19th International Conference on Renewable Energies and Power Quality (ICREPQ'21)
Almeria (Spain), 28th to 30th July 2021
Renewable Energy and Power Quality Journal (RE&PQJ)

The Effects of High-Frequency Residual Currents on the Operation of Residual Current Devices

T. M. H. Slangen, B. R. F. Lustenhouwer, V. Ćuk and J. F. G. Cobben

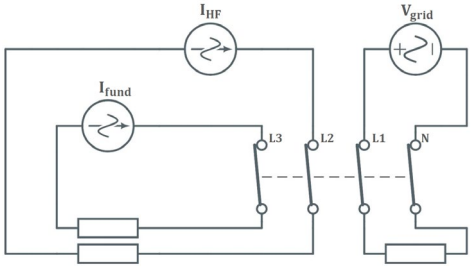
Department of Electrical Energy Systems, Eindhoven University of Technology, The Netherlands
E-mail: t.m.h.slangen(at)tue.nl

Abstract

This research investigates the effects of high frequency currents between 50 Hz and 150 kHz on the operation of Residual Current Devices (RCDs). The purpose of a RCD is to detect earth fault currents and to prevent humans from dangerous currents through the body and protecting installations against fires. A set-up is developed to introduce both 50 Hz and high-frequency leakage currents. The tripping current for non-nominal frequencies (between 50 Hz and 150 kHz) is determined to verify the possibility for false tripping and, the 50 Hz tripping current for the RCD is tested in the presence of a high-frequency current. The most important conclusion is that RCDs of type A and AC have an increased fundamental (50 Hz) tripping current when there are HF-components present. This potentially results in a safety risk.

Test set-up

- 4-pole RCDs are used because they have a combined measurement of the phases and neutral using the primary winding. In practice, the high-frequency leakage current will be superimposed on the fundamental current.
- 2 function generators and 2 amplifiers with a sufficient bandwidth connected to small resistive loads are used to create fundamental and HF leakage currents .
- 5 different RCDs of types A, AC and B are tested. Type A is mostly used in residential installations for the detection of sinusoidal and pulsed DC faults. Type B is used in installations were smooth DC faults > 6 mA can occur were no other protection against these DC leakage currents is installed [1].
- In the figure below, I_{fund} represents the created fundamental (50 Hz) leakage current, I_{HF} the high-frequency (50Hz – 150 kHz) leakage current, both non-returning via the RCD. The mains V_{grid} energizes the RCD and feeds a small resistive load.



Experiments

A. Nominal 50 Hz tripping current $I_{fund,trip}$

All RCDs were able to respond to leakage currents at purely 50 Hz according to their specification ($I_{\Delta n}$ equal to 30 mA or 300 mA; trip between 0.5 $I_{\Delta n}$ and $I_{\Delta n}$)

B. HF tripping current $I_{HF,trip}$ and f_{max}

All RCDs trip for frequencies above 50 Hz but not according to the IEC 60479 standard [2] which specifies safe leakage currents below 1 kHz ($F_f I_{\Delta n}$), see below.

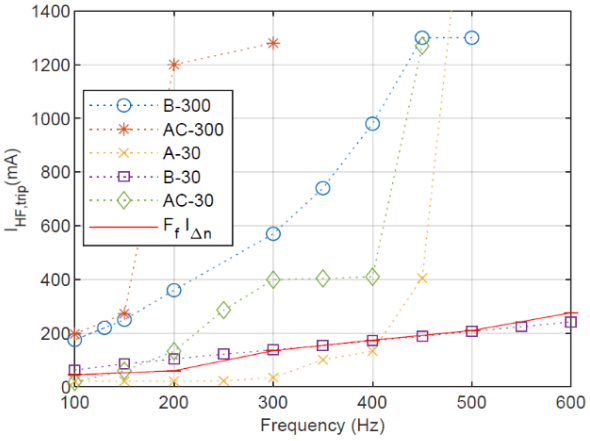


Table I. – Maximum frequencies for which the RCDs tripped

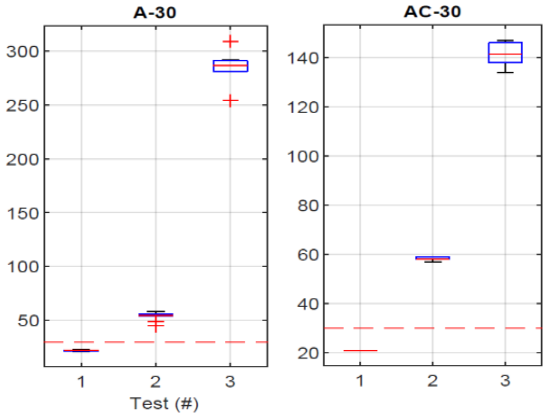
RCD #	B-300	AC-300	A-30	B-30	AC-30
f_{max} (Hz)	500	300	500	150k	450

C. HF tripping current in the presence of 0.5 $I_{\Delta n}$

Slightly different results are found compared to experiment B. This is due to the increased composite tripping current that the RCD sees. There is however no clear relation between the decrease in tripping current and the total leakage current that was measured by the RCD.

D. Fundamental tripping current in the presence of HF

- In this experiment HF leakage currents with frequencies above the determined f_{max} (except for RCD-4) are created. The RCDs that where affected the most where the types A-30 and AC-30 and the results are shown below. Here the calculated median values are used following the 10 outcomes for each test.
- The red line indicates the value at which the RCDs should ultimately trip; 30 mA in both case. The figure below shows the measured fundamental (50 Hz) tripping current of the 2 RCDs in a normal situation (Test 1, result from Experiment A), in the presence of an 800 mA, 1 kHz leakage current (Test 2) and in the presence of a 1300 mA, 1 kHz leakage current (Test 3). All measurements are repeated 10 times. - The RCDs indicated as A-30 and AC-30 fail to trip within their rated maximum tripping current of 30 mA. The other RCDs are also affected but still within specification and less significant.
- This potentially results in a safety issue as these RCDs allow 50 Hz leakage currents with dangerously high amplitude up to 300 mA to flow for seemingly indefinite time.



Conclusion

- The RCDs of type A-30 and AC-30 show a **dangerous increase in fundamental tripping current** in the presence of a high-frequency leakage current (false negative) resulting in a **serious safety issue**
- All tested RCDs are sensitive to part of the frequencies above 50 Hz and this can lead to false-positive operation.
- None of the 30 mA types operates according to IEC 60479, in which – for humans considered safe – maximum residual currents for frequencies between 50 Hz and 1 kHz are defined
- The definition of $I_{\Delta n}$ needs to be clarified in standardization

References

[1] S. Czapp, 'The effect of earth fault current harmonics on tripping of residual current devices', in *2008 International School on Nonsinusoidal Currents and Compensation*, Lagow, Poland, Jun. 2008, pp. 1–6, doi: 10.1109/ISNCC.2008.4627489.
[2] IEC, 'IEC 60479 - Effect of current on human being and livestock', 2017.