Problem PE-N relay timing on
Deye SUN 12K-SG04LP3

Contents

Introduction:

I have observed several instances where the RCDs (Residual Current Devices) in my installation are triggered after the hybrid inverter switches from Off-Grid back to On-Grid mode. Interestingly, it wasn't always the same RCD, which made the behavior even more puzzling.

To investigate the root cause of this issue, I decided to create a test setup and measure the voltages on the load side—where my home installation is typically connected. The test setup, shown in Figure 1, consists of a minimal configuration: two fuses and a power socket with a connected hairdryer acting as a load.

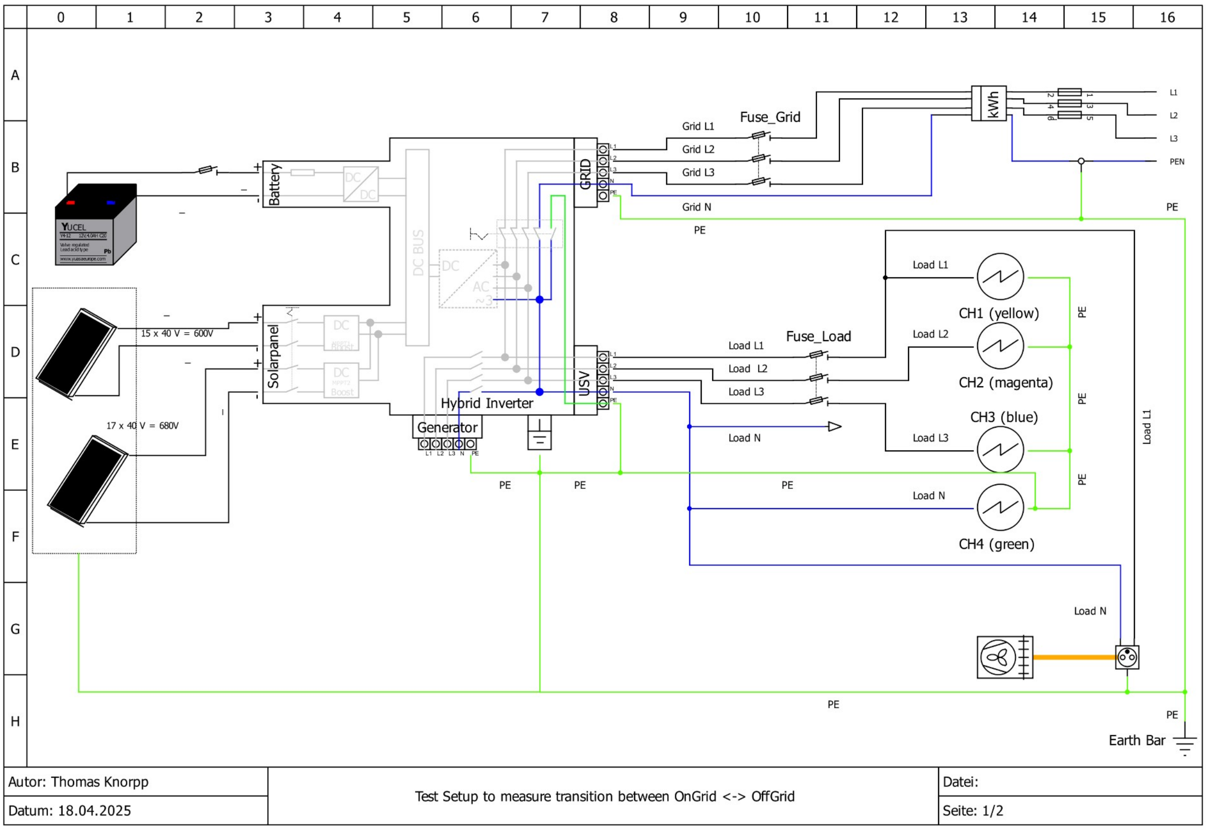

Figure 1: Test setup

Measurement Setup

- **Inverter:** Deye SUN 12K-SG04LP3
  - Signal Island Mode: Enabled
  - VDE4105 compliant
  - Firmware: MAIN 2005-1128-1807 / HMI 1001-C031
- **Probes:** measure L1, L2, L3, and N (load side) against PE with 10:1 divider.
- **Load:** Hairdryer connected between L1 and N.

