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## Ground sensor current transformer cable routing

Zero-sequence ground current sensing has been used for sensitive ground current protection for decades, but questions still are raised by installers and specifiers. This issue of TechTopics discusses the proper installation of load cables to achieve correct ground current sensing.

Strictly speaking, any method of ground current sensing involves detecting zero-sequence currents. For solidly grounded systems, connecting the phase current transformers together with a common return allows measurement of zero-sequence current in the common lead, if there is no neutral load current. The vector sum of the phase currents is equal to the zero-sequence ground current. This technique is appropriate if the system is solidly grounded and the potential ground currents are high. However, if ground current magnitude is restricted (as by a ground resistor), the sensitivity of the residual connection is ordinarily not adequate. The phase current transformer ratio must exceed the maximum expected continuous load current or expected overloads, and therefore the ground current sensitivity is limited.

When the system is grounded through an impedance, an alternative method is needed to sense ground current. To achieve the required sensitivity, the current transformer (CT) ratio must be independent of the expected phase currents. A toroidal CT with a window that is large enough to enclose all phase conductors is used. This CT is commonly referred to as a zero-sequence CT, even though it is only one means to monitor zero-sequence currents.

When there are too many cables for one zero-sequence ground CT, multiple zero-sequence CTs can be used. It is essential that each set of three-phase cables and the corresponding ground cables pass through a single, zero-sequence CT. For example, with three cables per phase, two three-phase sets of cable and the corresponding ground cables could pass through one CT, and the remaining three-phase set of cables and the corresponding ground cables would pass through a second CT. This assures that all of the currents are balanced, and that the continuous current-carrying capability of the zero-sequence ground CT is not exceeded.

Under normal load conditions, the vector sum of the three-phase currents is near zero. It is not exactly zero as the system capacitive charging current of the load circuit is non-zero. The three-phase cable charging currents sum to a zero-sequence current, typically under 1 A for a relatively short distance of load-side cable. For our purposes, we can ignore this current and consider the normal current as zero.

When one load-side phase conductor fails to ground, the resulting vector sum of the phase currents no longer is zero. If the system is resistance grounded, the zero-sequence ground CT will see a ground current determined by the resistance of the ground resistor, plus the resistance of the load circuit. For example, if the phase cable faults to ground, the voltage across the ground resistor will be the normal phase-neutral voltage, and the ground current will equal the ground resistor rating. On the other hand, suppose the load is a motor with wye-connected windings, and a fault occurs in one phase 90 percent of the winding distance from line to the neutral (e.g., the fault is within 10 percent of the neutral point). Then, the voltage across the ground resistor will be only 10 percent of the normal phase-neutral voltage, and the ground current will be only 10 percent of the ground resistor rating.

So, the objective is to measure the ground return current, and only the ground return current. This means that the load-side cables must be installed so that the ground return current will not affect the current transformer output current.

Figure 1 shows the proper installation of phase and ground cables with a zero-sequence ground current transformer. The important features are:

- All phase cables must pass through the CT opening.
- The phase cable shield must be terminated with a stress cone kit between the zero-sequence ground CT and the cable lug.
- The phase cable shield ground conductor must be routed back through the zero-sequence ground CT.
- The cable shields and the cable shield ground conductors must not contact any grounded surface of the switchgear enclosure between the cable lugs and the zero-sequence ground CT.
- The cable shields must be connected to the switchgear ground bus on the load side of the zero-sequence ground CT.
- The incoming conduit (or armor for IAC cable) must be properly bonded and connected to ground on the load side of the zero-sequence ground CT.
- The cables should be located toward the center of the CT opening, and should not be allowed to contact the CT case. If the cables are directly against the CT case, it could lead to localized saturation of the CT core under through-fault conditions, leading to false operation. Typically, the mounting plate for the zero-sequence ground CT can be used to restrict the cables so that they pass through the approximate center of the CT window.

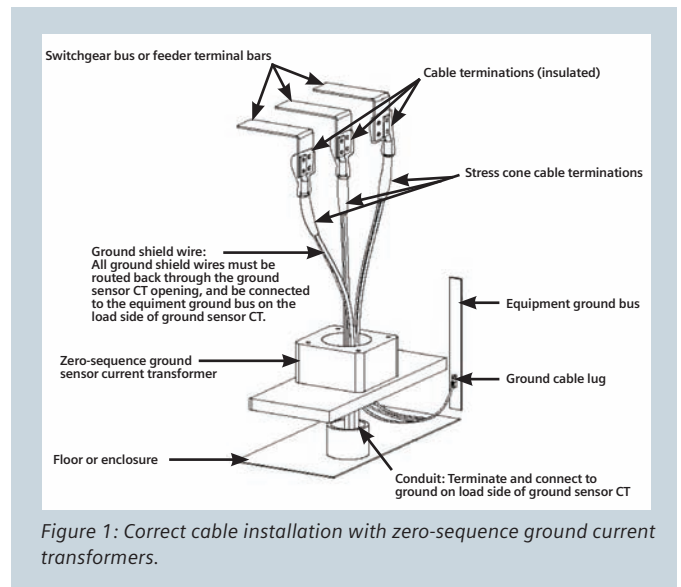


Figure 1: Correct cable installation with zero-sequence ground current transformers.

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