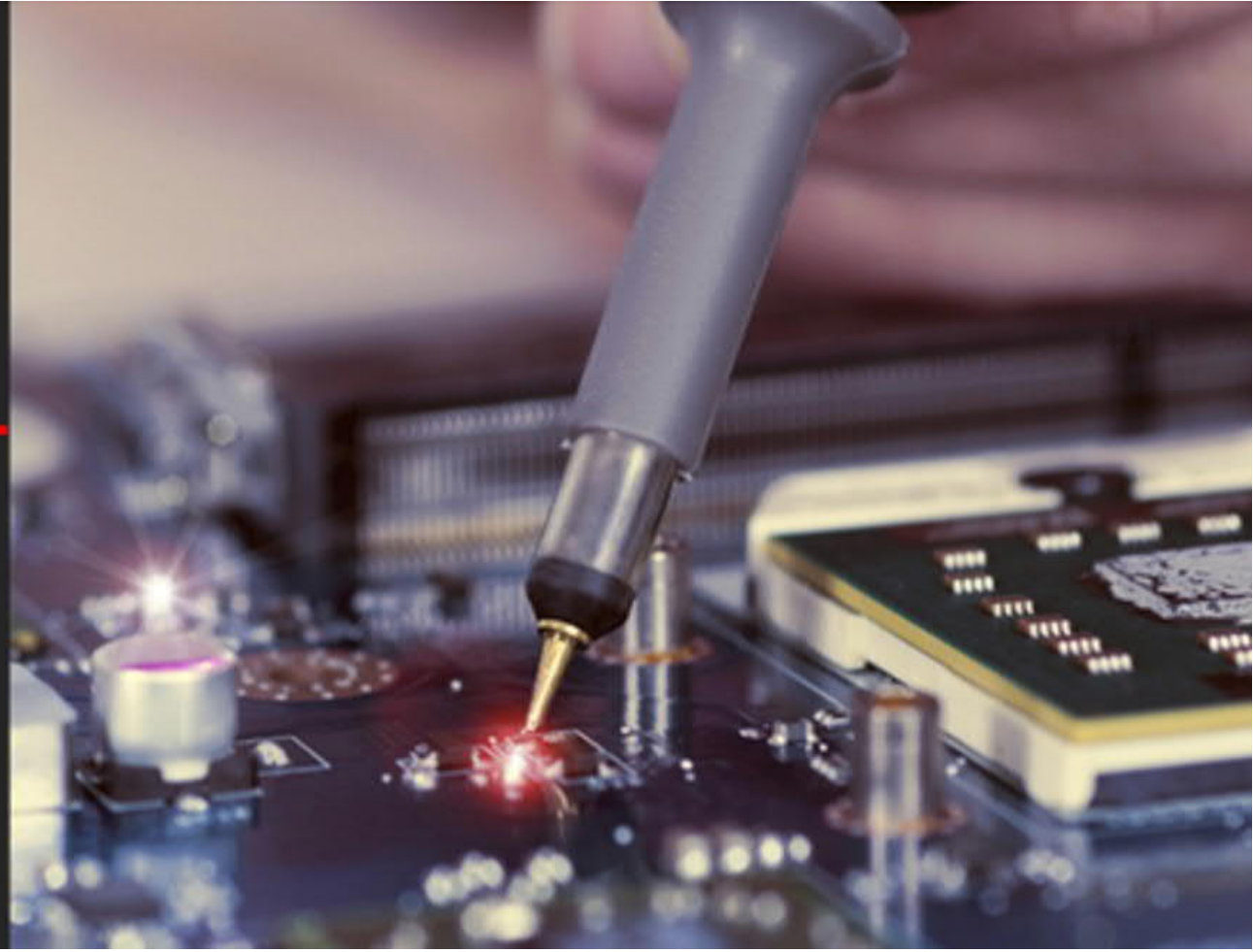
DEVELOPMENT AND MANUFACTURING OF HIGH ACCURACY CURRENT TRANSDUCERS

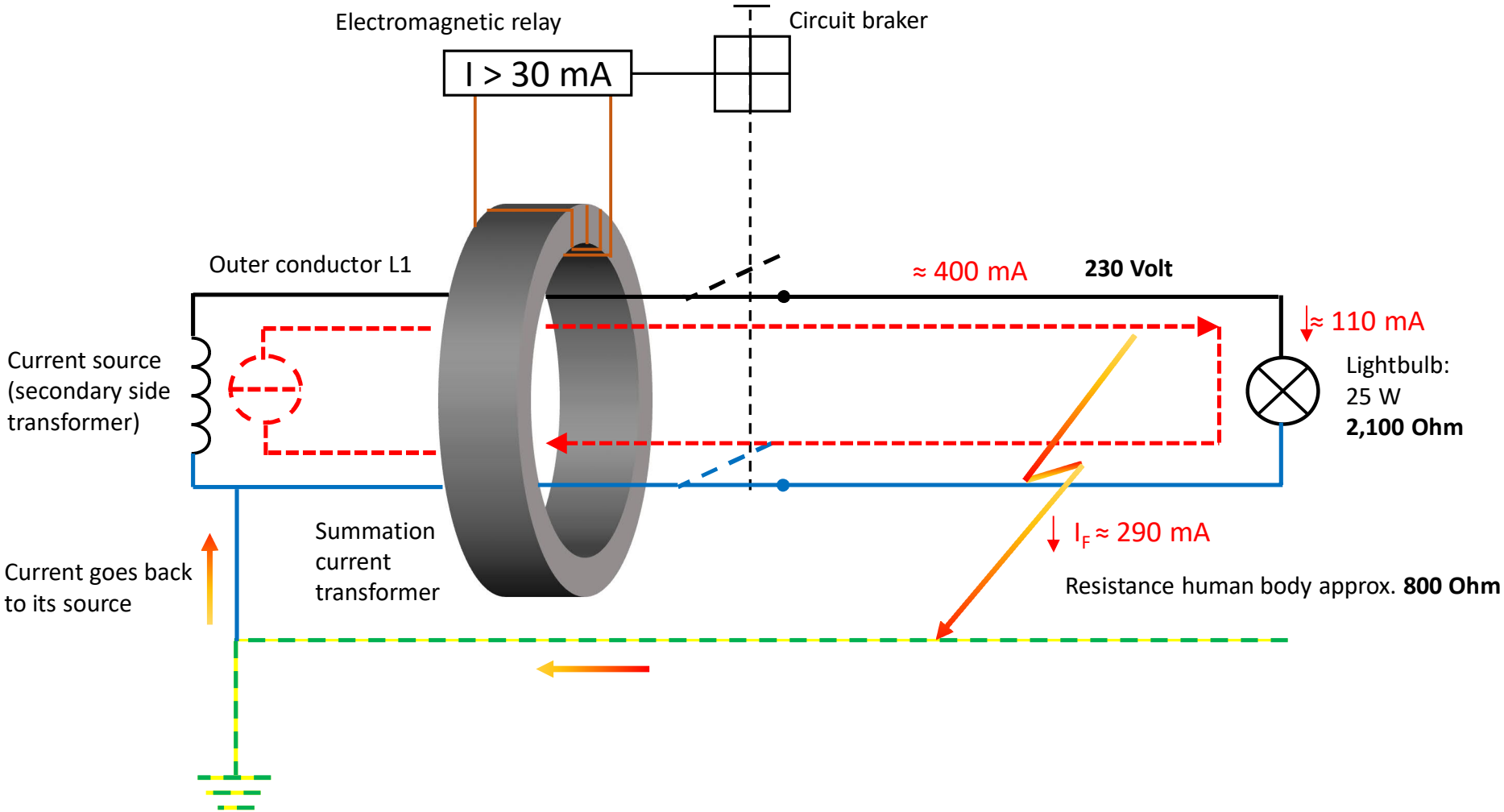


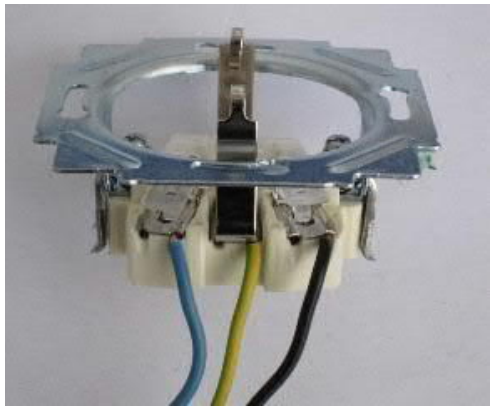
Residual Current Monitor Devices by Danisense

Oct. 2021

What is a residual current?

"Differential current is the difference between the current flowing in the outer conductor (L) and the current flowing in the neutral conductor (N)."

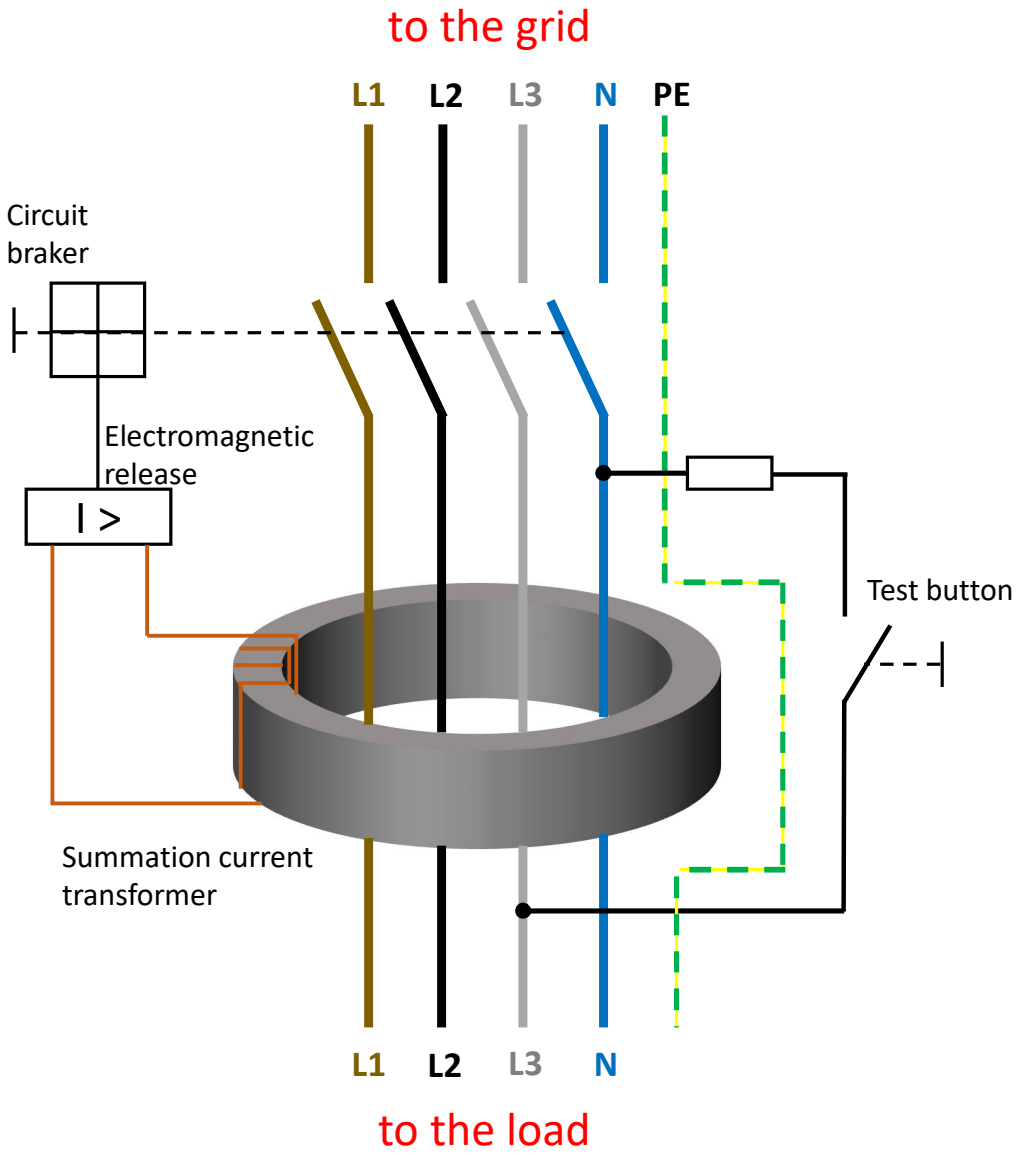


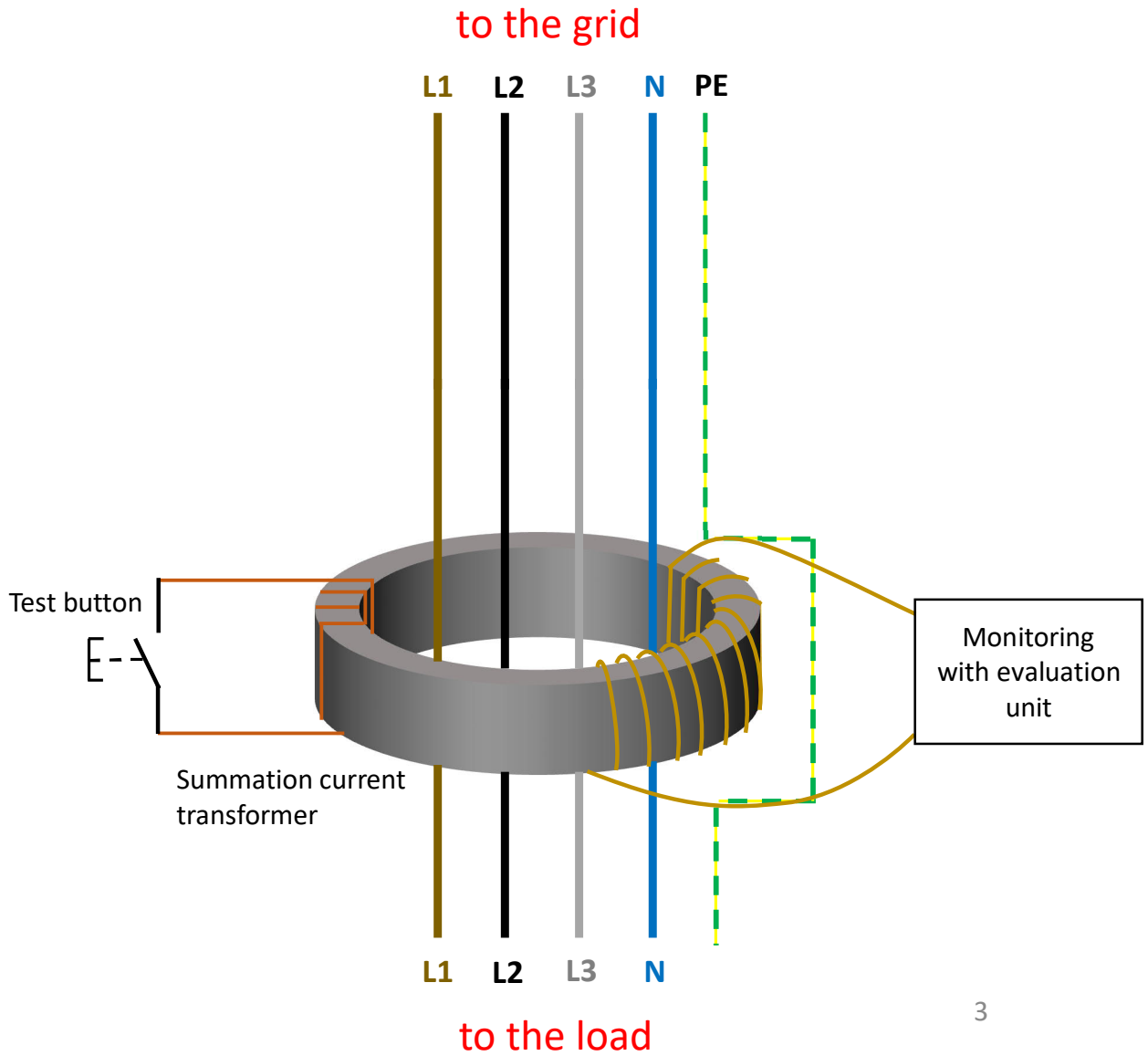


Neutral conductor Outer conductor

PE protective conductor (earth)

Residual Current protective Device (RCD) vs. RCM





Defined protection levels (@ rated frequency)

Currents from **50 mA** onwards are life threatening. The risk increases with higher amperage and longer exposure time.