Test description

The Deye SUN 12K-SG04LP3 is configured for the VDE 4105 and signal island mode → On which is the correct setting for Germany and my TN-C-S grid.
The Deye SUN 12K-SG04LP3 is configured according to VDE 4105 and set to "Signal Island Mode

ON," which is correct for Germany and my TN-C-S grid. The inverter is connected to a 30 kWh battery pack (Pylontech protocol) and a solar array.

Initially, the hybrid inverter operates in normal mode, with the hairdryer powered by both battery and grid. Then, the grid connection is interrupted by switching off the "Fuse_Grid." After some time in Off-Grid mode, the Fuse_Grid is turned back on while the hairdryer continues running.

Throughout this switching process between On-Grid and Off-Grid modes, the hairdryer continues operating without interruption. At first glance, everything appears to work correctly. However, a closer look at the oscilloscope readings reveals a significant issue with the PE-N connection during the transition from Off-Grid to On-Grid.

Transition OnGrid<->OffGrid

The Off-Grid mode is triggered by opening the Fuse_Grid, as shown in Figure 2.

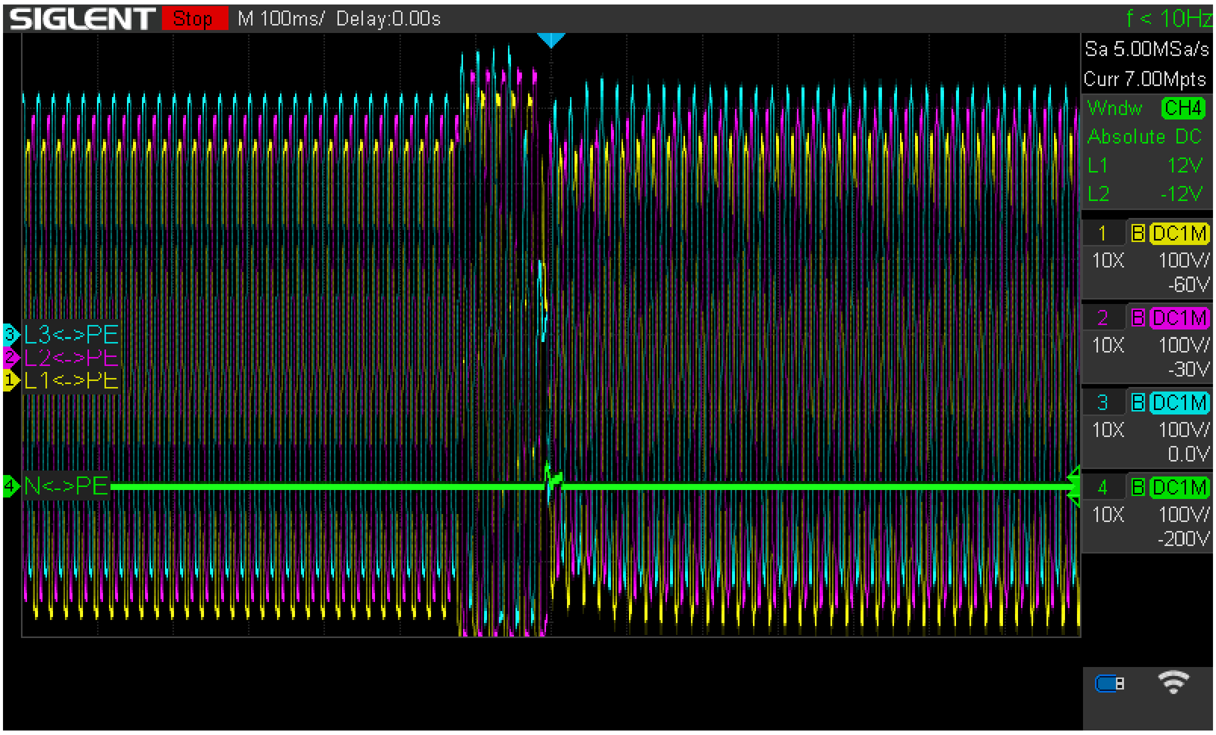

Figure 2: Transition OnGrid<->OffGrid

The transition is smooth, with only a minor ripple in the green signal representing the voltage between N and PE. Ideally, this signal should always be ~0V, as the neutral conductor (N) should be directly connected to protective earth (PE), either via the earth bar or through the PEN relay (in signal island mode) inside the Deye inverter.

