

Residual currents and residual current protective devices

General

Residual currents, some of them very powerful, travel toward the earth (PE) during operation of frequency inverters. Residual current protection devices (RCCB triggers, RCD, RCCB) interpret these as "residual current". This sometimes results in malfunction. The spectral structure of the total residual current and the amplitudes of the respective frequencies are primarily influenced by the following factors:

- Pulse frequency
- Motor rotary frequency
- Type and length of the motor cable (shielded / unshielded)
- Motor characteristics (capacitive coupling of the stator windings against PE)
- Capacitive link circuit connection to PE (jumper position 'B' motor output)
- Optional use of mains input and output filters (sine filters)

There are two basic pulse frequency components: a low-frequency, narrowband (150 Hz at 50 Hz low frequency or 180 Hz at 60 Hz mains frequency plus corresponding harmonics) and a portion in the pulse frequency area that is broadband in most part. A small, low-frequency part results from the 3 mains phases being not quite 100% symmetrical when *Jumper 'A'* (mains input) is in a normal position. Even asymmetrical interference voltages from the mains phases may lead to further shares in the spectrum of the total residual current.

The following illustration shows a typical spectrum of the residual current of a frequency inverter with long (30 m) shielded motor cable.

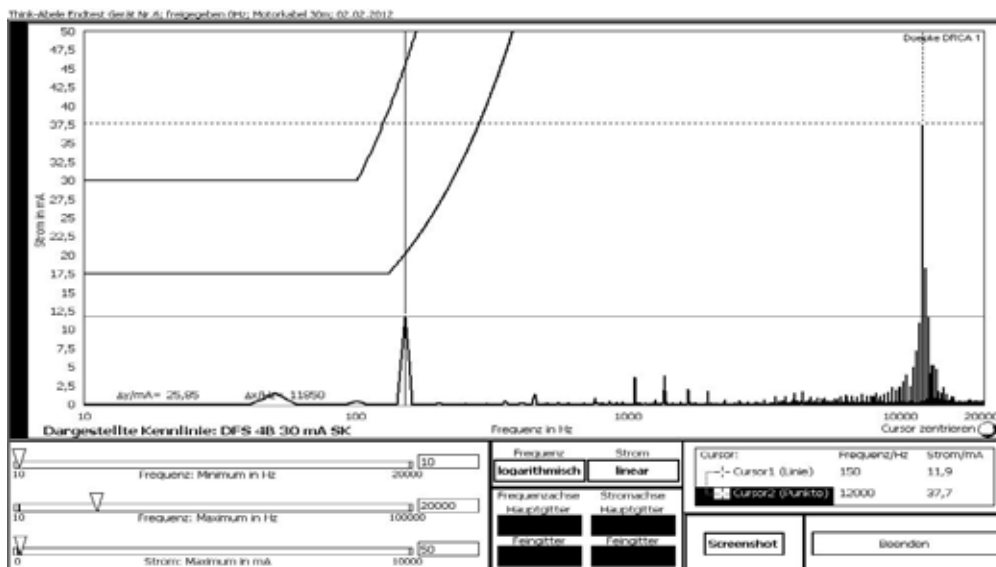


Figure 1: Typical spectrum of the residual current of a frequency inverter, Pulse frequency = 12 kHz, motor cable = 30 m shielded

Technical Information / Datasheet	Residual currents and residual current protective devices			
Frequency inverters	T1800_00000003	V 1.0	0313	EN

Interpretation of residual current specifications in the manual

The information on residual current in the manual is based on measurements according to DIN EN 60990 (VDE 0106 part 102). These are *rated* measurements for "noticeability or reaction", i.e. *high-frequency* parts of residual current, which may turn into "touch current", are *reduced* corresponding to the physiological effects on the human body.

By and large, the specifications in the manual therefore pertain to the already mentioned *low-frequency* part of residual current. This information does not match the specifications of residual current protective devices as these also include *high-frequency* parts in the sum total, depending on the selected type (release frequency response).

Rules for connecting and earthing devices

Special rules apply for connecting and earthing devices with increased residual current during operations (≥ 3.5 mA AC or ≥ 10 mA DC), such as the NORD frequency inverter (**DIN EN 61800-5-1**). The following conditions must be met pursuant to 1 or 2:

1. **Fixed connection and:**

- a protective earthing conductor with a cross-section of at least 10 mm² Cu or 16 mm² Al
- or
- automatic mains switch-off if the protective earthing conductor is interrupted
- or
- connection of an additional connection terminal for a second protective earthing conductor with the same cross-section as the original protective earthing conductor
- or

2. **Plug connection** for industrial use in compliance with IEC 60309 and a protective earthing conductor with a minimum cross-section of 2.5 mm² as part of a multi-core supply cable. Appropriate strain relief must be implemented.

It is also **extremely important** to earth the motor sufficiently (minimum at all times is a connection via the PE conductor of the motor cable so that high-frequency residual currents can flow back to the inverter in the most direct way possible).

When **using shielded motor cables**, the shielding must be applied over a large area and conduct well on both sides (on the motor and on the inverter/switching cabinet).

The motor or motor cable shielding **must never** be operated **without** being earthed as the residual current, which would travel through the human body instead upon contact, may be fatal!