Rated residual current max. $I_{\Delta n}$	Additional protection Protection against direct contact, personal protection (IEC 60364-4-41)	Fire protection Protection against electrically ignited fires	Fault protection / Unit protection Protection in case of indirect contact (IEC 60364-4-41)
30 mA	X	X	X
100 mA		X	X
300 mA		X	X
> 500 mA			X

Which final circuit has to be measured how fine?

Measurement target >300 mA (unit protection)

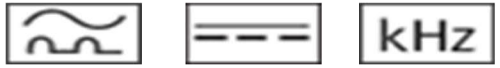
- Replacement of the insulation measurement acc. to IEC 60364-6 Edition 2.0 2016-04

Measurement target <300 mA (fire protection)

- Redidual current measurement in fire-endangered facilities

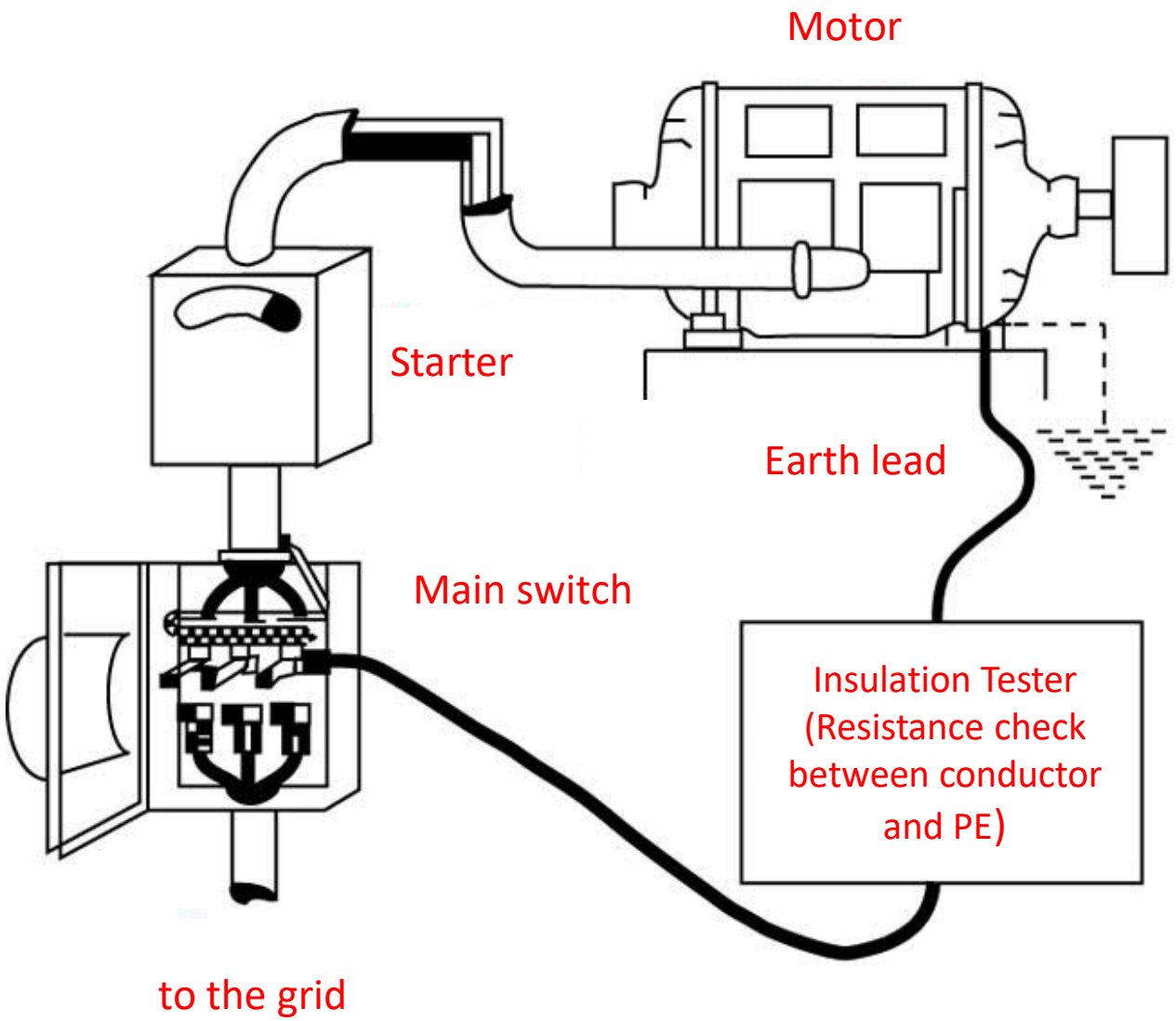
RCD-different versions

1)

RCD-Type	Symbol	Scope of application (examples)
AC		No longer allowed in Germany since 1985, as only purely sinusoidal variables are recognized!
A		Only for networks with sinusoidal AC residual currents and pulsating DC residual currents
F		Like type A, but also for fault currents with mixed frequencies (e.g. consumers with frequency converters in single-phase AC networks)
B		Like type A, but also for smooth DC residual currents and high-frequency residual currents (e.g. caused by multi-phase frequency converters)
B+		Like type B, but also for high-frequency fault currents up to 20 kHz

1) source: https://new.abb.com/products/de/2CSF204001R1400/f204ac-40-0-03-fi-schutzschalter-4p-typ-ac-40a-30ma

Traditional insulation testing



The insulation resistance must be measured between each active conductor and the protective conductor or earth.

IEC 60364-6 Edition 2.0 2016-04

IEC 60364-6:2016 provides requirements for initial and periodic verification of an electrical installation. This second edition cancels and replaces the first edition published in 2006 and constitutes a technical revision.

DANISENSE

Low voltage electrical installations – Part 6: Verification

6.5.1.2 Periodic verification shall be carried out without dismantling, or with partial dismantling, as required, supplemented by appropriate tests and measurements from Clause 6.4, to provide for:

a) the safety of persons and livestock against the effects of elctric shock and burns,
b) protection against damage to property by fire and heat arising from an electrical installation defect,
c) confirmation of correct rating and setting of protective devices required by IEC 60364-4-41,
d) confirmation of correct rating and setting of monitoring devices,
e) confirmation that the installation is not damaged or deteriorated so as to impair safety,
f) the identification of installation defects and non-compliances with the requirements of the relevant parts of the IEC 60364 series, that may give rise to danger,
g) confirmation of correct rating and setting of protective devices, and
h) confirmation of correct rating and setting of monitoring devices.

Where a circuit is permanently monitored by an RCM in accordance with IEC 62020 or an IMD in accordance with IEC 61557-8 **it is not necessary to measure the insulation resistance** if the function of the IMD or RCM is correct.

The functioning of the RCM or IMD shall be verfied.

Residual current monitoring acc. IEC 62020 !

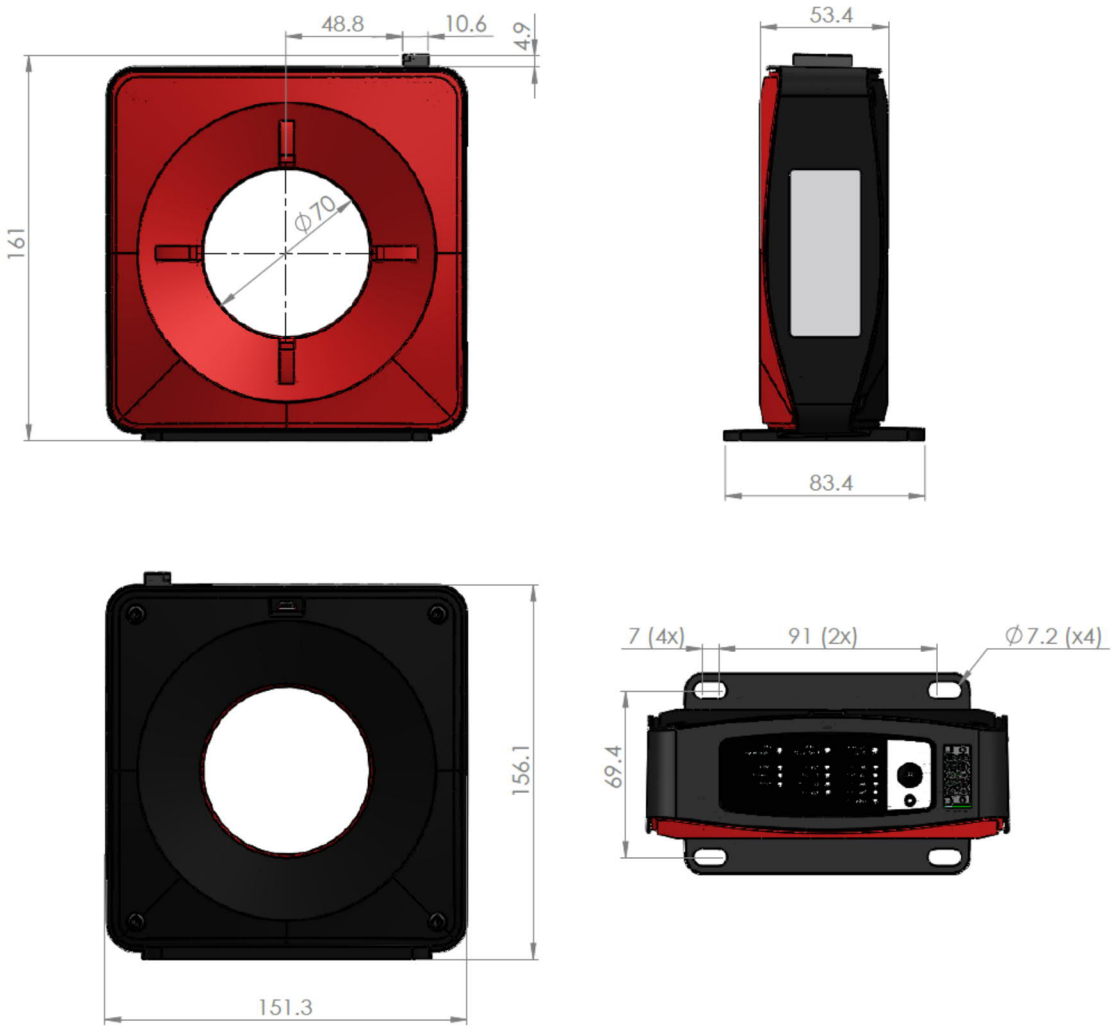
RCMH070B+

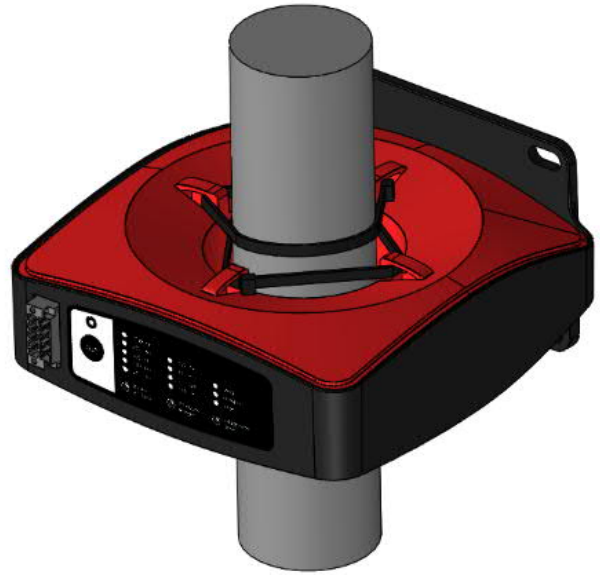
SRCMH070B+ (S=Software)

Mechanical specifications

Mounting instructions

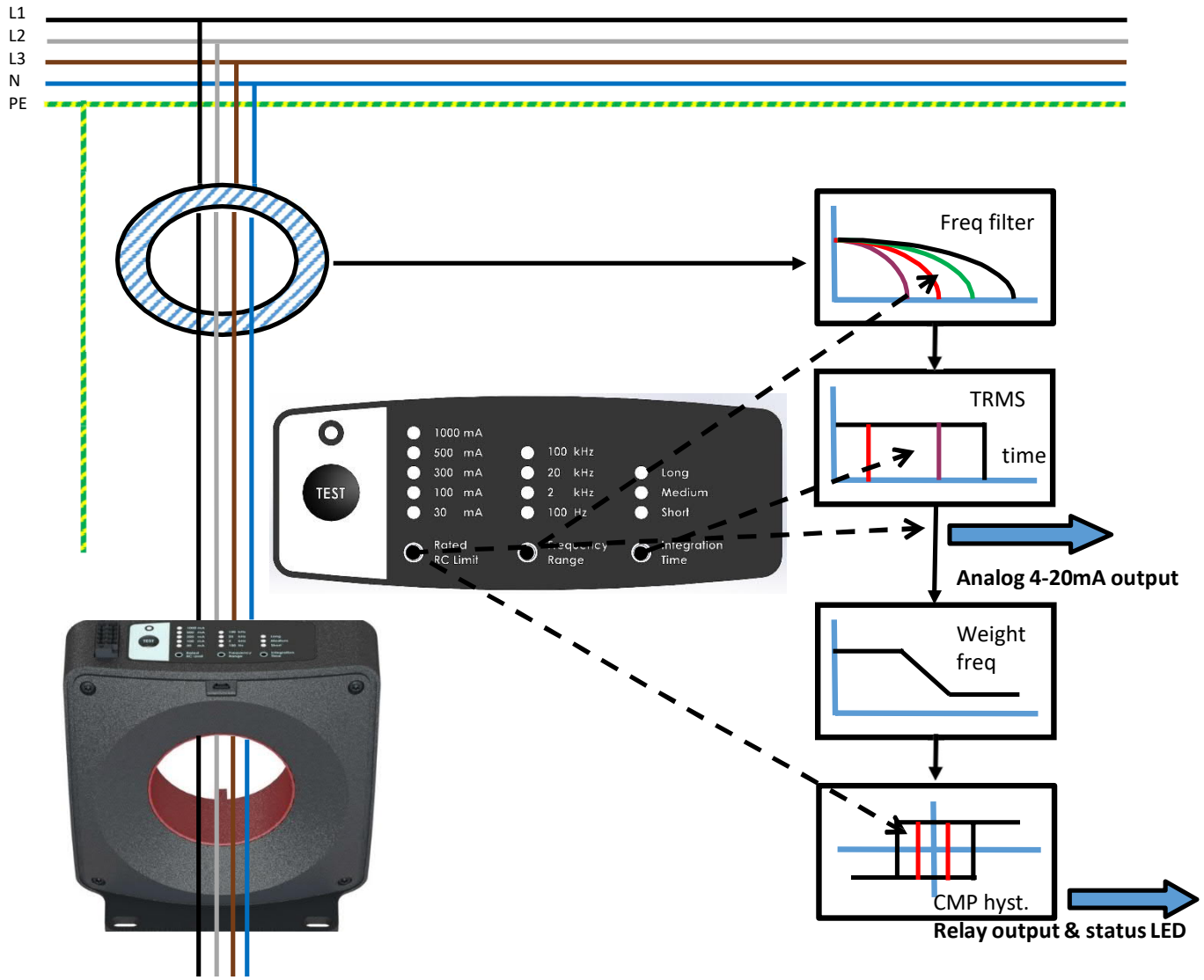
- Base plate mounting with screws in the four holes
- Free-hanging on the cable by using cable strips through the hooks on the backside for fixation





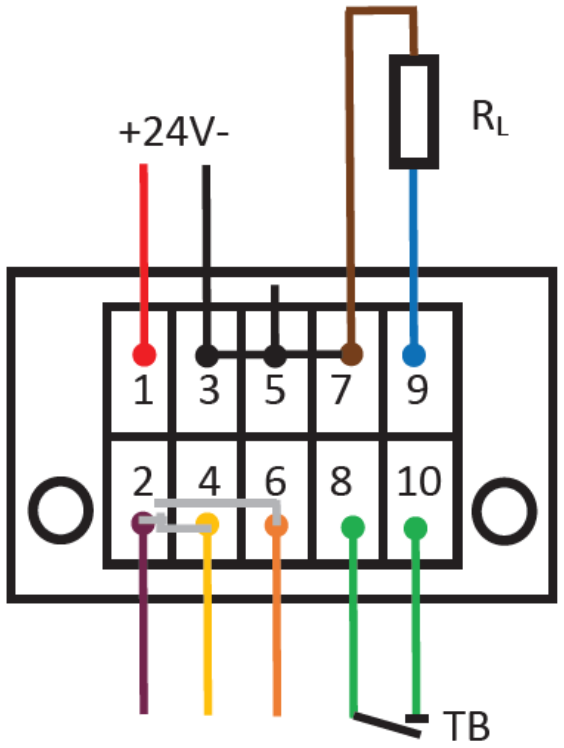
(general tolerance 0.3mm unless otherwise stated)

Functionality



Connector

Connector



Pinout:

1: 24 Vdc
2: Relay common
3: 0Vdc
4: Relais NC contact, alarm: closed
5: 0Vdc
6: Relais NO contact, alarm: open
7: 0Vdc
8: External Test button, contact 1
9: Analog 4-20mA output
10: External Test button, contact 2

User Interface

Status LED

Lights in green colour with heart-beat* during normal operation with low residual currents. Changes colour to red with heart-beat when the measured TRMS of residual current is higher than the rated RC limit. Flashing red light is indicator of fault status, requiring RCM service.