Figure 3 to Figure 5 offer zoomed-in views of this transition.

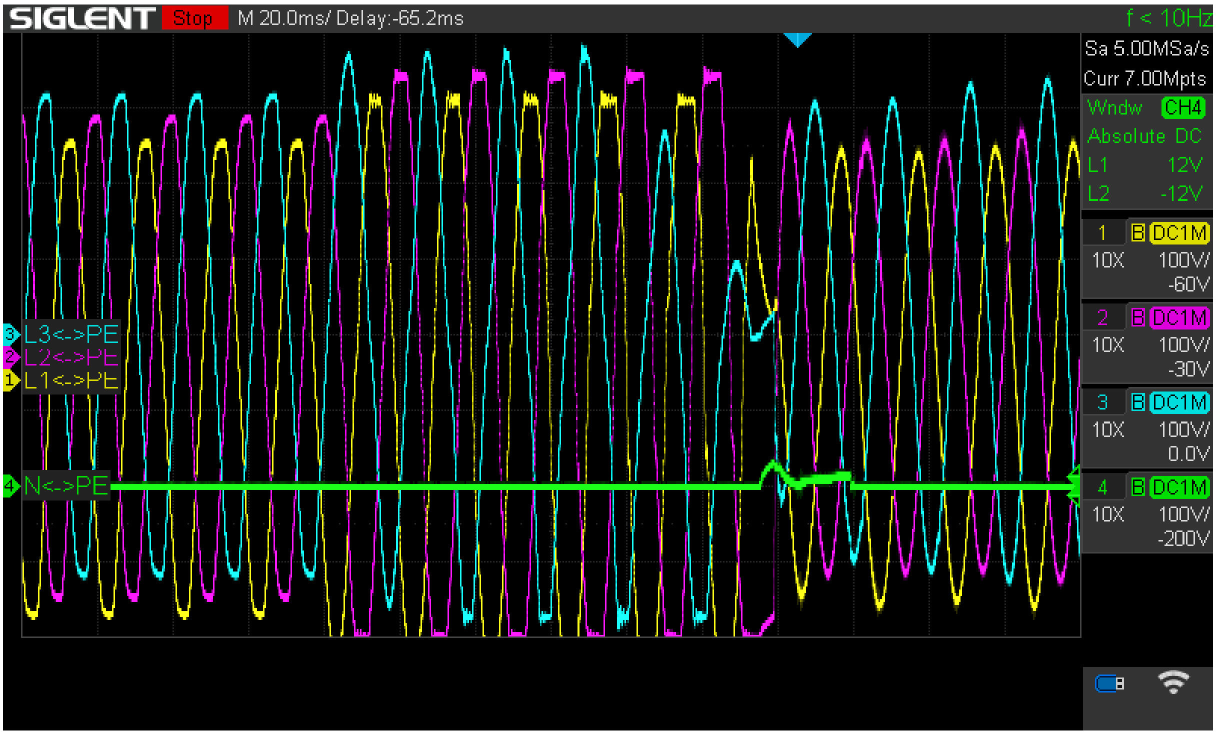

Figure 3: Transition OnGrid<->OffGrid (Zoom1

Figure 4: Transition OnGrid<->OffGrid (Zoom 2)

Figure 5: Transition OnGrid<->OffGrid (Zoom 3)

Transition OffGrid<->OnGrid

The On-Grid mode is reactivated by closing the Fuse_Grid (Figure 6). This reveals the main issue behind the RCD tripping:

Upon detecting grid availability, the Deye inverter opens the PEN relay for over 392 ms before closing the grid relays to reconnect the load to the grid.

During this period, the N conductor loses its connection to PE. As a result, N is no longer neutral, especially since the load is asymmetrical (only L1 is active). This causes a voltage imbalance, and a DC offset of approximately 50V is observed, likely related to the battery voltage level.

Figure 7 to Figure 9 provide detailed views of this problematic transition. Once the PEN relay is reclosed, neutrality is restored, and the voltage offset disappears.

