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Nuisance tripping of residual current circuit breakers: A practical case

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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 some installations, tripping may occur for no apparent reason. Furthermore, it is very laborious and difficult to find the cause of such nuisance tripping in RCCBs. This article presents a case studied by the authors in the La Fe Hospital in Valencia (Spain), where the nuisance tripping of RCCBs became a serious problem. The methodology followed to find the causes and the solutions adopted are described.

1. Introduction

Sometimes random tripping of residual current circuit breakers (RCCB) occurs without apparent cause, and after the reconnection of the equipment the RCCB runs properly. There are references to buildings where tripping events have become common during a period of time and then ceased, without the cause being discovered [1]. In some buildings, a common solution is to replace the devices for immunized residual current circuit breakers (SI RCCBs, commercial acronym for an improved type A RCCB of brands as Schneider Electric), but 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 [2,3]. Some researchers have attempted to establish the relationship between current harmonics and RCCB sensitivity [4–7]. Recently, an interesting work [1] analyzed the influence of harmonics on the value of the current that produces RCCB tripping. The influences of the time constant of an aperiodic current following an earth fault and the response of RCCBs to current pulses were also analyzed [2,7].

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]. RCCB tripping is primarily determined by the peak value of the current. Low-order harmonic components with angle that increase the peak value of the current facilitate the RCCB tripping. In contrast, a desensitization of the RCCB is produced with the presence of high-order harmonics and the minimum tripping current generally increases with increasing harmonic frequency [1].

This article presents an investigation of the causes of false tripping in the La Fe Hospital in Valencia. Section 2 summarizes the basic checks carried out and the laboratory analysis using distorted waveforms. Transients detected in the connection and the disconnection of some receptors is discussed in Section 3. Section 4 details the design of a test system installed at the site that finally enabled the detection of the origin of the problem. Section 5 presents the measurements and results. Finally, some conclusions are drawn in Section 6.

2. Problem statement and basic checks

The tripping occurred in a large hospital which became operational in February 2011. During the first days of use there were many incidents with RCCBs. On 21 February some 42 events occurred, 31 events occurred the following day, another 31 occurred the day after that, and 23 events occurred on 24 February. Given the need to find an urgent solution, on the 24 February maintenance staff began replacing AC RCCBs by SI RCCBs and the number of trips was reduced to a normal number of one or two a day. 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 first checks were carried out to measure the leakage currents in receivers and various circuits where the trips had occurred. The measured values for leakage currents (between 0.5 mA and 1 mA) were very low and did not explain the tripping of the RCCBs with a nominal leakage current $I_{\Delta n}$ = 30 mA.

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Some RCCBs were returned to the manufacturer so that their correct operation could be confirmed. It was confirmed that they were working correctly.

The ground circuit was tested by measuring a neutral ground loop and a normal resistance value of between 1.5 and 2 Ω was obtained.

In conclusion, this preliminary analysis found no obvious cause for random tripping.

3. Effect of high frequency currents, transient receptor connection, and harmonic disturbances in RCCB tripping

Assuming that any phenomenon that caused the tripping of the RCCBs should produce an appreciable effect on the RCCB tripping coil, the authors begin to analyze the effect in the tripping coil when the RCCB trips.

Analysing the voltage and current in the circuits where the tripping had occurred, the first phenomenon that caught the attention of the authors was the permanent presence of a high frequency voltage component (about 30 kHz). After analyzing in detail the current wave of consumption, a high frequency component was also observed. The loads fed by the circuit were basically electronic lights, TVs, and some medical equipment. Authors assumed that the cause of the high frequency component was the operation of electronic lights in the analyzed circuits. However, this could not cause the RCCBs to trip because they are not sensitive to this amplitude and frequency [3].

The connection and disconnection of some receptors, notably lighting (4 downlights 2 × 26 W, 1 fluorescent 36 W lamp, and the electronic equipment fitted to the bed per room) caused much greater effect in the RCCB tripping coil.

Installed RCCBs in the studied circuit were rated by a $I_{\Delta n}$ = 30 mA, a current in the range of 15–30 mA could produce the trip and the trip must be assured with residual operating currents higher than 30 mA in accordance with IEC.

The connections and disconnections of these loads produced high frequency voltage transients in the RCCB tripping coil of several volts in amplitude, with currents of more than 150 mA in amplitude (Fig. 1). Likewise, transient residual currents of more than 500 mA in amplitude were detected. Although these effects are clearly detectable, the high frequency of disturbances (between 30 and 50 kHz) makes RCCBs very insensitive and do not trip. So this phenomenon was not the cause of the tripping of the AC RCCBs.

Although low-order harmonics can vary the value of the leakage current of the RCCBs that force the trip, this change is small, and can never explain the tripping of a 30 mA RCCB with 50 Hz residual currents of 1 mA (values detected in the analyzed circuits), regardless the presence of these harmonic components.