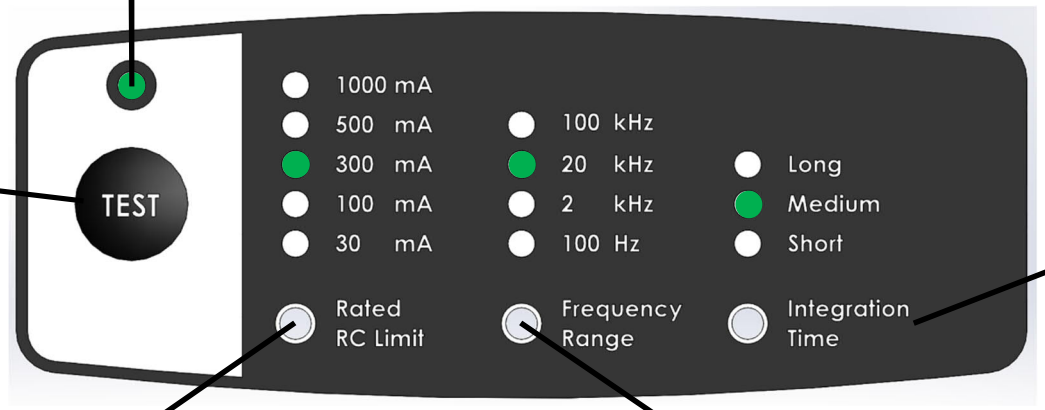
*Light intensity of the status LED changes continuously in a heart-beat fashion to mark correct execution of the software. It is a mere indication of the RCM being awake and taking care of user assets.

Test button

It is used to activate the test sequence for testing the operation of the RCM.

Successful test will activate the relay and cause LED to turn red.

When relay is latched in alarm state, pressing the button for 3s will reset the condition if residual current is normal.



Integration time (IT)

Refers to the time window for calculating TRMS value.
Hints:

- Longer IT makes the RCM less sensitive to short peaks during startup situations; better for low frequency operation
- Shorter integration times result in faster RCM response, especially if short residual current pulses are of interest

Rated RC Limit (RL)

Refers to the measured TRMS value of the residual current which will trip the relay output. Additionally, selecting the three lower ranges (30-100-300mA) changes the analog output range to 0-0.4Arms, while selecting the two higher ranges (500-1000mA) changes the analog output range to 0-2Arms. Hints:

- Set the RL low if it is required to get early warning of increasing residual current levels
- To avoid nuissance alarms, set RL to higher values which correspond to the residual current levels the user can tolerate in the electrical power system before system check or maintenance is going to be required

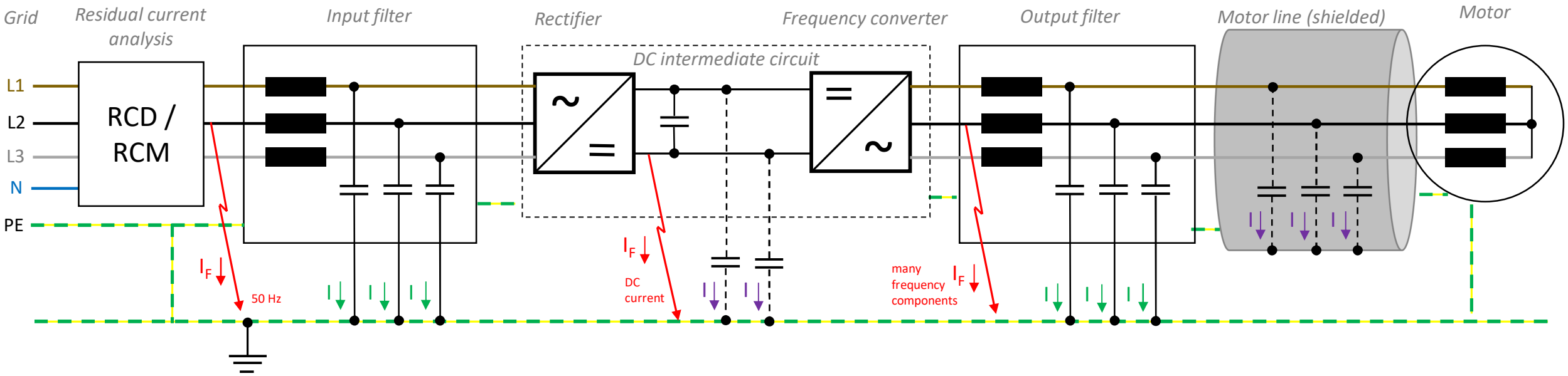
Frequency range (FR)

Refers to the measurement bandwidth for the residual current.
Hints:

- If only DC and low frequency AC (50/60 Hz) are of interest, use the 100 Hz setting
- If protection of switch-mode frequency converters is imperative, increase FR towards 2 kHz, 20 kHz or even full bandwidth 100 kHz

Monitoring machine with frequency converter

Typical residual currents in a motor drive with frequnency converter



$I\downarrow$ = *residual current due to parasitic capacitances*

\+ $I\downarrow$ = *residual current due to capacitive filter*

= *constant system-related residual current*

\+ $I_F\downarrow$ = *leakage current / fault current*

= *measured total residual current of the RCM device*

Sample:

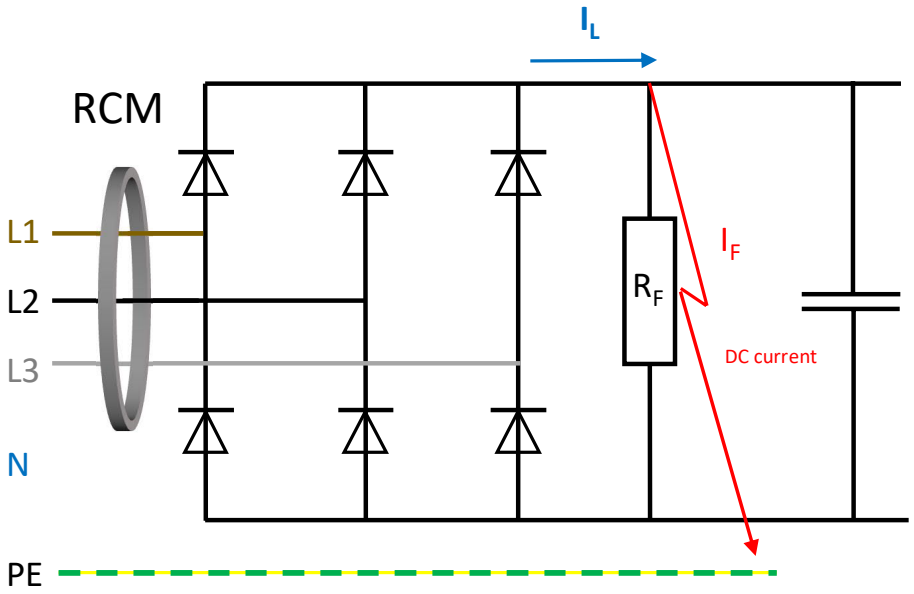
System-related residual current of the plant 250 – 300 mA

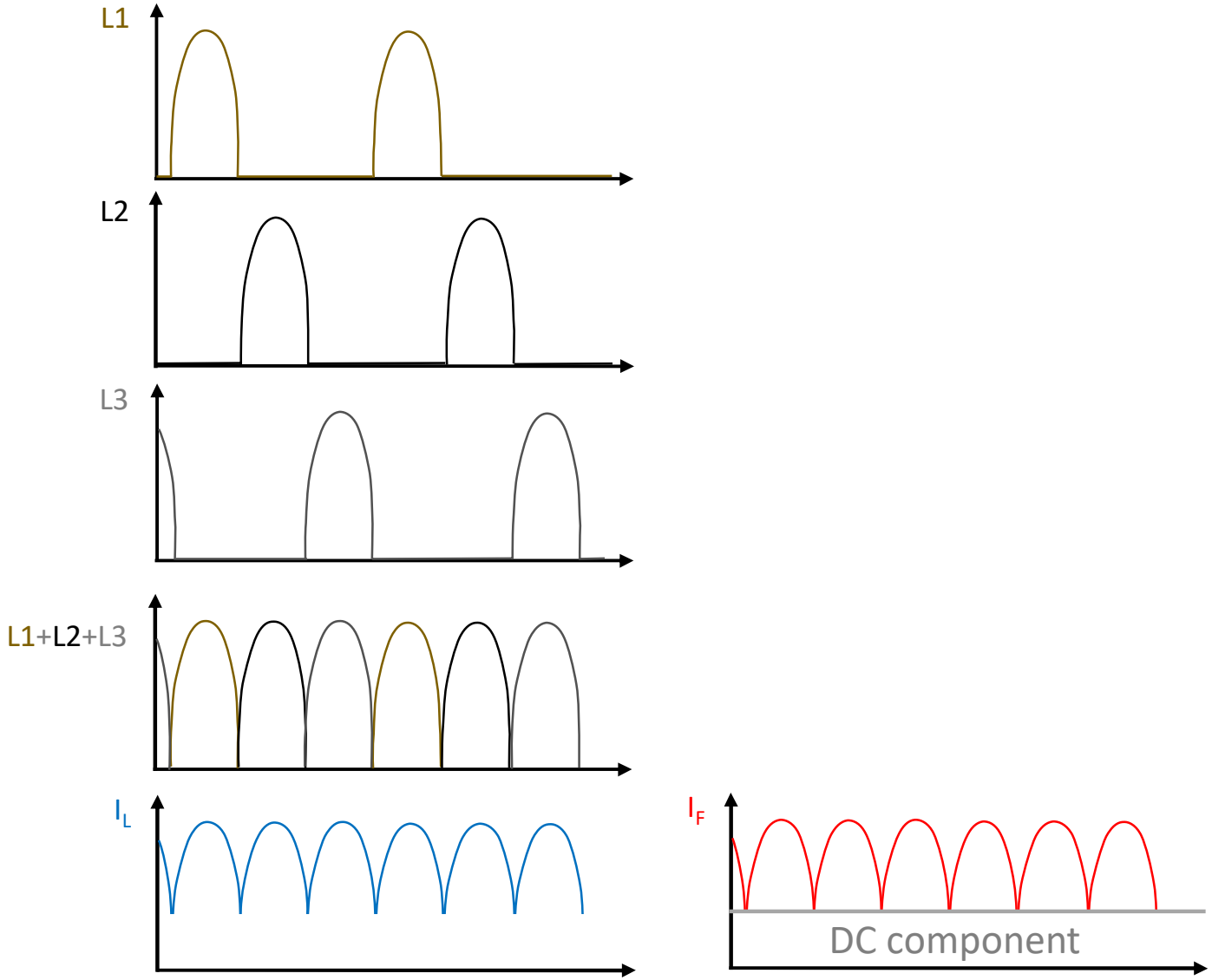
Fire protection RCD is triggered under 300 mA

Alarm threshold 1: 400 mA (Pre-alarm)

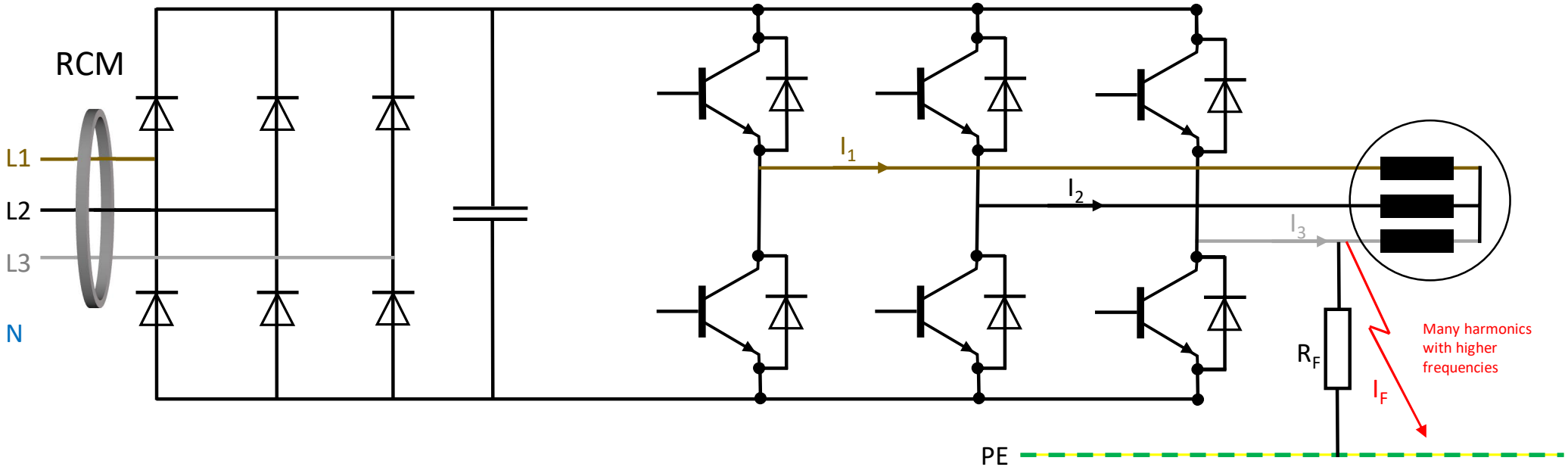
Alarm threshold 2: 600 mA (shutdown of the plant)

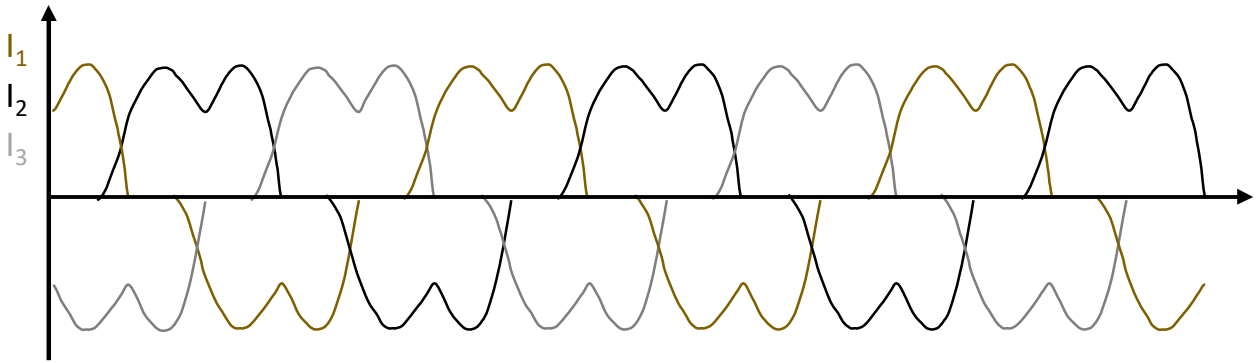
What kind of fault currents are to be expected?