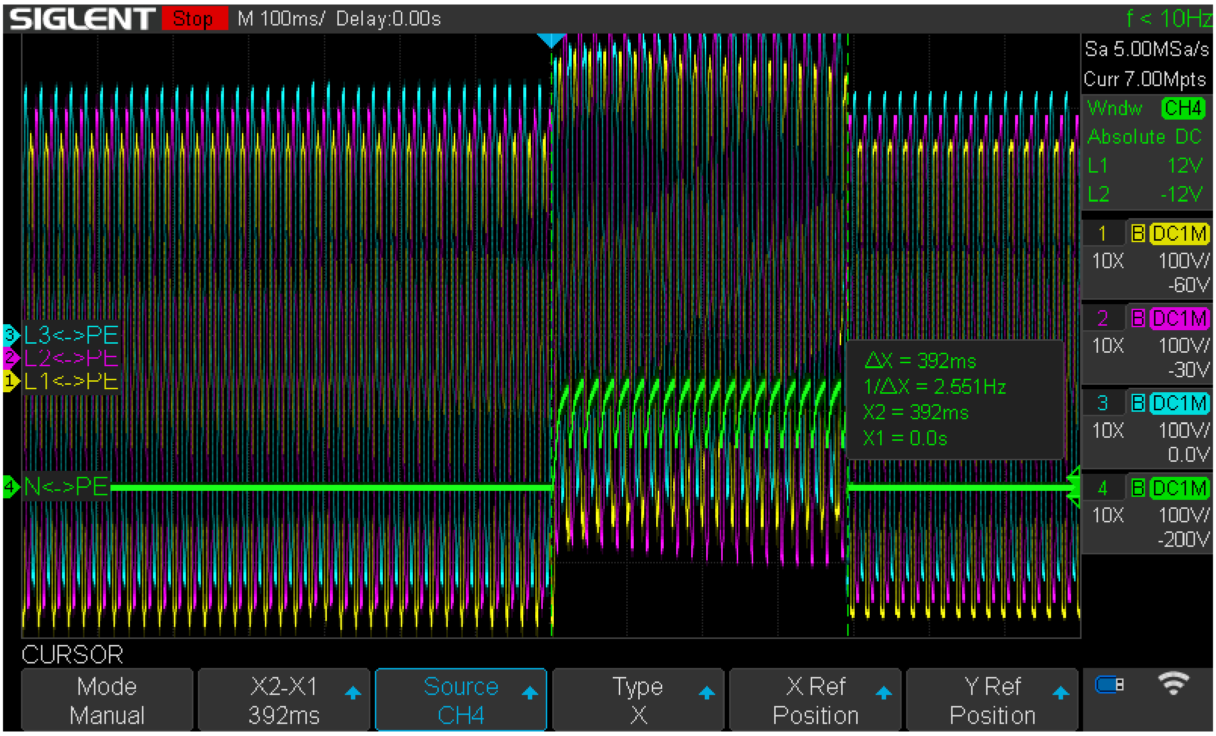

Figure 6: Transition OffGrid<->OnGrid

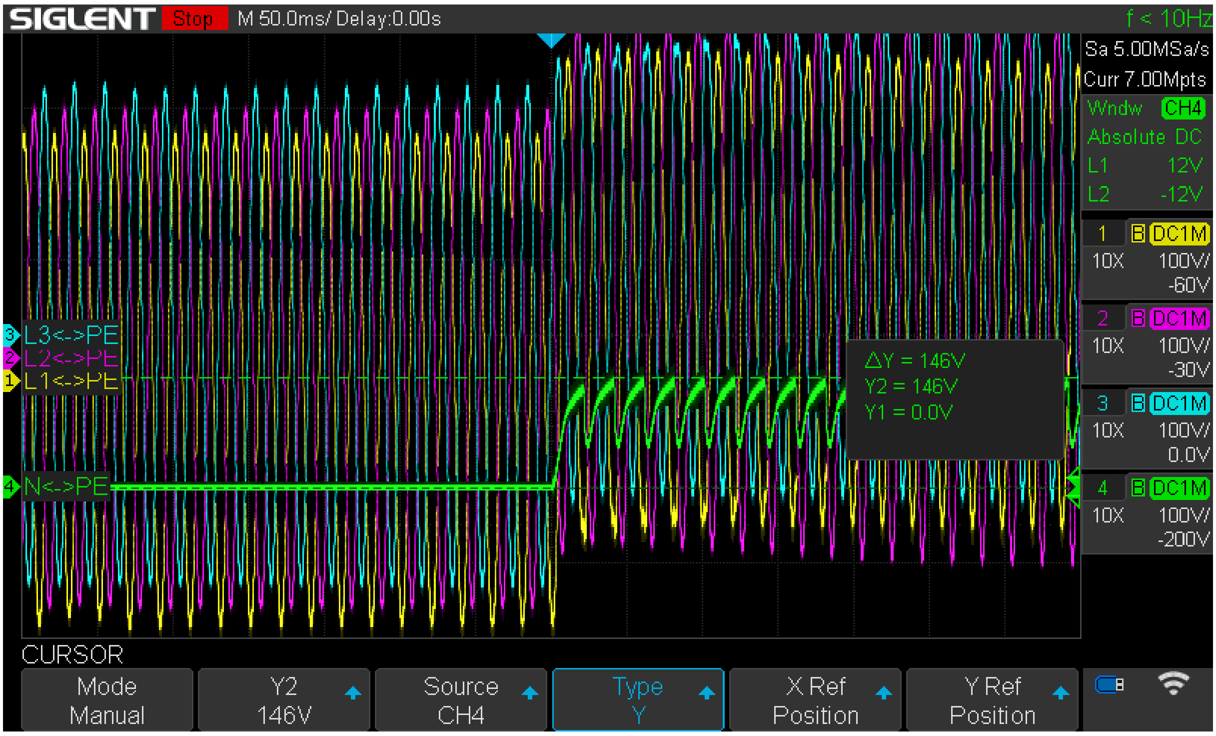