Using residual current protective devices (RCD, RCCB) with the NORD frequency inverters

Since 2002, the abbreviation "RCD" (residual current protective device) has found its way from the international standards into German standards. "RCCB" (Residual Current Circuit Breaker) is another commonly used term.

The following points should be considered when selecting a suitable RCD:

- **Conventional type A or AC RCDs are unsuitable as protection and must not be used!**
- Only all-current sensitive RCDs (**type B and B+**) may be used in connection with frequency inverters. Please note that there are switches with varying triggering characteristics and frequency responses (e.g. Doepke DFS 4B **NK**, DFS 4B **SK**).

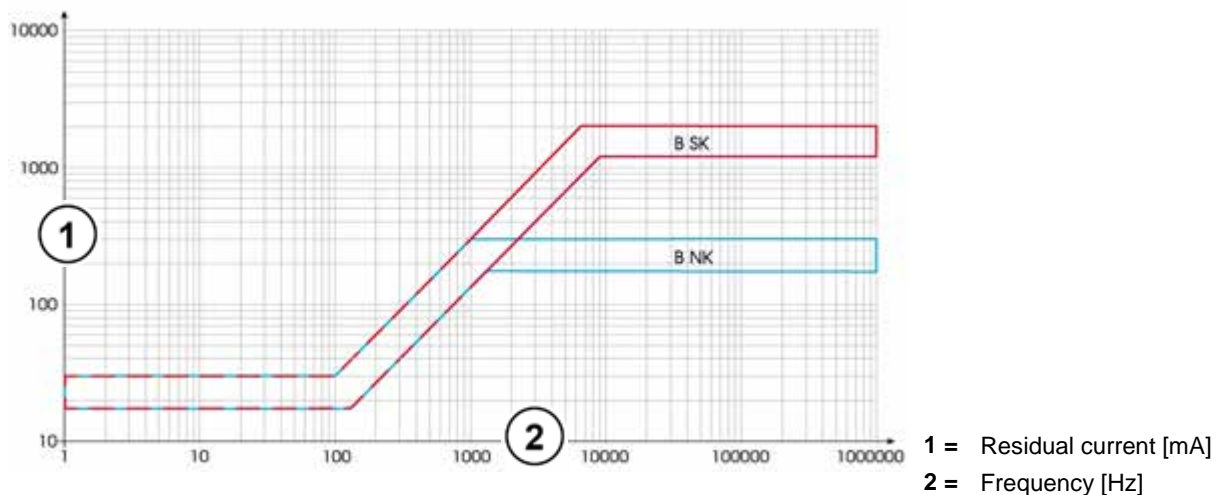


Figure 2: Frequency response of Doepke residual current switch type DFS 4B NK / SK 30 mA

The difference between types B **NK** and B **SK** is the triggering sensitivity for frequencies of 1 kHz and above. The triggering point for NK types is 300 mA, but SK types only trigger at 2 A.

Selection criteria and user tips

Today, users have a choice of RCDs with varying triggering characteristics (frequency response). They have to select the type best suited to their application and requirements.

- The rated residual current is the *maximum* permissible value at which the switch is triggered. This value has a *tolerance of up to – 50 %*. For a 30 mA - FI, e.g., this means that the residual current *may not exceed 15 mA* for fault-free operation!
- The protection level provided by an RCD should not be higher than necessary to ensure that the system is not shut down unnecessarily. In other words, the rated residual current should not be less than 300 mA and the release frequency response should rate parts above 1 kHz lower by selecting the corresponding triggering characteristics and by increasing the triggering point. Users must comply with the regulations relevant to their specific applications (*a question of personal safety and fire regulations*).
- Only RCDs with a rated residual current ≤ 30 mA offer protection in the case of direct contact. Depending on the type used, this protection may be limited to a certain frequency range.
- Depending on the pulse frequency, residual currents of up to 20 kHz may occur when using NORD frequency inverters.
- A separate RCD should be installed for each inverter if possible.
- The all-current sensitive RCDs DFS 4B SK, DFS 4B NK and DFS 4B+ made by **Doepke** are suitable and recommended for use with NORD frequency inverters, subject to certain limitations:

- DFS 4B SK is the best choice for systems that **do not require fire protection**. Its reduced sensitivity in the higher frequencies (above 1 kHz) largely prevents it from being triggered incorrectly.

Please note that the DFS 4B SK 30 mA only protects in the case of indirect touch for frequencies > 1 kHz (earthing resistance ≤ 25 Ohm).

- The DFS 4B NK is problematic to use or unsuitable for long (> 5 m) or shielded motor cables and/or when operating several motors, especially if the rated residual current is 30 mA.
- B+ is a compromise between SK and NK types. It protects against residual currents up to 20 kHz and has a trigger limit of 420 mA. This also complies with the requirements of insurance companies (fire prevention).

It must be decided on an individual basis if this type can be used, if necessary by measuring the actual residual currents.

- It may be useful to reduce the low-frequency part of the residual current by placing *jumper 'B'* in the "*reduced residual current*" position, but only for applications with very short, unshielded motor cables (< 5 m), the reason being that in return, the high-frequency part increases, depending on the connected motor accessories and selected pulse frequency. This measure therefore only provides the required result if circuit breakers with a reduced sensitivity in the high frequencies are used.
- In the case of symmetrical mains conditions, the position of *jumper 'A'* (mains input) is of minor importance for the amount of residual current and should, if possible, remain in the *normal position* (high filter effect).