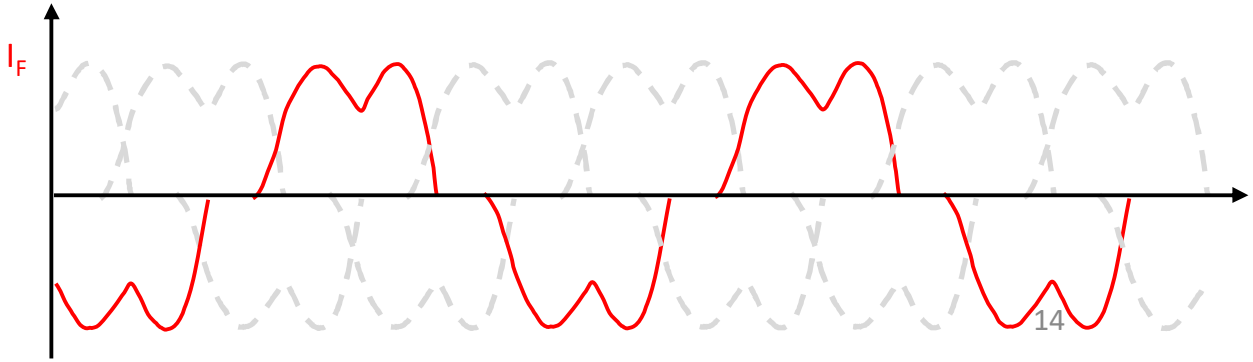




What kind of fault currents are to be expected?







System with FC: Do we need type B RCM?

Do we need AC / DC sensitive RCD and RCM devices?

If an RCD or RCM device is used for systems with frequency converter technoloy, an all-current-sensitive device (also called type B) must be used. In the German standard VDE 0100-530 we found the following senstences:

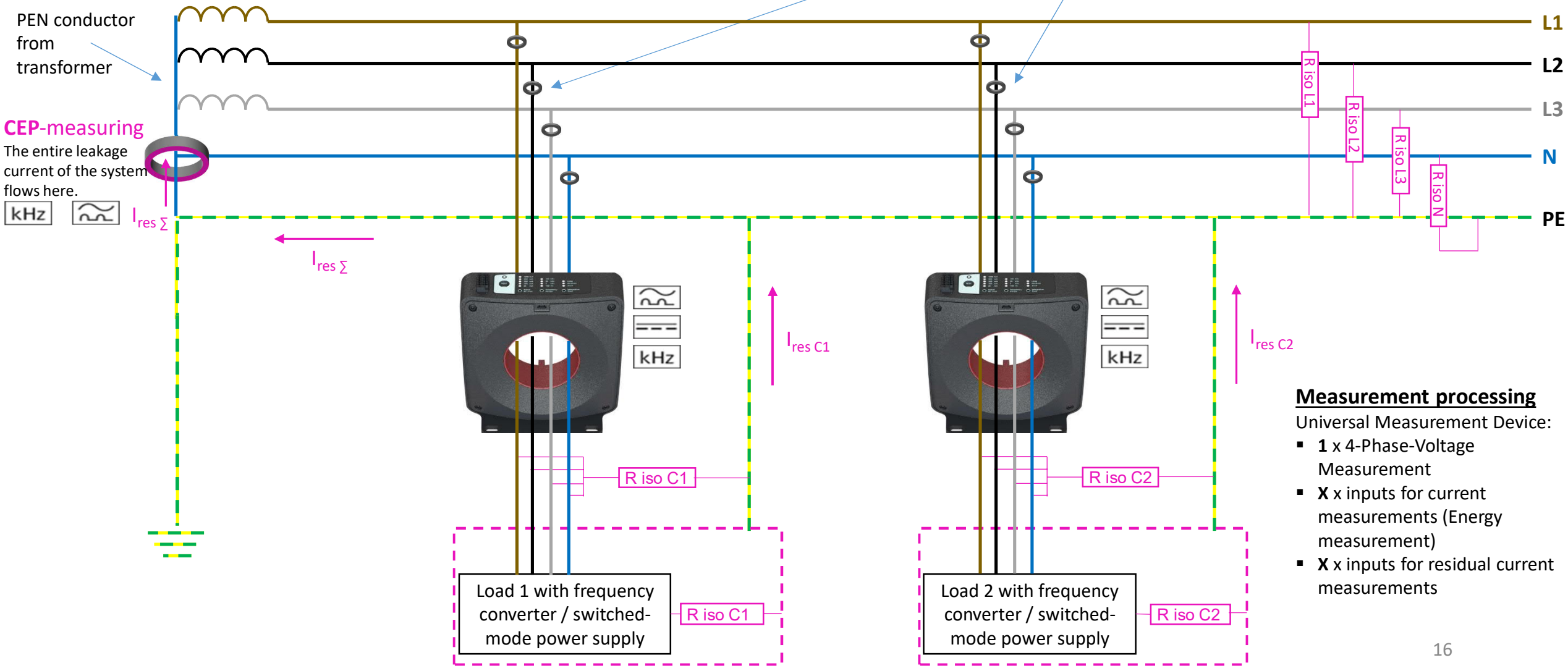
"If parts of electrical equipment that are permanently installed on the load side of a residual current device (RCD) can generate pure DC residual currents, the residual current device (RCD) must be of type B."

In the event of a fault, a frequency converter can also generate DC residual currents or high-frequency pulsating residual currents. Only a type B RCD can detect these currents.

RCM in TN-S systems

Current sensors for energy measurement

By measuring the current in the central earthing point (CEP), the insulation of the entire system can be assessed.

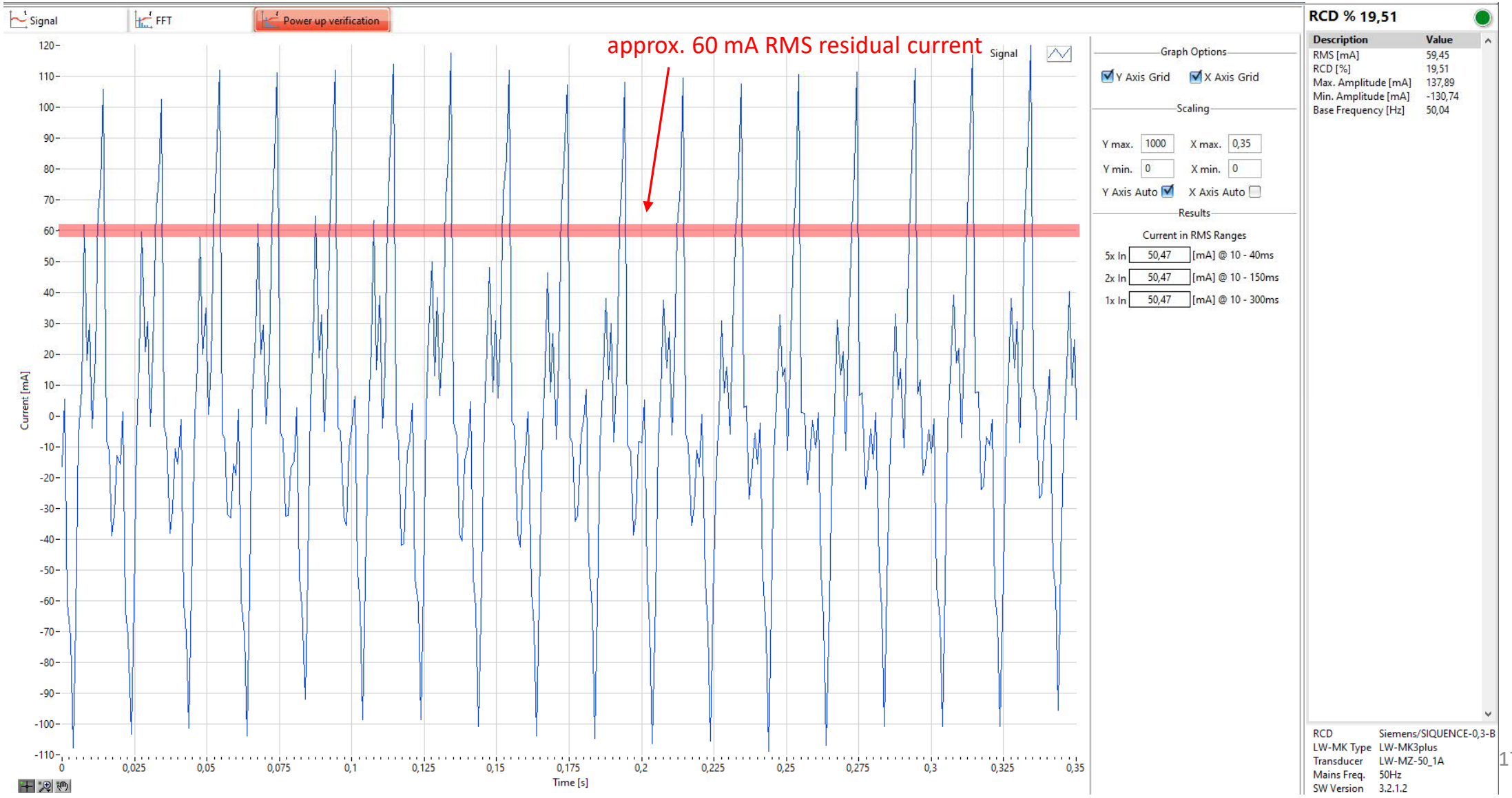


Measurement processing

Universal Measurement Device:

- **1** x 4-Phase-Voltage Measurement
- **X** x inputs for current measurements (Energy measurement)
- **X** x inputs for residual current measurements

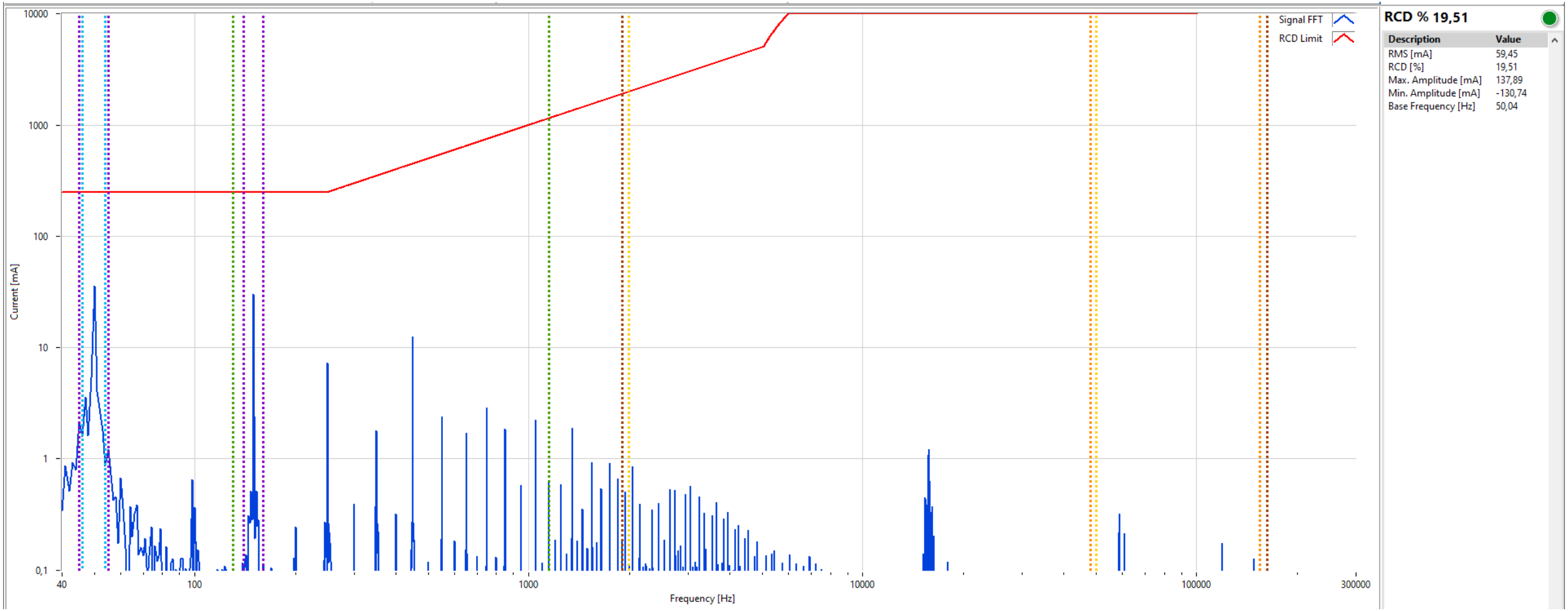
CNC machine (I_{pr} 130 A)