Figure 7: Transition OffGrid<->OnGrid (Zoom1)

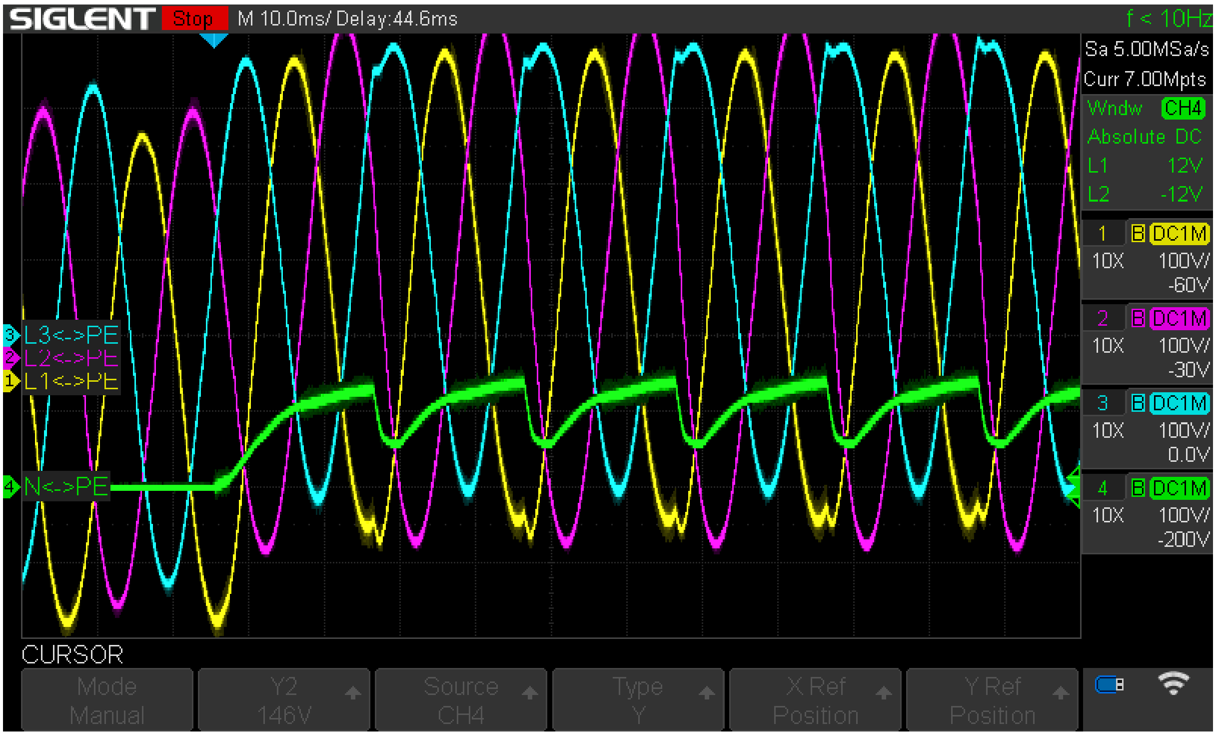

Figure 8: Transition OffGrid<->OnGrid (Zoom2)

