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Nuisance tripping of residual current circuit breakers in circuits supplying electronic loads

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ABSTRACT

Residual current circuit breakers (RCCBs) are often used to provide protection against indirect contacts in a grounded electrical installation. However, there are situations where the use of RCCBs presents certain problems. In circuits that feed electronic loads RCCBs often cause nuisance tripping. This article discusses the reasons why RCCBs trip in this type of circuit based on a previous case studied by the authors at 'La Fe' hospital in Valencia (Spain) and several tests performed in a power flexible laboratory. A theoretical circuit used to explain the phenomena is also presented.

1. Introduction

Nuisance tripping of residual current circuit breakers (RCCBs) is often related to the presence of electronic loads, especially computers [1]. In some facilities, a common solution is to install immunised residual current circuit breakers (known as SI RCCBs following the commercial acronym for an improved type A RCCB—such those as manufactured by Schneider Electric). However, SI RCCBs are much more expensive than type A or AC standard residual current circuit breakers (A RCCBs or AC RCCBs).

Among the possible causes of random tripping, the presence of harmonic currents is often cited [2–7]. Recently, an interesting work [1] analysed the influence of harmonics on the value of the current that produces RCCB tripping. The influence of the time constant of an aperiodic current following an earth fault and the response of RCCBs to current pulses were also analysed [2,8].

In currents with the presence of low-order harmonics, the minimum tripping current varies with harmonic content, as well as the phase angle of the harmonic component [1,2]. RCCB tripping is primarily determined by the peak value of the current. Low-order harmonic components with angles that increase the peak value of the current facilitate RCCB tripping. In contrast, a desensitisation of the RCCB is produced by the presence of high-order harmonics and the minimum tripping current generally increases with increasing harmonic frequency [1].

Low-order harmonics with small values can vary the value of the leakage current that forces the RCCB trips. However, this change is small and it is very improbable that it can explain the tripping of an AC RCCB. Moreover, higher order harmonics (frequencies up 1 kHz), or the fast transient connection or disconnection of some devices, rarely causes RCCB tripping [1,2].

Thus, a current containing a high component of harmonics, as in circuits that feed electronic loads is not a cause of nuisance tripping. However, this type of circuit often suffers this problem. An explanation is presented in this paper.

In computer rooms RCCBs sometimes trip when the computers are running, and even when they are turned off. Therefore, the type of load present in a circuit should be considered because the load may increase the transient current, raising the neutral-earth voltages and leakage currents, and so increasing the frequency of trip events.

This article presents an investigation into the causes of RCCB nuisance tripping in circuits supplying electronic loads. Section 2 summarises the detected phenomena in a previous work at 'La Fe' hospital. Test results obtained in a laboratory with circuits feeding computers are discussed in Section 3. Section 4 details a theoretical circuit that explains the detected phenomena. Finally, some conclusions are drawn in Section 5.

2. Detected phenomena in a previous work

The detected phenomena in a facility with RCCB nuisance tripping was analysed by the authors in a previous work [1]. The

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nuisance tripping occurred in a large hospital which became operational in February 2011. During the first days of use there were many RCCB incidents. Given the need to find an urgent solution, maintenance staff began replacing AC RCCBs by SI RCCBs and the number of trips was reduced to a normal number in one or two days. More than 2000 RCCBs were replaced at a significant cost. After the devices were replaced, the authors were asked to investigate the cause of the problem.

The presence of strong disturbances in the grid voltage waveforms were detected after using a power quality analyzer (PQA) to record transients. Peak value increments (of up to 30% of the nominal amplitude) and deformations (0.5–2 ms duration) in voltage waveforms in the three phases in the feeder were detected. It appeared that these disturbances caused the high current discharges that sometimes caused the RCCBs to trip.

Two electrical points were measured, first a circuit feeding nine rooms on a floor (circuit A), and second, a circuit feeding the main panel of the seventh floor of one of the blocks of the analysed hospital (circuit B).

Fig. 1 shows voltage waveforms and Fig. 2 shows currents obtained during an RCCB tripping event using the PQA in circuit A. When the trip occurs the voltage of phase B falls to zero due to the measuring circuit used on the site [1]. The fault caused a peak in the currents (Fig. 2).

Fig. 3 shows the leakage current calculated using the values of currents in the event shown in Fig. 2. Values of the leakage current are higher than 2 A and this clearly explains why a 30 mA AC RCCB tripped.

Similar behaviour was recorded in circuit B. Voltage and current recorded measurements during a trip were obtained at 3.54 pm on the 24/03 (Fig. 4).

Summarising the results obtained in circuits A and B, the phenomena occurring when an RCCB trips are:

- High peak voltages in some phases (amplitude values close to 500 V were measured versus 325 V corresponding to a nominal voltage line-neutral of 230 V).
- High peak voltages in the neutral voltage to ground.
- Currents in phases reached higher peak values (more than 200% over normal value currents depending on the value of the phase voltage at the time of the event). These values may also trip the circuit breaker of the circuit.
- Neutral current is increased in the same order values as the phases.