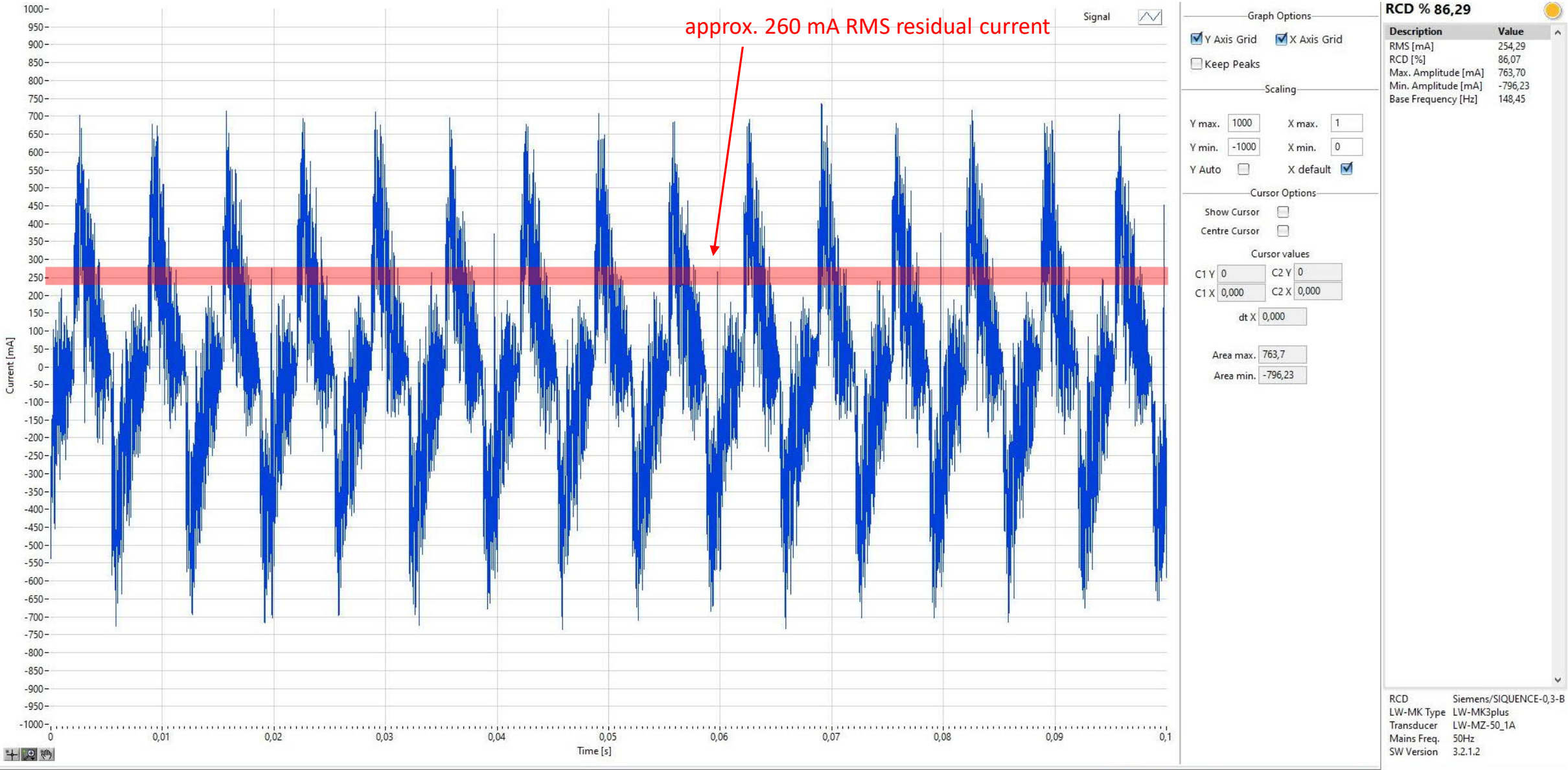
Frequency spectrum up to 100 kHz

FFT residual current

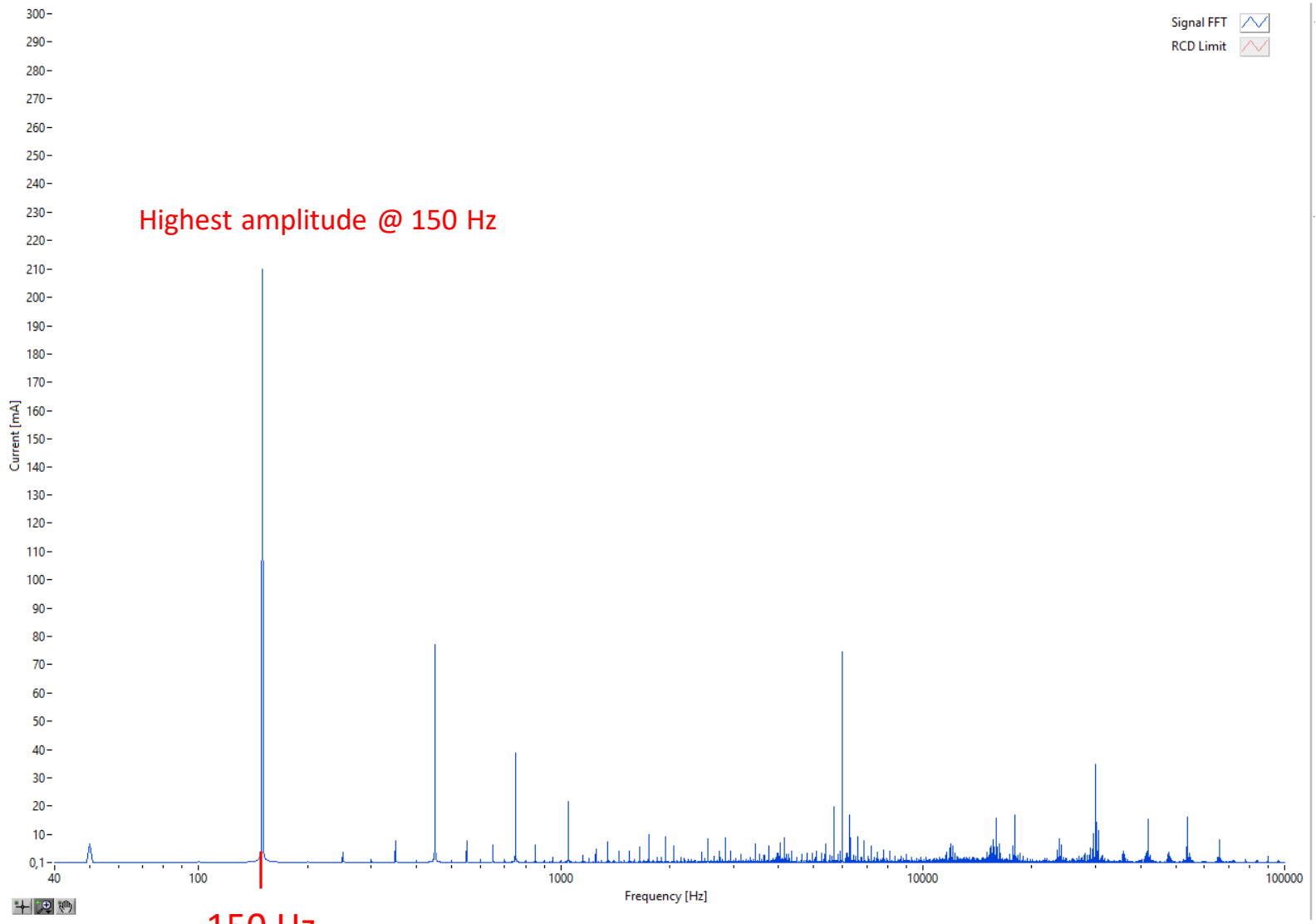
Frequency	Typical causes
50 Hz	power supply, line filter (low pass), interference suppression capacitors
50 Hz + 150 Hz	Single-phase frequency converter with internal EMC filter
150 – 1050 Hz	Three-phase frequency converter with internal EMC filter
2k – 50k Hz	Long shielded motor cable
50k – 150 kHz	Insufficient EMC filter
2k – 150 kHz	Long shielded motor cable + insufficient EMC filter



Residual current (production plant; I_{pr} 280 A)



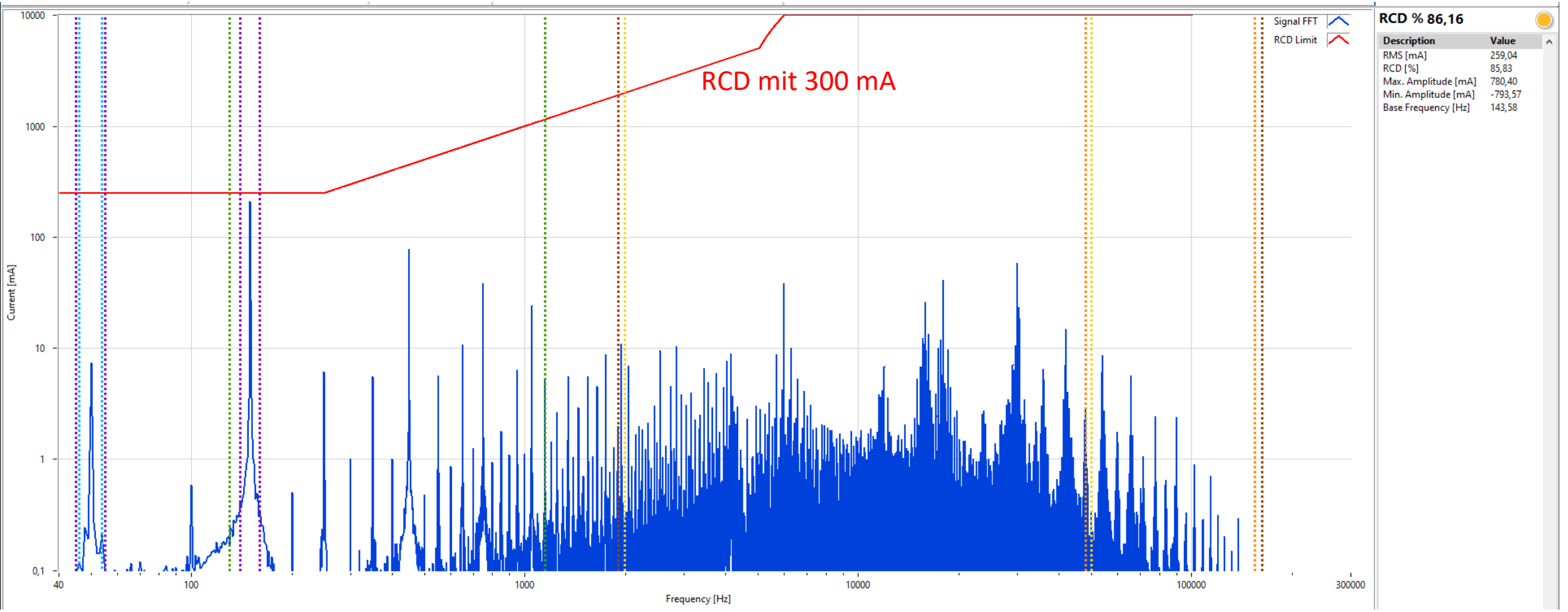
Frequency spectrum



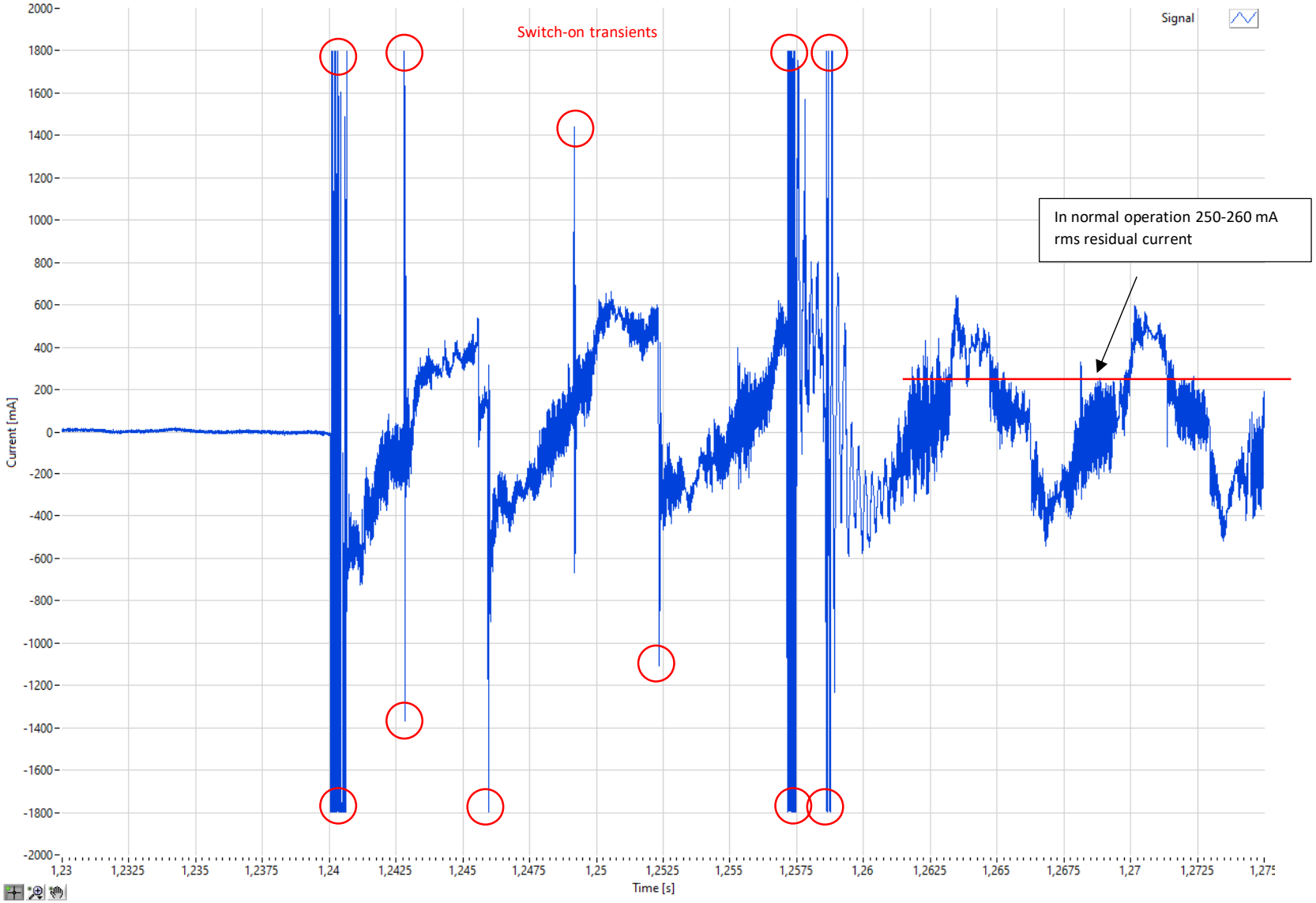
Residual current

(logarithmic x and y axis)

Frequency	Typical causes
50 Hz	power supply, line filter (low pass), interference suppression capacitors
50 Hz + 150 Hz	Single-phase frequency converter with internal EMC filter
150 – 1050 Hz	Three-phase frequency converter with internal EMC filter
2k – 50k Hz	Long shielded motor cable
50k – 150 kHz	Insufficient EMC filter
2k – 150 kHz	Long shielded motor cable + insufficient EMC filter



Switch-on transients



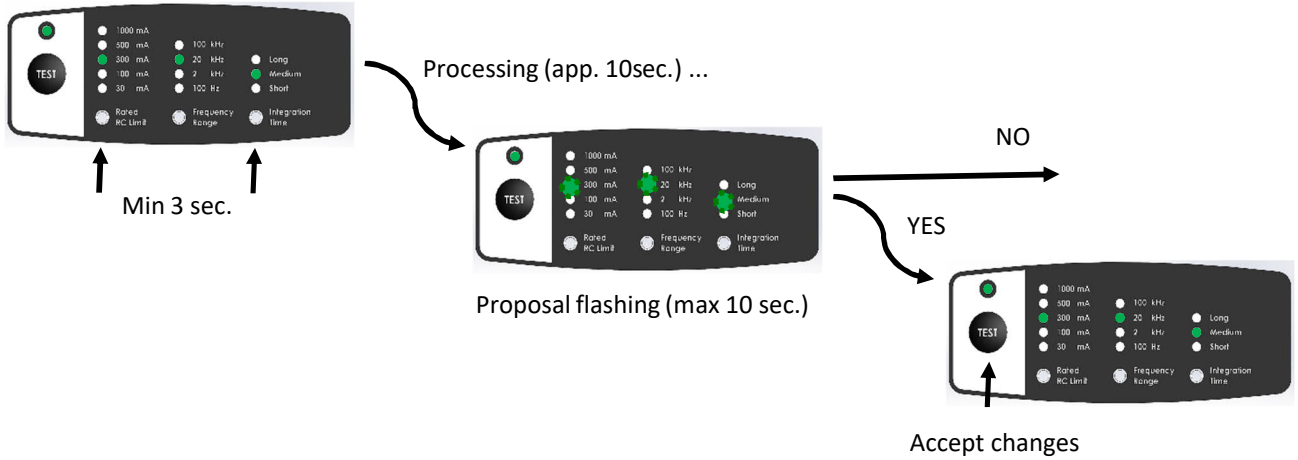
Auto setup function

Auto setup

Danisense SRCM is capable of performing automatic setup of the user selectable settings for installations in proper condition taken as baseline. This means that when the auto setup is initiated, the RCM will automatically measure the residual currents at the location of the installation with different frequency ranges & integration time settings and select the rated residual current limit which is at least 50% higher than the measured value. In this way the RCM will operate with comfortable margin for future development of the measured residual current towards the trip limit of the relay. The auto setup will also propose an appropriate frequency range and integration time.