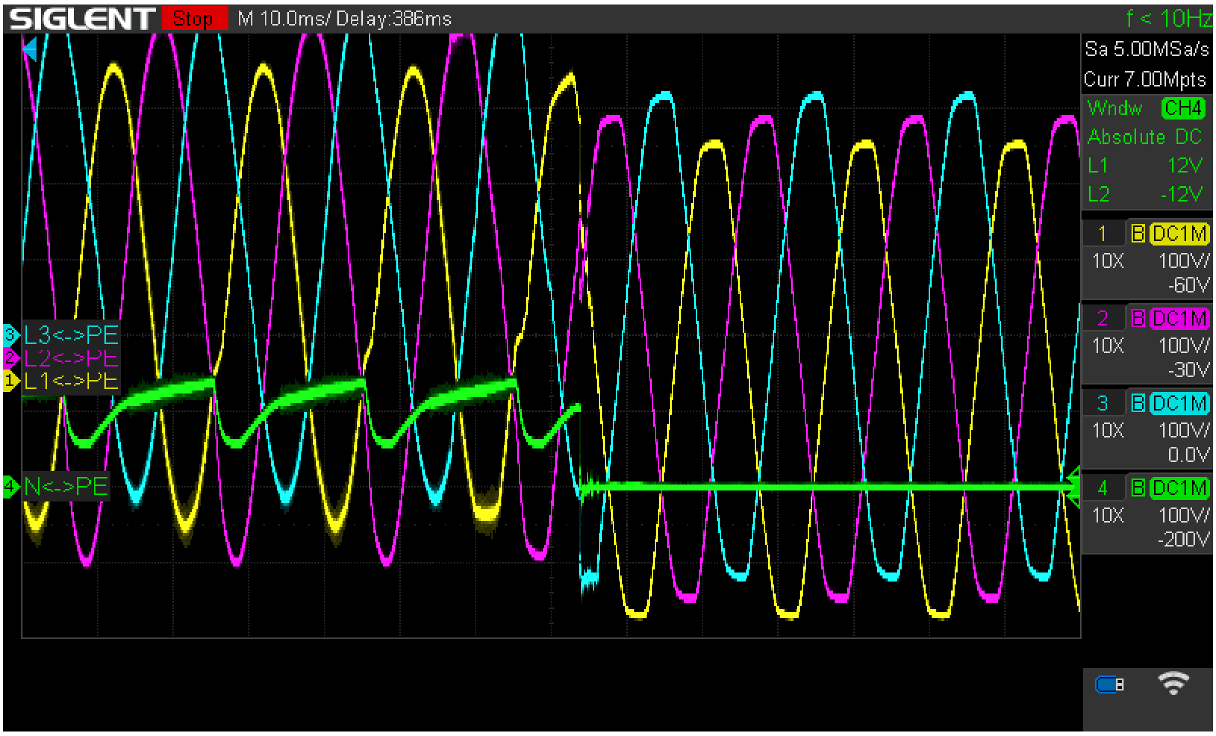

Figure 9: Transition OffGrid<->OnGrid (Zoom3)

In Figure 9 we can see that immediately after the PEN relay is closed, the N is neutral again and the offset is gone and all voltages are in range again.

Why the RCD Sometimes Trips

My installation includes an overvoltage protection unit monitoring L1, L2, L3, and N. It uses VDRs (Voltage Dependent Resistors), as illustrated in Figure 10. These components compare the voltage between PE and each phase conductor. When the voltage exceeds a threshold, the VDRs conduct and current is flowing over PE to reduce the potential difference. Figure 11 shows a typical VDR characteristic: at ~300V, resistance drops, and current starts to flow.

