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APPLICATION OF RESIDUAL CURRENT DEVICES IN ELECTRICAL INSTALLATIONS WITH FREQUENCY CONVERTERS

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Residual current devices are applied to ensure protection against indirect contact using automatic disconnection of supply in low voltage systems. In electrical installations with frequency converters various frequency and also direct earth fault current can occur. Most of residual current devices cannot operate if direct earth current flows thus protection against electric shock is not effective. Only few residual current devices operate in these circumstances. In circuits with frequency converters transient and steady state leakage current can occur as well. This influences residual current devices selection. If residual current devices are improperly selected and installed, their unwanted tripping occurs even if there is no risk of electric shock. This paper presentes the principles governing residual current devices selection to the circuits with frequency converters and their installation.

1. INTRODUCTION

In low voltage systems protection against electric shock shall be provided by application of:

- protection both in normal service and in case of fault, or
- protection in normal service, and
- protection in case of fault.

One of the means of protection in case of fault is automatic disconnection of supply. Automatic disconnection of supply is required where a risk of harmful pathophysiological effects on human can arise, resulting from dangerous touch voltage. Very often residual current devices are applied to ensure protection against indirect contact using automatic disconnection of supply.

Residual current devices (RCD) are also applied as additonal protection. Then the use of residual current devices is intended only to augument other measures for protection against electric shock in normal services. The use of residual current with a rated operating residual current not exceeding 30 mA, is recognized as additional protection against electric shock in normal service in case of failure of other protective measures or carelessness of users.

The effectiveness of the protecion against electric shock using residual current devices depends especially on their proper selection.

Recenzent: Dr inż. Edward Musiał – Wydział Elektrotechniki i Automatyki Politechniki Gdańskiej

Electronic equipment e.g. personal computers, switch mode power supply, rectifiers, filters etc. widely used in modern installations influence operation of the residual current devices. These devices may operate under no risk of electric shock. The problem exist when a circuit with electronic equipment is switched on and transient current with high peak value in protective conductor flows. In steady state, in normal service significant value of leakage current may flow in protective conductor so that residual current devices operate. Also earth current frequency and waveform influence RCD operation. Improper selection of RCD may cause electric shock because in circuits with frequency converters only certain RCD types operate properly.

2. PRINCIPLES OF THE RESIDUAL CURRENT CIRCUIT BREAKERS OPERATION

A residual current device usually comprises coils on a magnetic circuit to carry the phase (three phase) and neutral current in opposing directions (Fig. 1). In balanced conditions no magnetic flux is set up, but if a fault occurs in the system, the phase and neutral current imbalance induces an electromagnetic force in a secondary circuit, tripping main circuit.

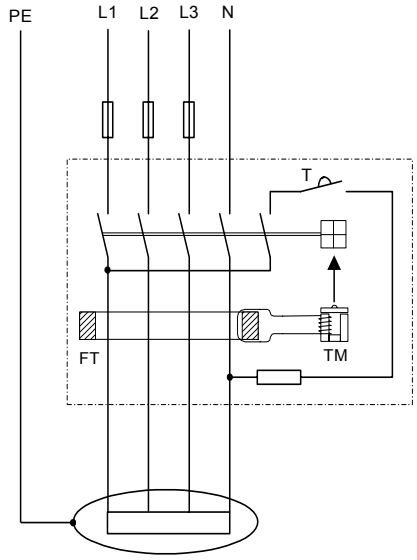


Fig. 1. Residual current circuit breaker diagram: FT – Ferranti transformer, TM – tripping mechanism, T – test button

Automatic disconnection of supply occurs if the residual current I_Δ exceeds rated operating residual current of RCD $I_{\Delta n}$.

Tripping characteristics of residual current devices are presented in Fig. 2. There are three types of RCD:

- general purpose RCD, without intentional time delay; without special symbol,
- delayed tripping with a minimum non actuating time of 10 ms; identified by the symbol G or VSK, or KV, or KVP,

– selective RCD (S-type) with short time delay 40 ms, to provide discrimination with downstream general purpose RCD; identified by the symbol S

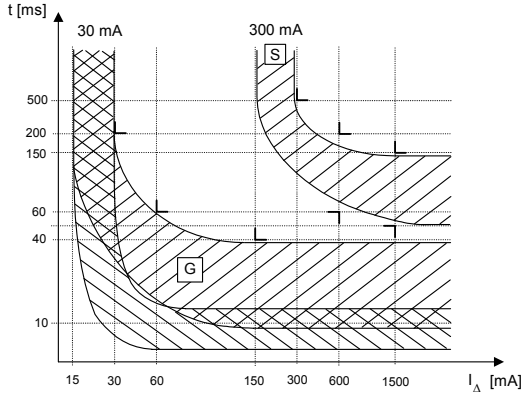


Fig. 2. Residual current circuit breakers tripping characteristics: general type, delayed tripping, S – type