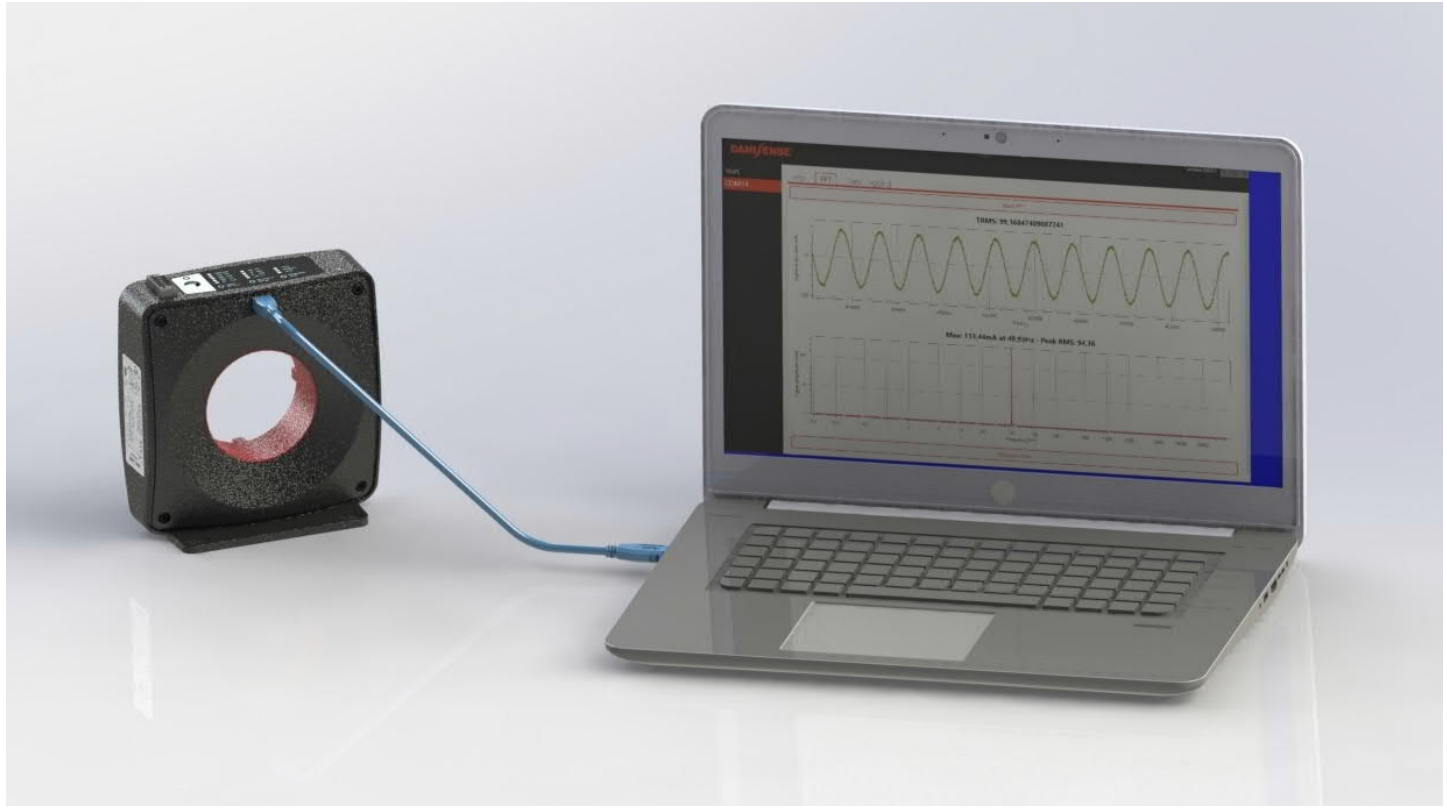
Necessary steps:

- Activate the auto setup by pressing ”Rated RC limit” and ”Integration time” buttons simultaneously for more than 3s
- RCM will perform sequence of residual current measurements with different settings
- Proposed settings for ”Rated RC limit”, ”Frequency range” and ”Integration time” are marked with flashing LEDs
- The proposed change of settings should be accepted by pressing the ”Test” button
- If the change is not accepted within 10s, the RCM will revert back to the old settings

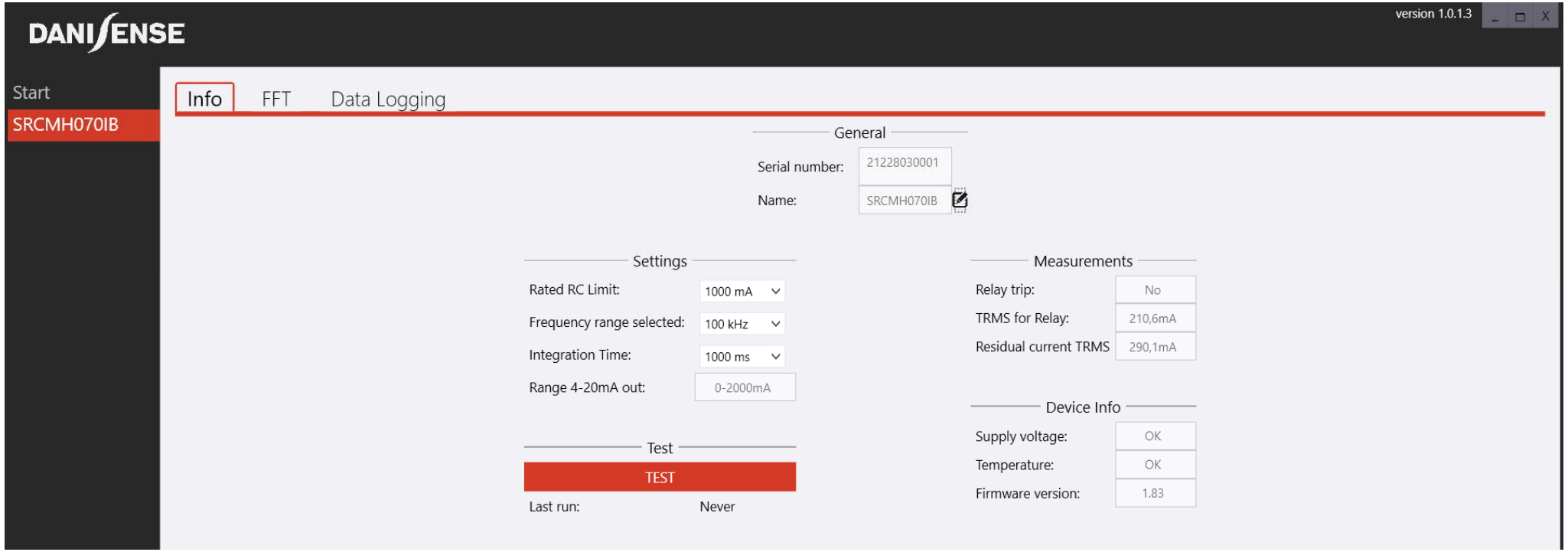


NB: Frequency range of 100Hz is not included in the auto setup feature i.e. if desired the user must select it manually. The RCM will always give priority to settings which make the RCM more sensitive i.e. higher frequency ranges and shorter integration times.

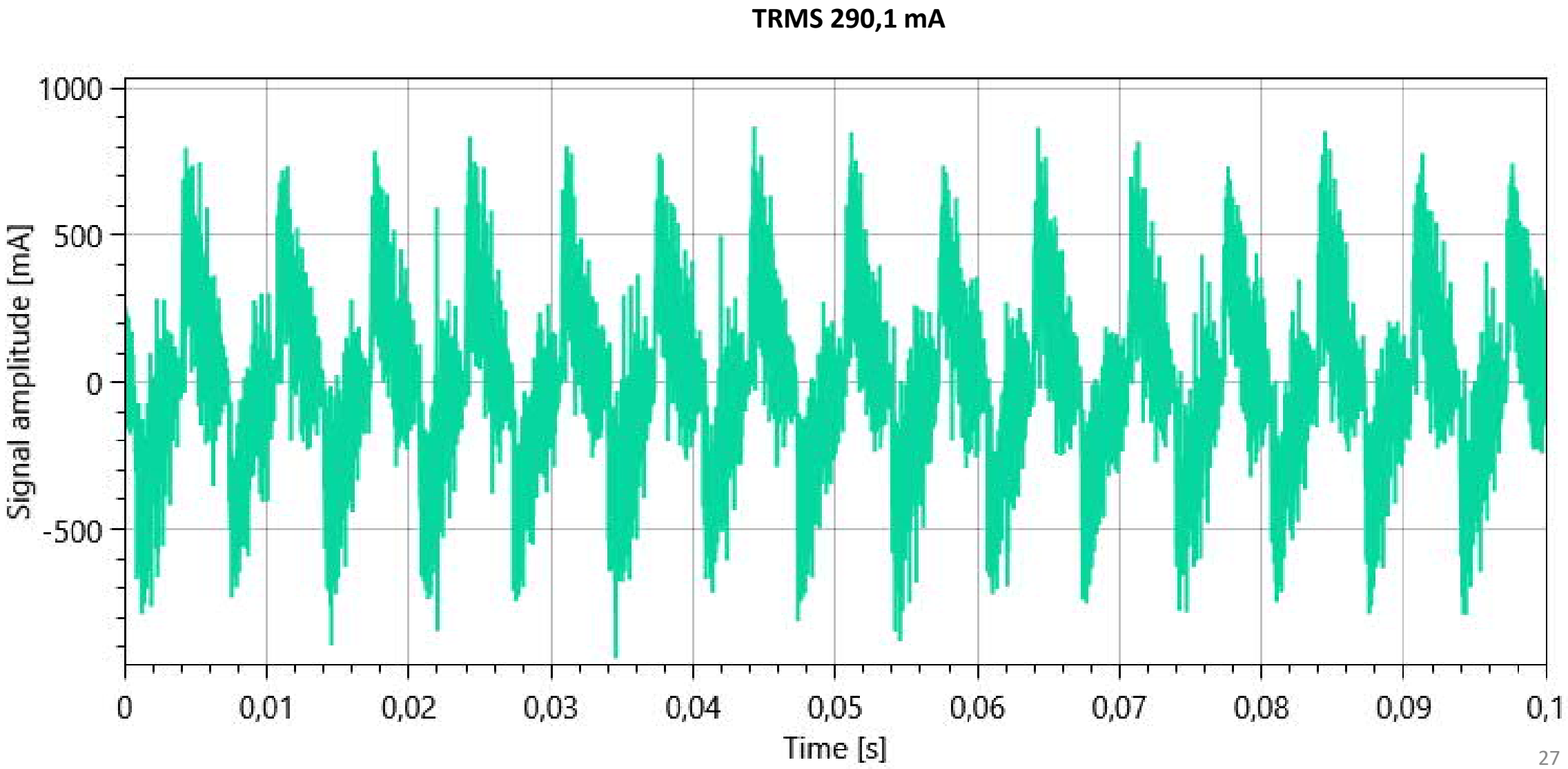
SRCMH070B+ with Windows software



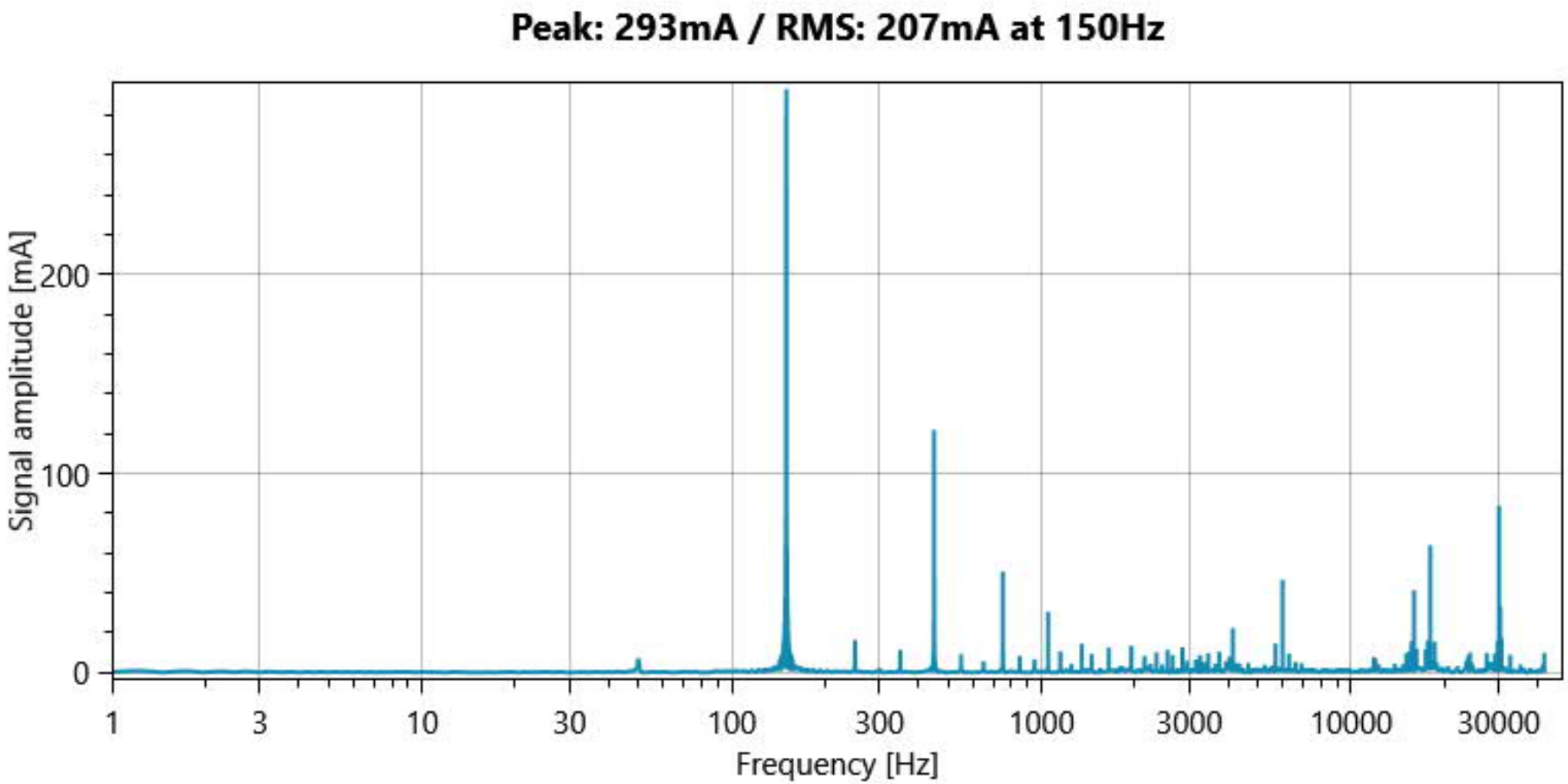
Software (1)


DANISENSE
version 1.0.1.3
Start
SRCMH070IB
Info
FFT
Data Logging
General
Serial number:
21228030001
Name:
SRCMH070IB
Settings
Rated RC Limit:
1000 mA
Frequency range selected:
100 kHz
Integration Time:
1000 ms
Range 4-20mA out:
0-2000mA
Test
TEST
Last run:
Never
Measurements
Relay trip:
No
TRMS for Relay:
210,6mA
Residual current TRMS
290,1mA
Device Info
Supply voltage:
OK
Temperature:
OK
Firmware version:
1.83