A test was performed in the laboratory to analyze the influence of harmonics in the tripping of the RCCBs. An AC RCCB tetra-pole, 25 A and $I_{\Delta n}$ = 30 mA (equal that those installed in the hospital) was tested. Fig. 2 shows the amplitude in function of the frequency of the fault current that caused the tripping of the analyzed AC RCCB. Note that at 50 Hz the tripping current amplitude is 40 mA (corresponding to 28 mA RMS). Authors stated that in currents with frequencies lower than 5 Hz the minimum tripping current amplitude increases. Also it is noted that the minimum tripping current rises gradually when the frequency is increased to 1 kHz and rises significantly after that frequency; conclusive results with those obtained in [1] section IV A.

Fig. 2 Amplitude of the minimum current that forced the AC RCCB tripping in function of the frequency

Other tests were performed to analyze the effect of the harmonic component addition to the fundamental current that forces RCCB tripping. A laboratory test was performed on the minimum fundamental component of the tripping current for different harmonic contents. Two function generators were used to perform the tests. A function generator generated the harmonic component of a certain amplitude and frequency. Another function generator generated the fundamental component with variable amplitude until the tripping occurred. A sliding of the harmonic component on the fundamental was found by minimal inaccuracies in the frequencies generated by the sources. This enabled the authors to detect that the tripping occurred in a 'critical' specific phase angle between the fundamental and harmonic component for specific amplitudes of both. The trip occurred when the total amplitude was maximal (as the addition of fundamental and harmonic components). Table 1 shows results for the test performed in the laboratory. For example, a minimum value of 25 mA of amplitude for the fundamental

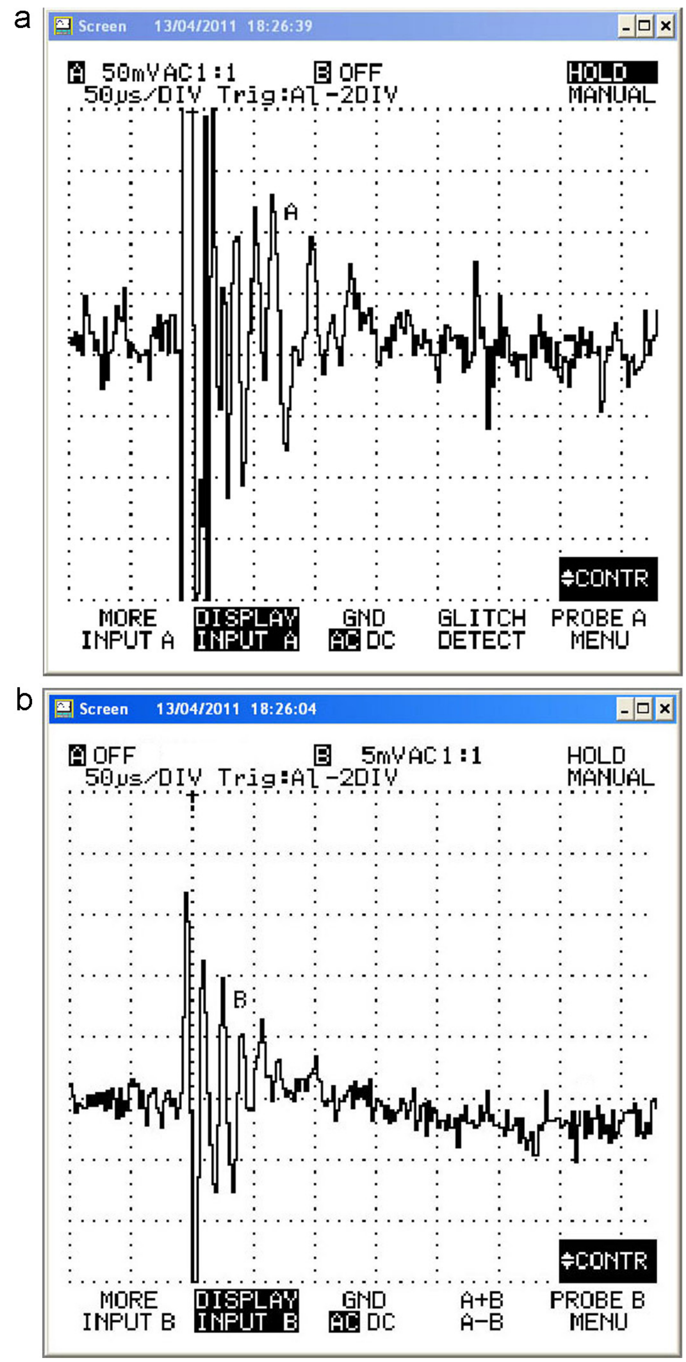

Fig. 1. Transients detected by turning off the lights in a room. The voltage in the tripping coil (a) is over 200 mV peak (50 mV per division) and the residual current (b) exceeds 150 mA peak (50 mA per division).