Residual operating currents $I_{\Delta n}$ of the RCD are as follows: 0,006 – 0,01 – 0,03 – 0,1 – 0,3 – 0,05 – 1 A. Devices with rated operating residual current exceeding one ampere are also possible. Residual current devices don't operate if the residual current is equal or less than 0,5 $I_{\Delta n}$, while their operation is required if the residual current equal to or more than $I_{\Delta n}$ occurs [1].

3. RESIDUAL CURRENT CIRCUIT BREAKERS IN CIRCUITS WITH FREQUENCY CONVERTERS

Frequency converters are commonly used to control the speed of a squirrel cage motors. The first part, starting from the supply side, is a rectifier (Fig. 3). In the second part (intermediate circuit), pulsating DC voltage produced by the rectifier is filtered. The last main part of the frequency converter is inverter which uses DC current or voltage from the intermediate circuit to produce AC current or voltage of desired frequency.

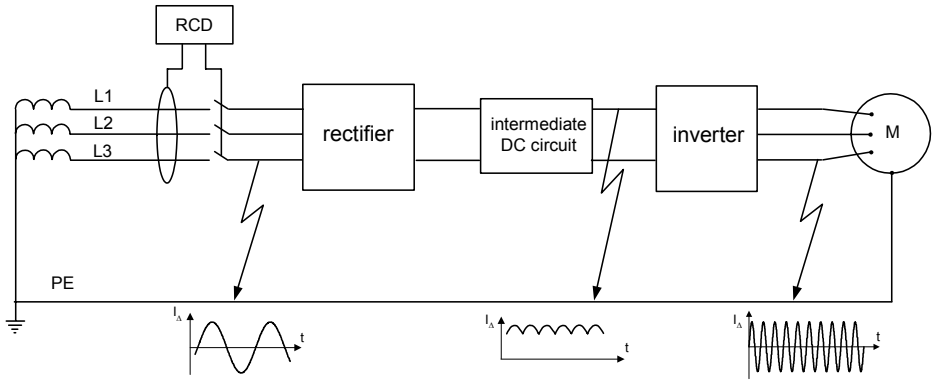
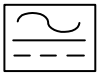


Fig. 3. Earth current waveform shape in the circuit with frequency converter

Taking the above into account, the spectrum of earth leakage current may be from smooth direct current to the current of very high frequency (Fig 3). At that point the most important thing is to select residual current device for detection alternating-current, pulse-current and current with high DC component.

Classic residual current device of type AC (Tab. 1), operates only if earth leakage current occurs at the entry of the converters circuit. In this case, the alternating current of 50 Hz flows from exposed part to earth. If the fault to earth occurs between rectifier and inverter, direct current may flow to protective conductor. It depends on the type of the frequency converters. Only special residual current device is able to operate. This type of residual current device is B as in Tab. 1. In certain cases the type A of residual current device is sufficient. It has to be considered in every particular situation.

Tab. 1. RCD sensitivity versus residual current waveform

AC or 	For alternating earth fault current
A or 	For alternating and pulsating direct earth fault current
B or 	For every kind of earth fault current

Only type A or B of the residual current devices shall be used in circuits with electronic equipment. It is also neccesary to install residual current device as in Fig 4. Otherwise, direct earth current can block the operation of the residual current device of type A.

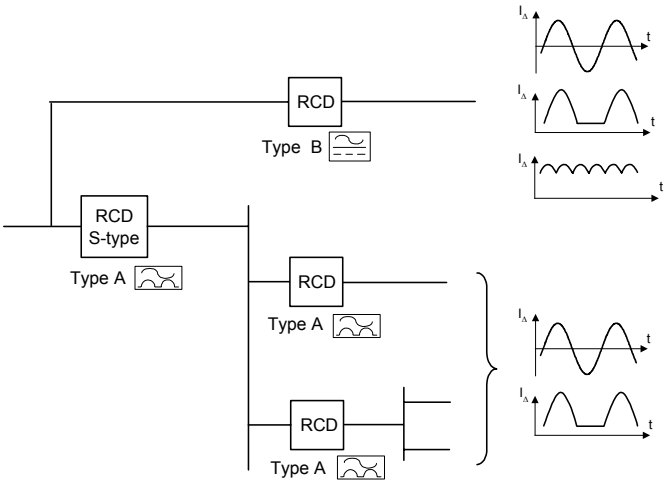


Fig. 4. Principle of the residual current devices installation in circuits with direct earth fault current

Also in certain medical locations only type A or B shall be selected. In that case, the use of type AC of RCD's is not allowed [2, 3].