Oscilloscope function

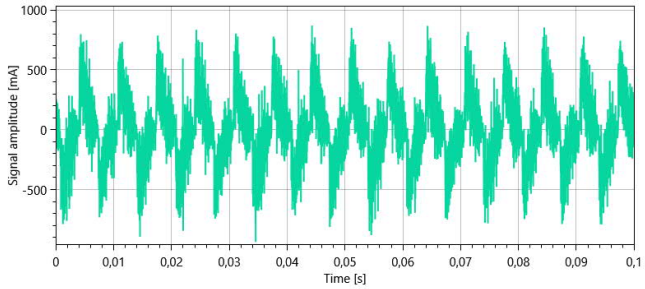


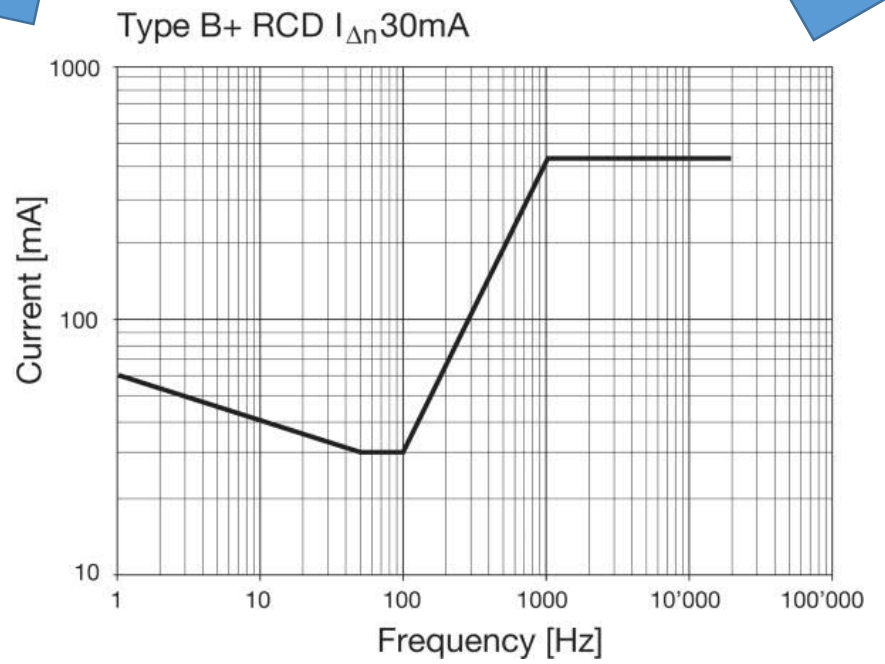
FFT-Function



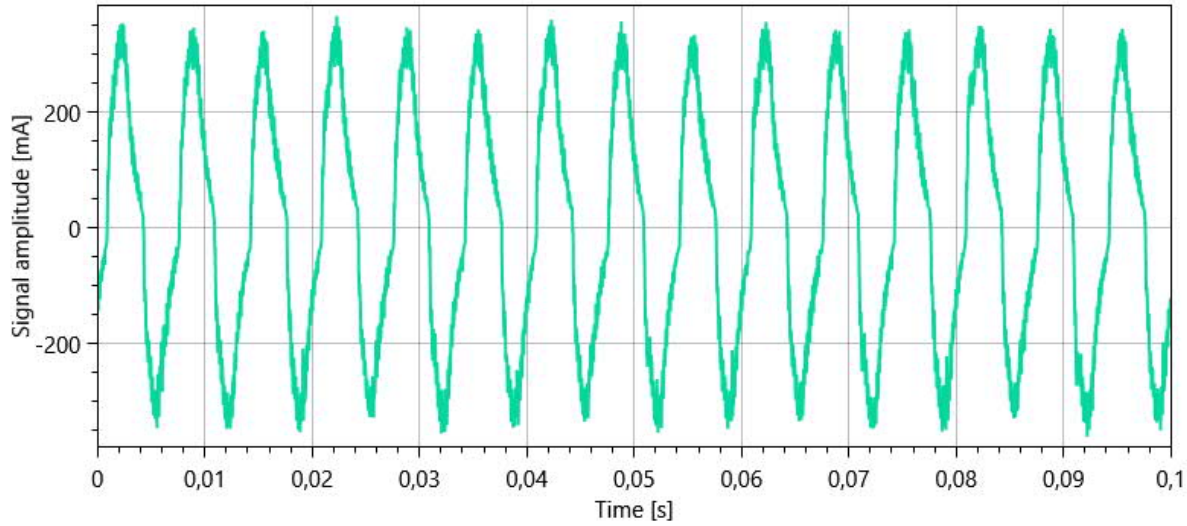
Relais function

TRMS 290,1 mA

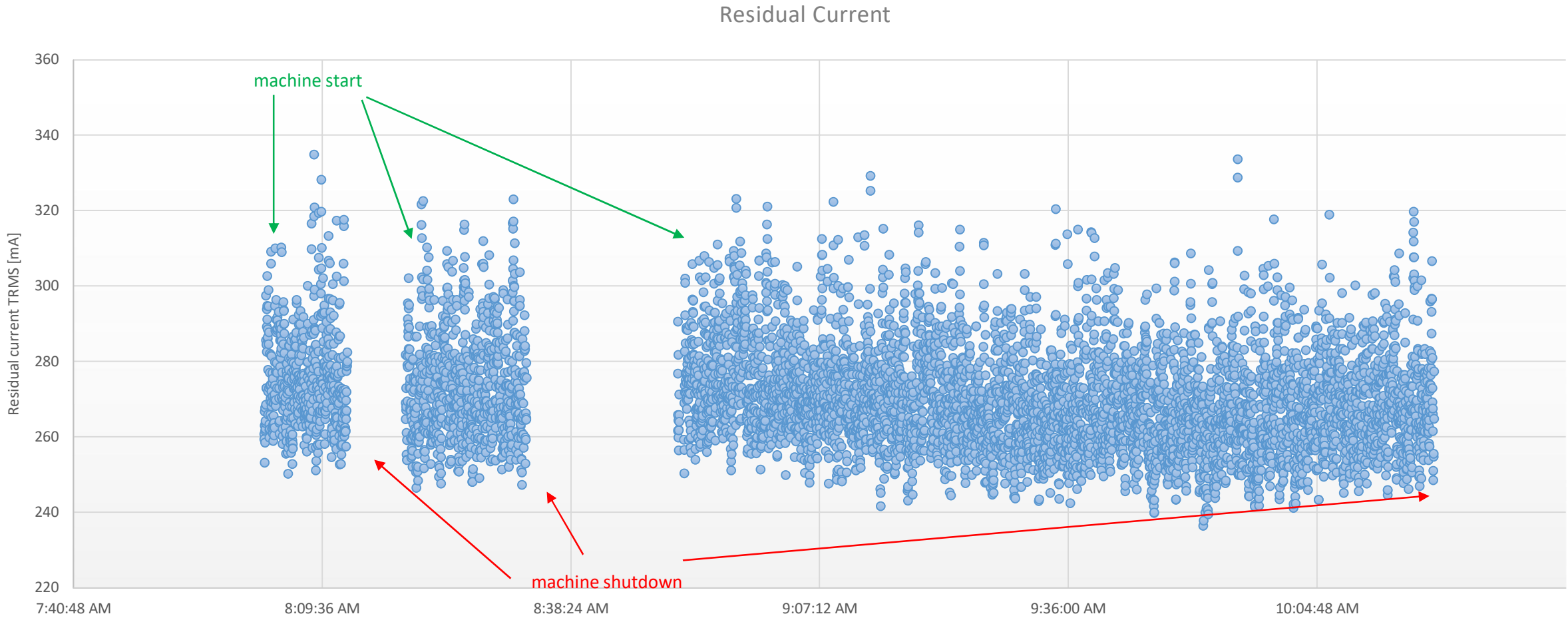




TRMS 210,6 mA

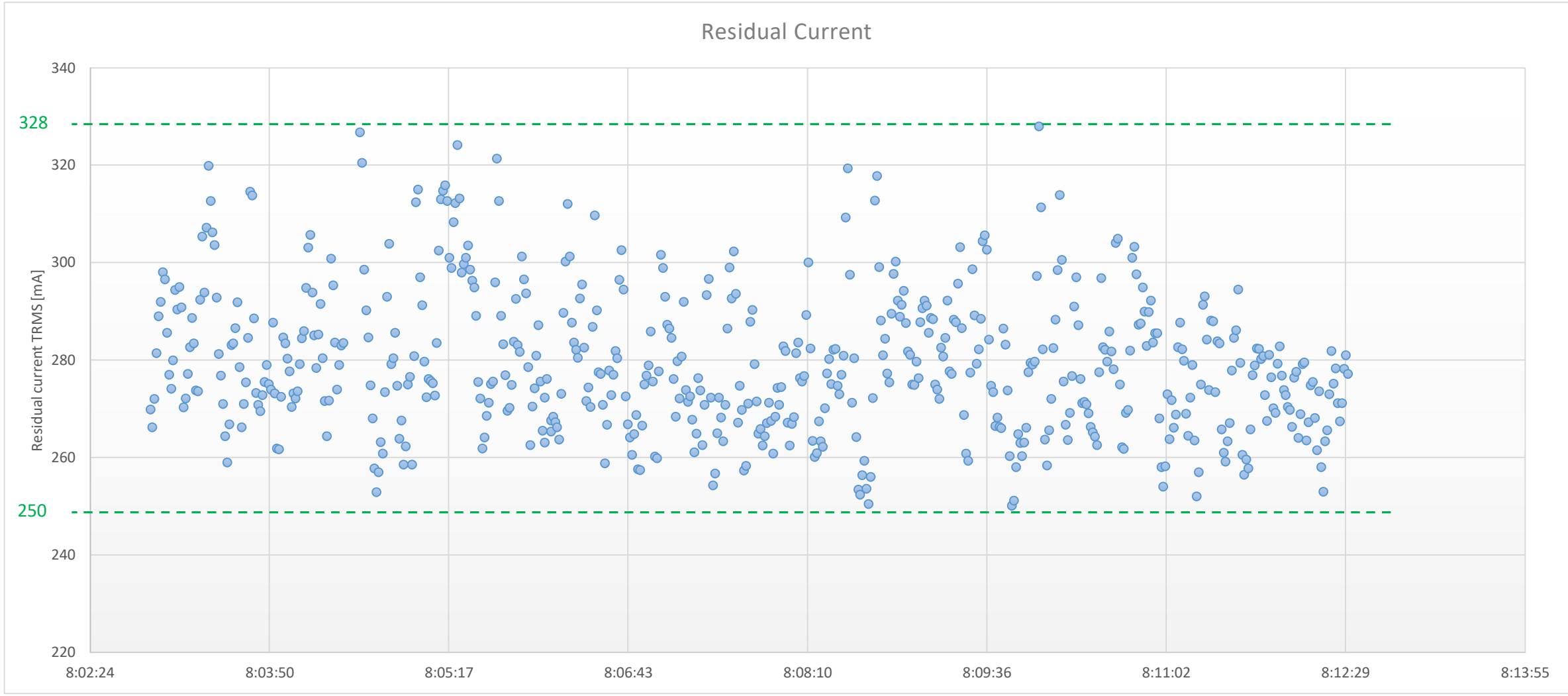


Monitoring using 4-20 mA output (1000 ms)



Due to the integration interval over 1000 ms, the current peaks during switch-on and switch-off processes are smoothed, so that no clearly increased values are recognizable via the TRMS calculation.

Monitoring using 4-20 mA output (400 ms)



What is the appropriate triggering threshold?

DIN VDE 0100-530 VDE 0100-530:2018-06
Low-voltage electrical installations
Part 530: Selection and erection of electrical equipment – Switchgear and controlgear

Section 531.3.2

The system-related residual current in protective conductor systems should not exceed **0.3 times** the rated residual current in residual current protective devices in order to avoid undesired shutdowns.

In the previous version of the DIN VDE 0100-530 **0.4 times** was the recommended value

Example
Fire protection (300 mA RCD):
$0.3 \times 300\ mA = \mathbf{90\ mA}$ max. system-related RC
Personal protection (30 mA RCD):
$0{,}3 \times 30\ mA = \mathbf{9\ mA}$ max. system-related RC

Basics of RCDs (product standard)
The RCD breaker monitors the correct current flow of a circuit between phases and N. Currents that flow via an undesired path (to earth or PE) are detected and the RCD switches the current off.

- The RCD should not trip with a fault current of 0 ... 49% of its nominal value.
- The RCD may trip in the event of a fault current of 50 ... 99% of its nominal value.
- The RCD must trip at the nominal residual current at the latest.

Preventive fire protection with an RCM

DIN VDE 0100-530 VDE 0100-530:2018-06
Low-voltage electrical installations
Part 530: Selection and erection of electrical equipment – Switchgear and controlgear

In section “532 Equipment for protection against fire risks”: “If a residual current device (RCD) according to 531.3.4.1 cannot be used for technical reasons, eg. because the operating current of the circuit to be protected is greater than the largest rated current of a residual current device (RCD), it is recommended to apply one of the following measures: Use of residual current monitoring devices (RCMs) according to DIN EN 62020 (VDE 0663) together with circuit breakers if their supply voltage is independent of the supply system. „

Insulation tests on systems with FC

ABB DRIVES FOR WATER

ACQ580-01 drives

(0.75 to 250 kW, 1.0 to 350 hp)

Hardware manual

On page 17!

WARNING! Do not install a drive with the EMC filter connected to a system that the filter is not suitable for. This can cause danger, or damage the drive.

Note: When the internal EMC filter is disconnected, the EMC compatibility of the drive is considerably reduced. See section *EMC compatibility and motor cable length* on page *283*.

- A drive with the ground-to-phase varistor connected can be installed to a symmetrically grounded TN-S system. If you install the drive to another system, check if you must disconnect the varistor. See sections
  - IEC: *When to disconnect EMC filter or ground-to-phase varistor: TN-S, IT, corner-grounded delta and midpoint-grounded delta systems* on page *112*, and *Guidelines for installing the drive to a TT system* on page *113*.
  - North America: *When to connect EMC filter or disconnect ground-to-phase varistor: TN-S, IT, corner-grounded delta and midpoint-grounded delta systems* on page *164*, and *Guidelines for installing the drive to a TT system* on page *165*.

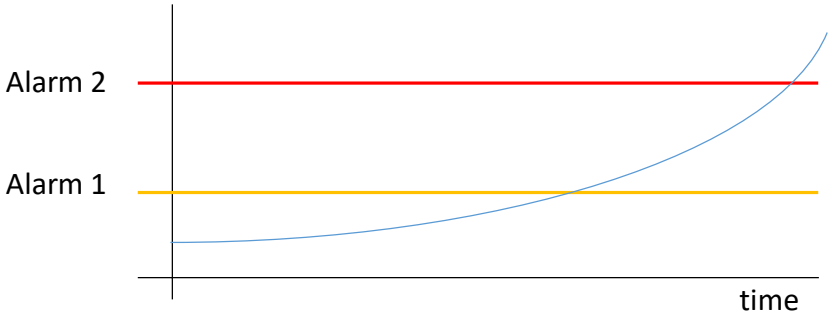
WARNING! Do not install a drive with the ground-to-phase varistor connected to a system that the varistor is not suitable for. If you do, the varistor circuit can be damaged.

