Lack of Neutral-to-Earth Bonding in 230 Vac PROsine Inverters and its Effect on GFCI / RCD Operation

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Abstract

PROsine models with 230 Vac output do not have their output neutral bonded to ground. As a result, the leakage current that can flow from the inverter output to ground is below the threshold required to trip Residual Current Devices (RCDs) or Ground Fault Circuit Interrupters (GFCIs) as they are also called. Most of these devices therefore do not trip when installed on a 230Vac PROsine inverter and their "Test" button is pushed. The lack of tripping is not indicative of a hazard, but is in fact just an indication of the inherently low leakage current that the products can source, and therefore of their inherent safety.

Background

The 230 Vac PROsine inverter does not have a "bonded neutral", that is, the neutral is not tied or "bonded" to earth on the AC output. This has been a Xantrex standard practice for 230 Vac inverters, and market research during the design suggested that the practice remain unchanged. The un-bonded neutral now gives rise to queries from the field, particularly regarding perceived "incorrect" operation of Ground Fault Circuit Interrupters (GFCIs) or Residual Current Devices (RCDs) as they are known in Europe.

This document explains why RCDs used on the output of the 230 Vac PROsine products may not trip when an earth-fault is placed downstream or when tested, and why this lack of tripping does not constitute a shock hazard.

Earth faults

Definition

The term "earth fault" refers to accidental contact between a live circuit and the chassis of a piece of equipment, typically resulting from failure of electrical insulation or the dislodging of a live part from its normal position. In effect, the failure shorts the line side of the supply to earth. The utility mains' supply to most equipment normally provides both a protective earth (PE) conductor and a bonded neutral conductor (the neutral is bonded or connected to the protective earth conductor at the source). This arrangement ensures that an earth-fault shorts out the supply, resulting in high currents that will quickly trip the over-current protection in the supply.

Shock hazards and earth faults

Equipment exists, however, that does not carry a protective earth conductor (for example in "double-insulated" or "Class 2" equipment) or has a faulty PE conductor. There are also some types of fault that do not give rise to high current flow, so the overcurrent protection will not trip. This unresolved earth-fault is hazardous if the energized chassis is touched by a user. Current can flow from the line side of the supply, through the chassis and through the user to earth, causing an electrical shock. It is important to note that the current only flows because there is a return path to the neutral side of the supply through the neutral-to-earth connection at the source of supply. RCDs provide protection against this sort of shock hazard and they are required in many jurisdictions.

RCD operation on the utility mains

The term RCD covers a range of circuit breakers and similar devices that provide protection against earth faults by measuring and reacting to the "residual current". This current is the difference between the current flowing out on the line conductor and that coming back on the neutral conductor.

Any difference is assumed to be residual or "leakage" current that could flow through a person, so the RCD opens the circuit. Typical RCDs are designed to open when leakage current exceeds a threshold of 3.5 mA to 20 mA or more, depending on the design. Different leakage current value RCDs are specified for different countries, different applications, etc.

RCD test buttons

There is usually a test button or switch on an RCD allowing users to periodically test that the device is still capable of tripping properly. This test button can function in two ways. It can:

- Provide a mechanical-only test simply to make sure that the contacts are not welded shut
- Ensure that the RCD is mechanically capable of opening the circuit

This does not test the detection circuitry or control circuitry. A true leakage test button places a resistance from line to earth, causing leakage current to flow. If the RCD is working properly, the leakage will be detected, and the control circuit will open the contacts. This tests the entire RCD.

RCD operation on the 230 Vac PROsine products

Unlike the utility mains, the AC output of the 230 Vac PROsine inverter does not have its neutral bonded to earth. Both the line and the neutral are isolated from earth, the chassis, and from the DC input. *As a result of this isolation, the earth cannot become part of a current path returning current back to the output of the PROsine.*

The only exception to this isolation is the use of a few small EMI-filter capacitors, connected between various parts of the circuitry and the chassis. However the leakage current from live parts to earth caused by those capacitors is below shock-hazardous levels. It is in compliance with the standards for leakage current, *and is below the level that will trip an RCD.*

In this situation, only this capacitive leakage current can flow from the line or neutral through the user and back to its source in the inverter. *Only that capacitive leakage current can flow through an RCD, and it is too low to cause one to trip*.

It is important to realize that *if a hazardous amount of leakage current were to flow through a person to earth, the RCD would trip as intended.* There is nothing about the PROsine that prevents the RCD from tripping *if* a high enough current were to flow through a user to ground. The PROsine design however, does not provide any leakage current path through which a high enough current *will* flow.

RCD responses on the PROsine

There are three scenarios in which RCDs appear to operate incorrectly when used on the output of a 230 Vac PROsine product, and one in which they appear to operate correctly:

Scenario 1: RCD test button of the true leakage type is pressed

In this scenario, the RCD will not trip and will appear to fail the test. This is because the test button works by applying a resistance or short from line to earth, but the PROsine cannot provide enough current through that test path to trip the RCD.

Scenario 2: An earth-fault is present on the protected side of the RCD

In this scenario, the RCD will not trip and the earth-fault remains present. This happens because the PROsine cannot provide enough current to trip the RCD. The RCD is still operative: if current above its threshold were somehow able to flow, it would trip as intended.

Scenario 3: RCD test button of the mechanical-only type is pressed

In this scenario, the RCD opens, and appears to pass the test. In fact, no leakage current has been created and the test does not test the detection circuitry. As a result, you cannot conclude that the mechanism has not welded or jammed.

Summary

The design of the 230 Vac PROsine does not allow for leakage current which will trip an RCD. The PROsine has *not* rendered the RCD inoperative, and the user still has the same level of protection from that RCD as though it were operating from the utility mains.