The use of residual current devices in circuits with converters results in the problems of

their unwanted tripping. If the frequency converter includes filters significant transient and steady state leakage current may flow. The current may reach the value of 200 mA. This excludes the use of the residual current device with high current sensitivity. Also parasitic capacity causes significant current in protective conductor. This current has impulse spectrum with frequency which depends on Pulse Width Modulation (PWM). Figure 5 presents the waveform of the current in the protective conductor in the circuit with frequency converter.

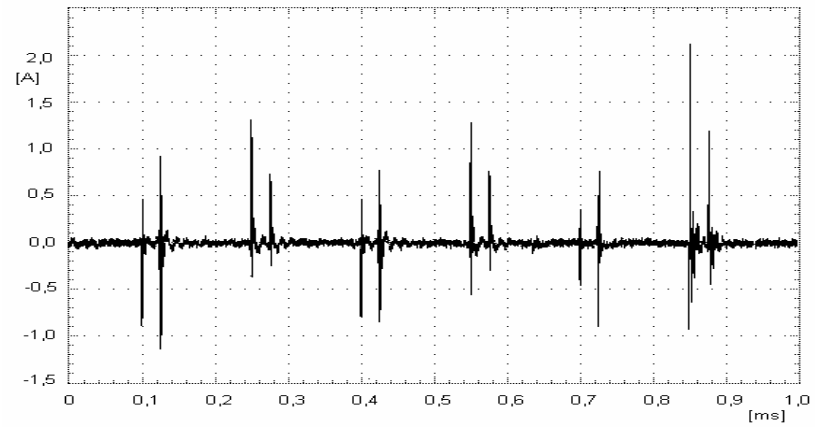


Fig. 5. Leakage current waveform in the circuit with frequency converter. Peak value I_{peak} = 2 A

The residual current device may operate if no electric shock risk exist because of significant value of the leakage current, but in some cases residual current device may not operate if electric shock risk is significant e.g. direct earth current occurs and type AC or type A of RCD do not operate.

4. CONCLUSION

In modern installations, residual current devices are commonly used. Use of RCD's increases the safety level of the electric equipment operation. However, selection of residual current devices has to be performed very carefully. In circuits with electronic, medical equipment direct or various frequency earth current may occur. Only certain types of residual current devices operate in these cases. In circuits with filters, electronic equipment significant value of transient and steady state leakage current may occur. This is the cause of unwanted tripping of the RCD's. It is also very important to avoid unwanted operation in terms of reliability of the supply. In circuits with very high value of steady state leakage current, residual current devices can be substituted by overcurrent protection, but the supplementary equipotential bonding shall be performed.

5. REFERENCES

[1] Czapp S. Problems of the selection and coordination of residual current devices. Conference Electroinstallations. Gdansk International Trade Center. Association of Polish Electrical Engineers. Gdansk 2002, ISBN 83-88829-41-6 (in polish).
[2] EN 50178 Electronic equipment for use in power installations.
[3] IEC 60364-7: Electrical installations of buildings, Part 7: Requirements for special installations or locations.

STOSOWANIE WYŁĄCZNIKÓW RÓŻNICOWOPRĄDOWYCH W INSTALACJACH ELEKTRYCZNYCH Z PRZEMIENNIKAMI CZĘSTOTLIWOŚCI

Wyłączniki różnicowoprądowe z reguły są stosowane jako urządzenie wyłączające dla spełnienia warunku samoczynnego wyłączenia zasilania przy zwarciu doziemnym w układach niskiego napięcia. W instalacjach elektrycznych, w których znajdują się przemienniki częstotliwości mogą pojawić się prądy zwarcia doziemnego o różnej częstotliwości lub stałe. Większość wyłączników różnicowoprądowych nie reaguje na tego typu prądy, co powoduje, że ochrona przeciwporażeniowa jest nieskuteczna. W obwodach z przemiennikami częstotliwość mogą pojawiać się przejściowe i ustalone prądy upływowe o znacznych wartościach. Prądy te znacząco wpływają na dobór wyłączników różnicowoprądowych. Jeżeli wyłączniki różnicowoprądowe są niepoprawnie dobrane mogą powodować zbędne zadziałania przy braku zagrożenia porażeniowego. Referat przedstawia zasady doboru i instalowania wyłączników różnicowoprądowych do obwodów z przemiennikami częstotliwości.