- Use all ELV (extra low voltage) circuits connected to the drive only within a zone of equipotential bonding, that is, within a zone where all simultaneously accessible conductive parts are electrically connected to prevent hazardous voltages appearing between them. You can accomplish this by a proper factory grounding, that is, make sure that all simultaneously accessible conductive parts are grounded to the protective earth (PE) bus of the building.
- Do not do insulation or voltage withstand tests on the drive or drive modules.

source: https://search.abb.com/library/Download.aspx?DocumentID=3AXD50000044862&LanguageCode=en&DocumentPartId=1&Action=Launch

Advantages of rc measurement acc. IEC 62020

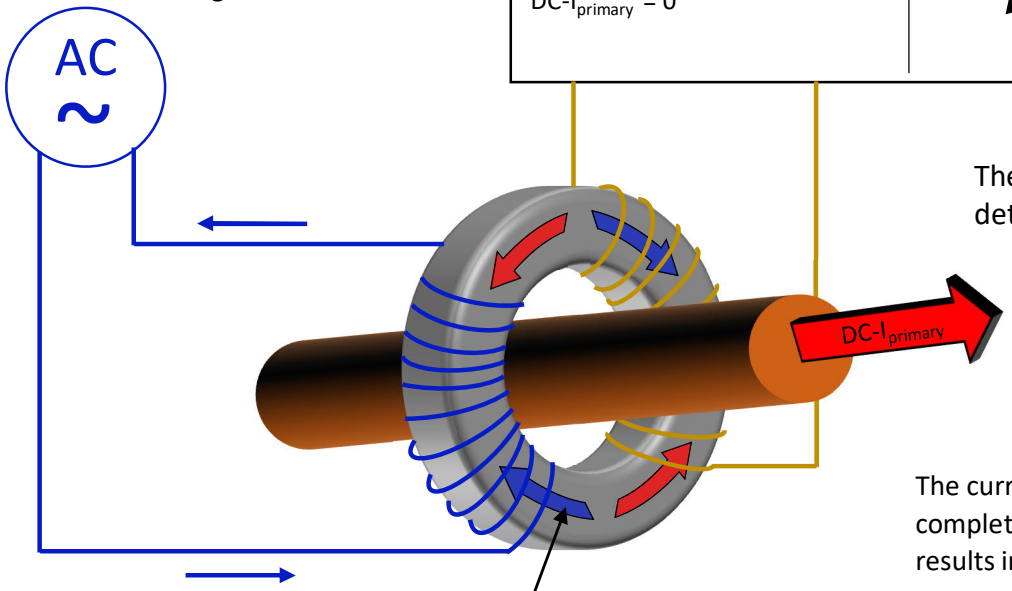
- Better system protection (early warning system)

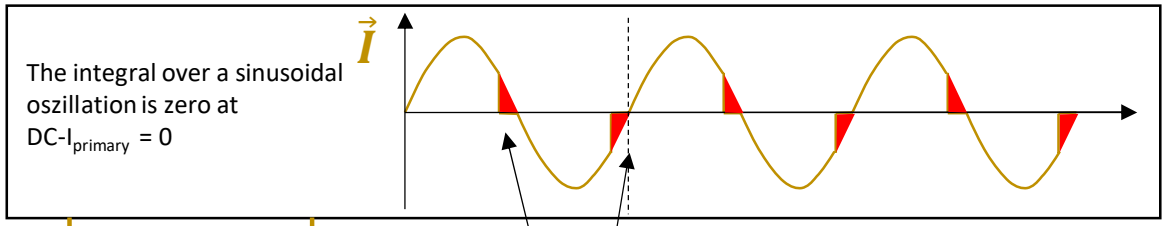


- Predictive Maintenance
- Better system availability in connection with an early warning system
- Possible fire protection (fault current <300 mA)
- No cost-intensive and bureaucratic repeat insulation tests according to IEC 60364-6

Measuring DC (DC-$I_{primary}$ = 0 A)

Power source for excitation winding

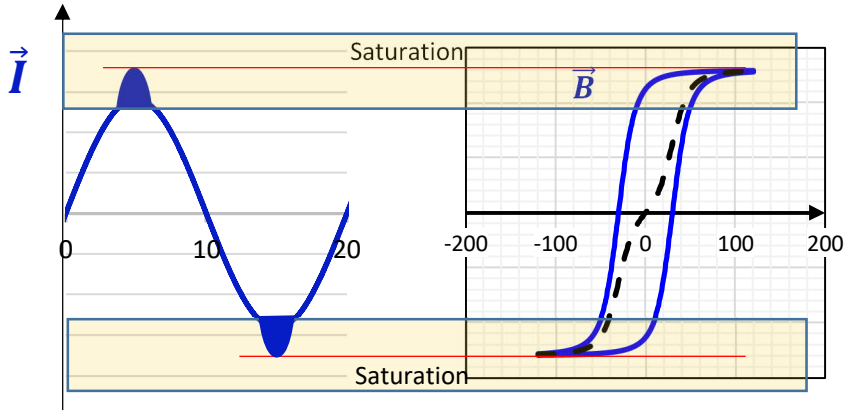




The deformations are the same. No DC primary current is detected

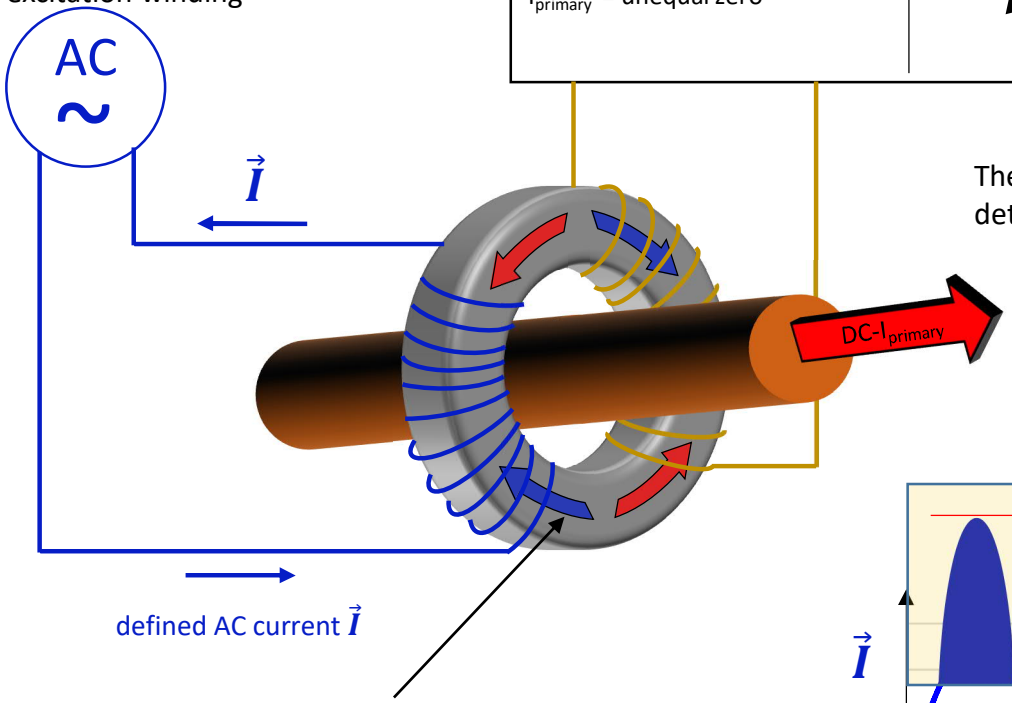
The current $\vec{I}$ averaged over a complete sinusoidal oscillation, results in zero!

Magnetic flux density $\vec{B}$ acc. the defined AC current of the excitation winding.

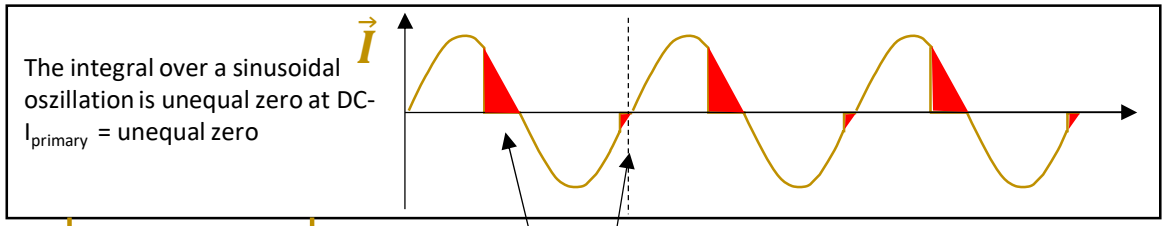


Measuring DC (DC-$I_{primary}$ ≠ 0 A)

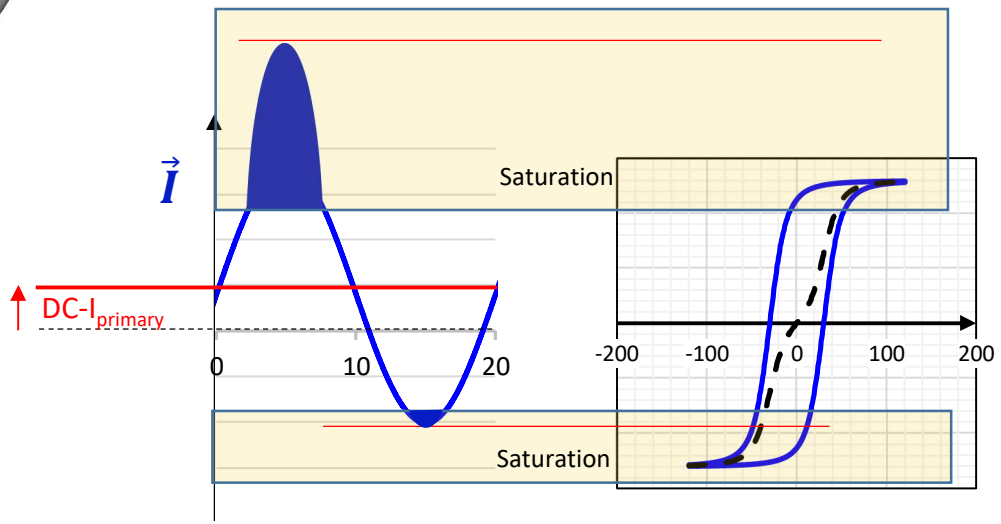
Power source for excitation winding



Magnetic flux density $\vec{B}$ acc. the defined AC current of the excitation winding.



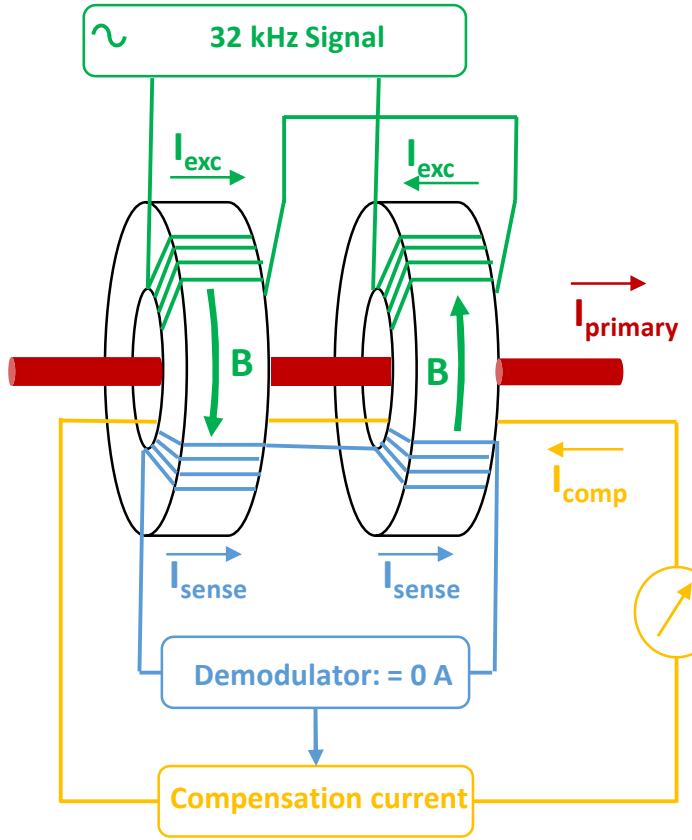
The deformations are of different sizes. A DC primary current is detected

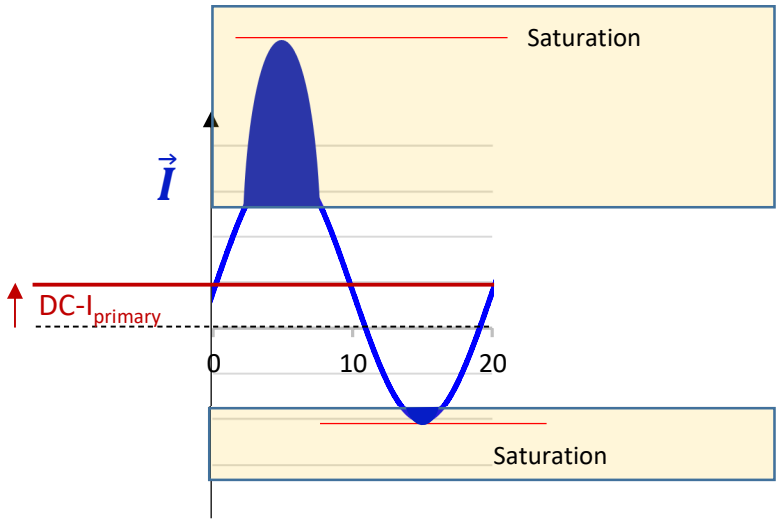


The magnetic flux density $\vec{B}$,averaged over a complete sinusoidal oscillation, results in zero.

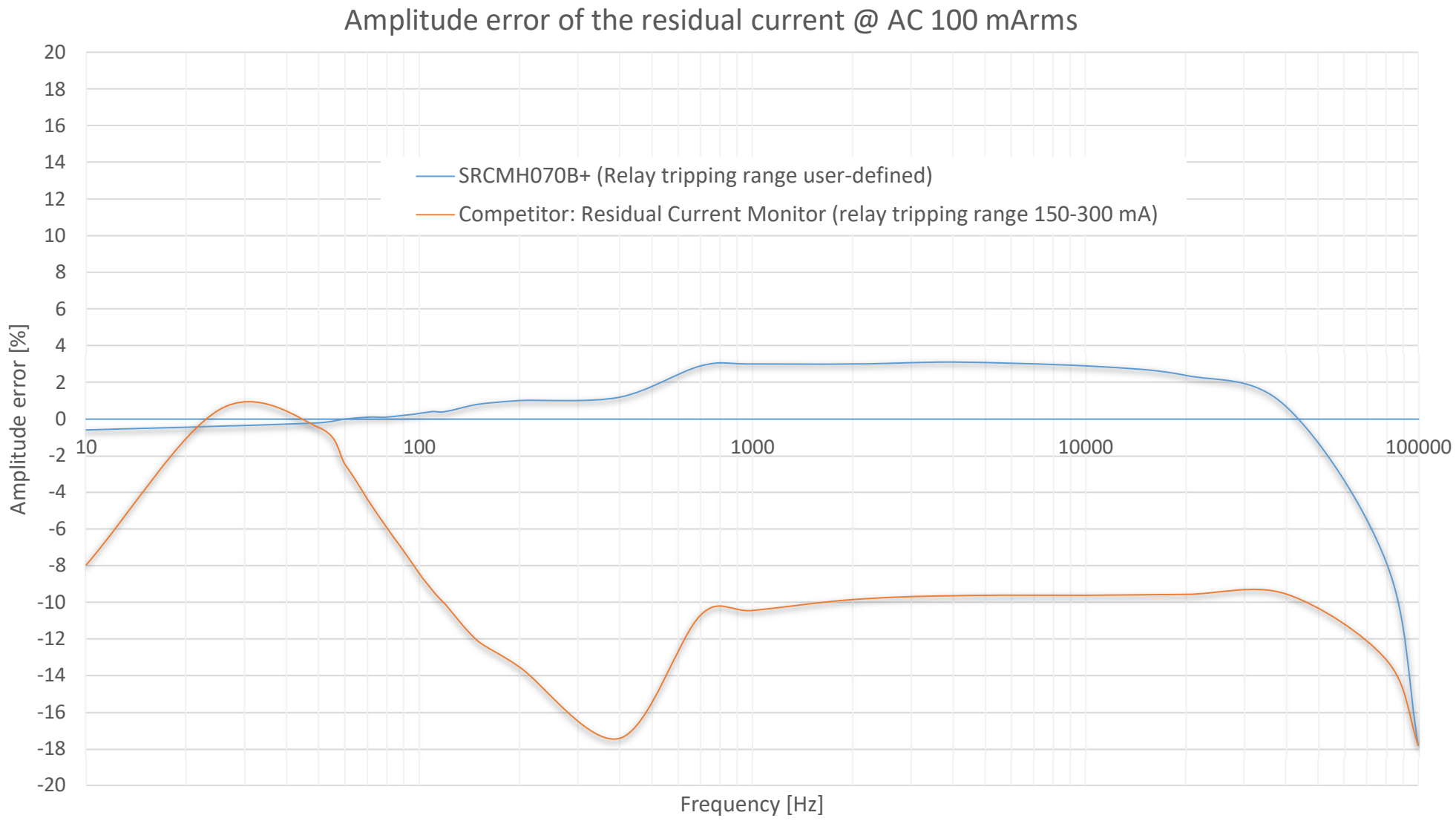
Flux-Gate-Technology

- **Excitation** of the primary windings forces both tori into saturation twice per cycle
- **Sense windings** measure the modulation signal and cancel each other. If $I_{primary}$ is zero, 0 A is measured.
- But with the $I_{primary}$ the saturation is shifted and I_{sense} is not zero
- Compensation current I_{comp} adjustable until I_{sense} is zero once again





Accuracy of the RCMH070B+ (AC)



Accuracy of the RCMH070B+ (AC+DC)