The conclusion of the research led to the detection of transient problems in power supply voltages that proved to be the cause of the RCCB nuisance tripping.

These disturbances produced leakage currents (by capacitive effect and varistor discharges in electronic equipment) and these leakage currents cause AC RCCBs to trip. Since these are short transients, they do not cause the SI RCCBs (an improved type A RCCB) to trip.

The type of loads present in the hospital (such as electronic loads, TV sets, electronic lights, and medical equipment with electronic power suppliers and batteries) contribute to increasing the transient currents which, in turn, raise the neutral-earth voltages and leakage currents, and so increase the frequency of tripping events.

3. Tests performed in circuits feeding electronic loads

Several tests were performed in a laboratory to study the influence of electronic loads in RCCB nuisance tripping. These tests were performed under the Transnational Access to the Flex Power Grid Lab Research Infrastructure at DNV KEMA (a Dutch business and technical consultancy that tests, inspects, certifies, and verifies the energy value chain) under the DERri project and supported by the European Commission under FP7 [9].

Many tests were performed and the specific single-line set-up diagram used for the tests is shown in Fig. 5.

The set-up of the test is prepared from the grid connection to a diverse range of loads. The transformer is earthed. A 250 kW AC to AC voltage source (FPGLab) is used to generate the desired voltage waveforms (containing transients). 840 V rms at the output of the AC voltage source (electrical point M_A) are required to obtain

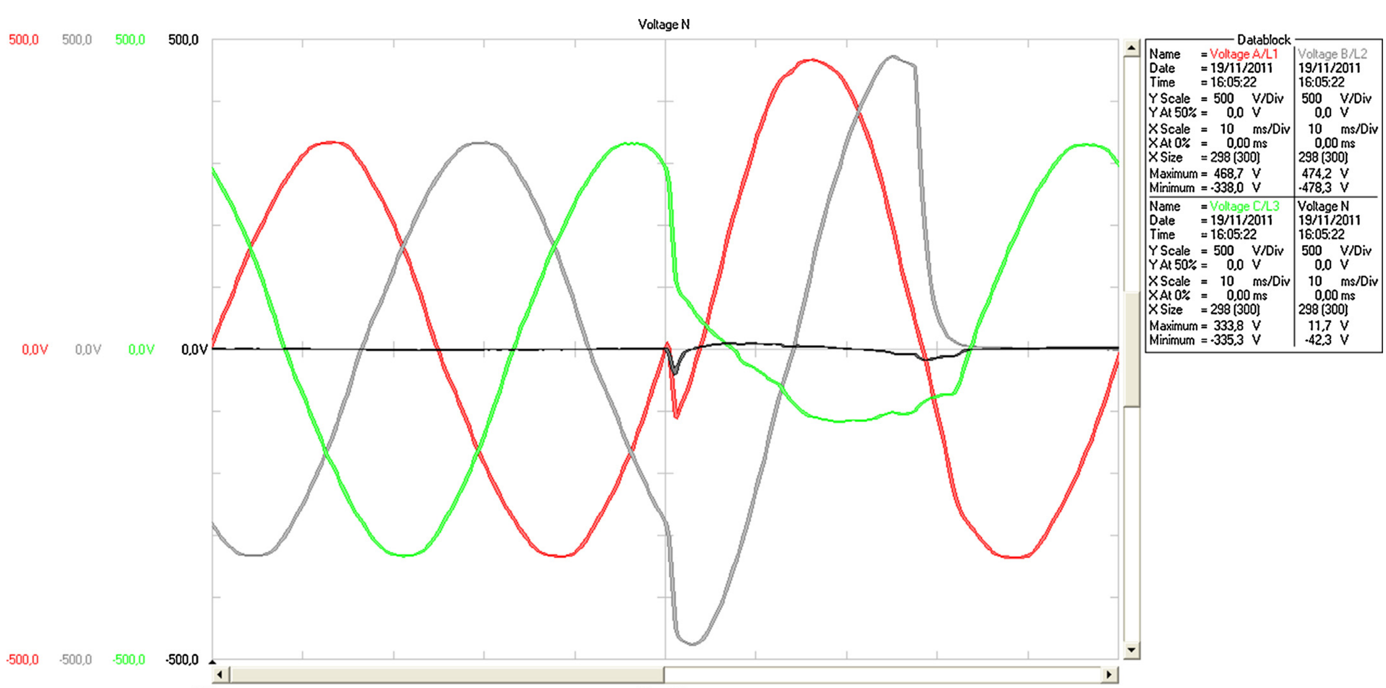

Fig. 1. Disturbance in the voltages produced during an RCCB tripping event on the 19/11/2011 at 4.05 pm in circuit A.