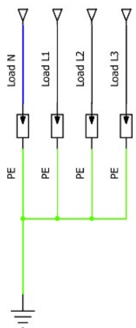

Figure 10: Schematic overvoltage protection

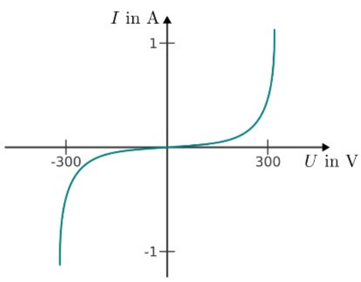

Figure 11: VDR characteristic

So, why does the RCD trip?

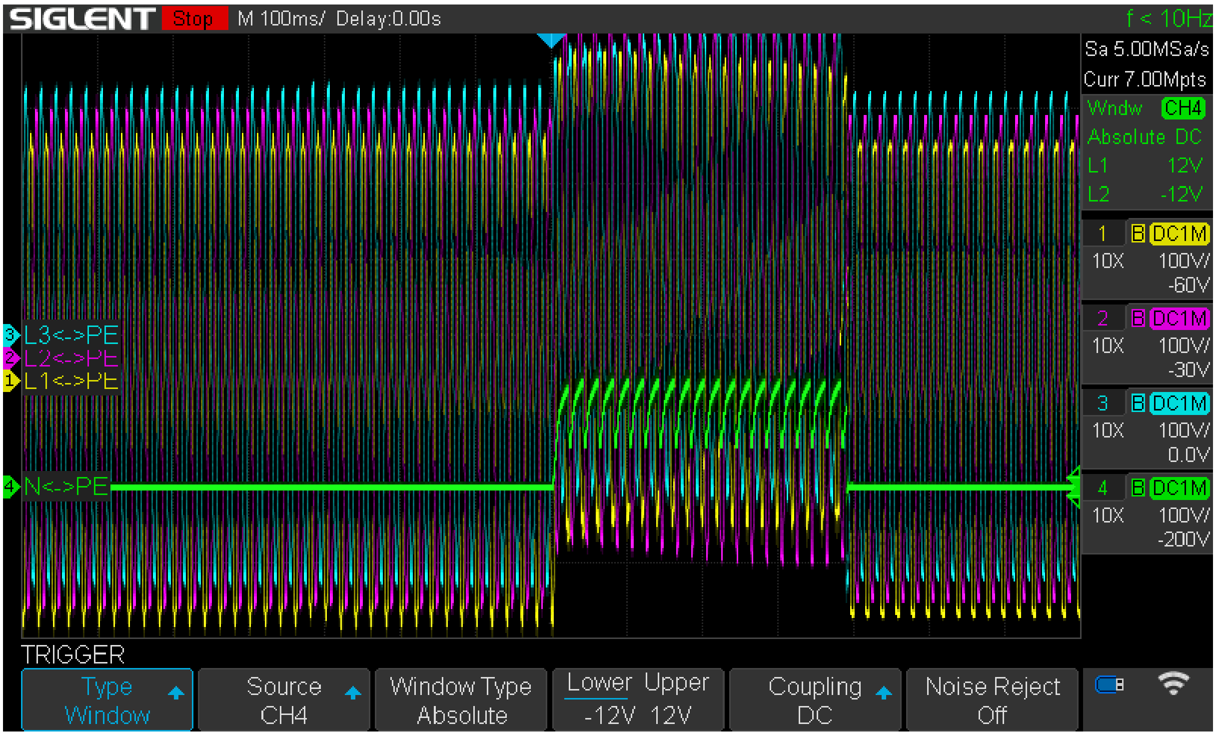

Figure 12: DC Offset

In Figure 12, we see that with the PEN relay open, a ~50V DC offset appears on N and all phase conductors relative to PE. The VDRs detect this as an overvoltage condition and begin conducting. Because the VDR's are all connected with one side to the PE and with the other side to N or one of the three phases. So we can calculate the worst-case voltage level the VDR's will see.

$$U_{VDR_{Max}} = U_{DcOffset} + \left(U_{Ac_{Eff}} * \sqrt{2}\right) = 50\,V + \left(230\,V * \sqrt{2}\right) = \underline{375\,V}$$

The RCD monitors that all current flowing out via L1/L2/L3 returns via N. If the overvoltage protection circuit begins conducting to PE instead of N, the RCD detects an imbalance. If this leakage current exceeds ~30 mA, the RCD trips down!

Settings Change & Recommendation

According to VDE guidelines, the PEN relay may remain closed for up to 100 ms after grid disconnection or before reconnection, provided the grid relays are already open or not yet closed.

