugs.
- "Through connection" of the PE conductor from inverter to inverter is not permissible.

### 4.2.1.2 PE connection on the motor side (within the connection unit)

- If the frequency inverter is mounted on the motor, the connection is made via the metallic housing of the motor stator and the frequency inverter connection unit.
- If the frequency inverter is operated with a wall-mounting kit and motor cable, the PE conductor of the motor cable must be fastened to one of the two PE connection terminals inside the connection unit.

### 4.2.1.3 Optional external PE connection (outside of the connection unit)



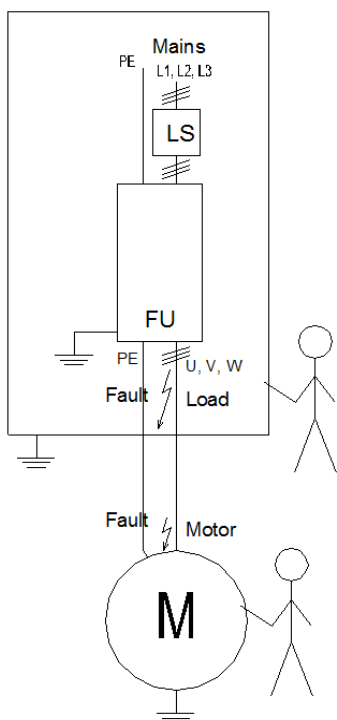
- The option: ANSCHLUSSERW SK TIE4-PE-M12-V2A (Part number 275274034,  see TI 275274034) must be fastened into one of the free M12x1.5 threaded holes in the connection unit.
- Push the M8 thread of the PE connection through the M12x1.5 threaded hole and screw it to the inside of the connection unit with the supplied washer and M8 nuts.
- The external PE connection must be connected to the central earthing of the system or machine or to the central earthing of the power supply by means of a separate conductor.
- The separate conductor must be connected to the PE connection terminal using an M16 ring cable lug and fastened with the supplied washer, spring lock washer and nut (M6).
- "Through connection" with a single PE conductor from inverter to inverter is not permissible.

## 5 Earth faults / short-circuit detection, protection against electric shock

Frequency inverters and motors fulfil the safety requirements which are described in the product standard IEC/EN 61800-5-1.

From the point of view of the operator, IEC/HD 60364-4-41 requires protection against electric shock.

If the frequency inverter and the load (motor) are designed and installed according to the standard, **basic protection (protection against electric shock due to direct contact)** is ensured.



**Care must be taken that the lines or cables which are used on the connection / mains side and the output / load / consumer side comply with the requirements for the line protection (LS) which is used (refer to the recommended values under "Technical Data" in the manual)**

The frequency inverters are equipped to monitor the current at the output terminals (load / consumer side (**U, V, W** – motor connection and **-B** – brake resistor connection)). If the current at these terminals exceeds 2.5 ... 3.5 times the rated output current, **the inverter / the output stage switches off within 8 ms.**

This function fulfils the requirement for a protective device for a **safety device** according to EC/HD 60364-4-41.

***It does not result in electrical isolation from the mains voltage.*** Any upstream protective devices (e.g. RCD) may therefore no longer trigger. Current monitoring is primarily used to protect the frequency inverter itself and is not an intrinsically safe protective function.

FI	Frequency inverter
LS	Line protection
M	Motor

**Notice: The output terminals +B and –DC<sup>1)</sup> are not monitored. These terminals do not have an upstream power semiconductor, so that switch-off is not possible.**

Depending on the ambient conditions it may be necessary to use **additional protective devices** (e.g. RCD fault current circuit breakers).

The responsibility for the design of the solution lies with the constructor of the plant or the machinery.

1) Terminal "-DC" is only available in SK 500E series devices (SK 500E ... SK 545E), but not in decentralised devices (Series SK 180E and SK 200E).