This allows a software-based fix: update the relay control sequence in the Deye inverter's firmware.

Currently, the PEN relay drops out too early during transition, resulting in up to 400 ms of overvoltage against PE. This can damage equipment and trip RCDs. Also, Deye does not fully comply with the all-pole disconnection principle:

When disconnecting from the grid, N should disconnect last.

When reconnecting, N should connect first..

The diagram in Figure 13 and the sequence in Table 1 illustrate the correct switching behaviour.

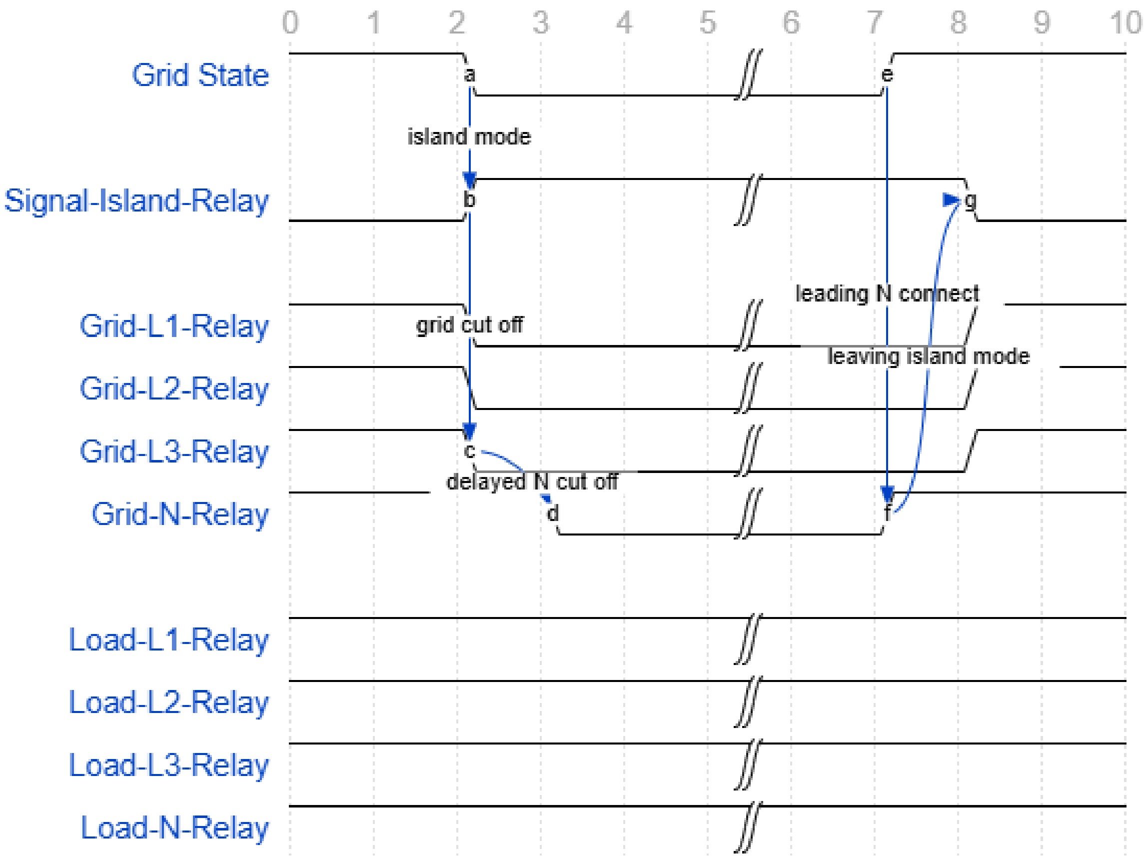

Figure 13 - expected sequence grid loss and recovery

Table 1 - description of sequences

a → b	Grid loss detected. PEN relay should close immediately.
b → c	All phase relay (L1,L2,L3) need to be opened.
c → d	Brief (under 100 ms) second PEN connection is active (over Grid and PEN relay)
d → e	Off-grid mode active. The grid is now fully disconnected.
e → f	The grid state is okay again. The reconnection process need to be started with leading neutral point relay on grid side. (allowed time from e to g <100ms)
f → g	The reconnection of the phase relay is starting now. All phase relays can be closed again and the PE-N relay can also be opened.

List of Figures