

Monitor Ground Fault Leakage Currents

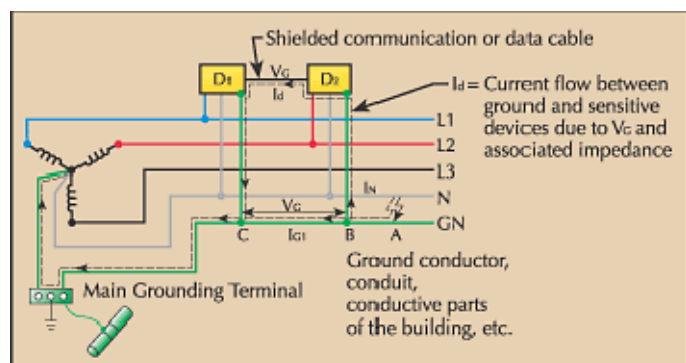
Pentti Taskinen / Muuntosähkö Oy - Trafox

Most power quality problems are due to incorrect connections of an electrical system. Using CTs and leakage current monitors, you can check an electrical system during acceptance testing of the installation and also during maintenance and renovation of the system.

Watch out for partial or complete short circuits between neutrals and your grounding network. They'll often create power quality disturbances that effect electronic devices connected to your power system, causing them to malfunction. This problem occurs when part (and at times all) of the return current in the neutral conductor flows through grounding conduit and conductive parts of the building back to the service entrance. This current is called ground fault leakage current. It can generate disturbances and other problems such as:

- Noise in an electrical system that often enters grounding circuits of sensitive electronic devices, causing them to malfunction.
- Strong stray magnetic fields that may detrimentally effect the operation of adjacent electrical equipment.
- High voltage differences between separate grounding points, which may be dangerous.

How do these problems occur? Let's look at Fig. 1 (right), a schematic of a grounded 3-phase system. Note the grounding circuit is bonded to the ground at one location: the main grounding terminal. Note also the other two grounding conductors leaving the main grounding point. One goes to the neutral of the main and other transformers in the system. The other is in the form of the conduit, a separate grounding conductor (so called isolated ground), and the conductive parts of the building.



Concentrating on Point A of Fig. 1, you can see the neutral conductor makes contact with ground. This causes the return current flowing from the load to be partly diverted from the neutral conductor to the grounding conduit as well as conductive parts of the building. The amount of the return current divides according to the paths' impedances. This partial (it could be a complete) diversion of current between the neutral conductor and the grounding network causes the problems we discussed earlier.

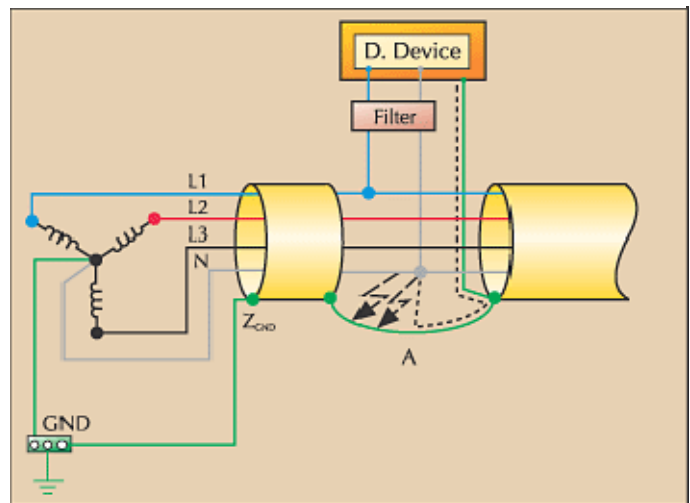
Yes, there's a certain amount of normal leakage current going from the neutral and the phase conductors to ground in all electrical systems. Usually, the level of this leakage current is from about 10mA to some 100mA, depending on the size of electrical system.

Voltage differences are between different grounding points. Let's assume we have two sensitive electronic devices, say a remote measuring probe and a PLC system, as shown in Fig. 1. (Let's call them D1 and D2 respectively.) Note these devices are connected to different parts of the electrical system. Between the electronic devices is a communication cable, which is shielded. This shielding is grounded to the grounding circuits of D1 and D2.

Because of contact between the neutral and ground at Point A, the return current flowing from the load also flows through the grounding network and the grounding circuits in Devices D1 and D2. And each device's cabinet, which is insulated from the internal working electronics, connects to the grounding conductor.

This return current causes a voltage (V_{subG}) between points B and C. This voltage is also present at the cabinet of each device. A voltage in the grounding conductor and associated impedance causes current (I_{subD}) to flow in the communication cable between Devices D1 and D2. This current may disrupt their operation because the voltage difference and resulting current are often quite high.

So, how does ground noise enter a sensitive electronic device? Current flowing in a neutral conductor consists of many kinds of disturbances such as harmonic waves and distortion, high frequency disturbances, transients, etc. In Fig. 2 (right), you can see a sensitive electronic device connected to an electrical system. The input circuit to this device is equipped with a filter or surge suppression circuit that prevents disturbances in the phase and neutral conductors from entering the device. At Point A of Fig. 2, the neutral conductor is partially or completely connected with the grounding conduit. In such a case, all disturbances in the neutral conductor pass onto the grounding circuit and the cabinet of Device D. These disturbances can effect the device's sensitive circuits. (Some examples of this kind of equipment are microcomputers, programmable controllers, etc.) Quite often, the grounding conduit has a high impedance (Z_{subGND}), but usually only at high frequencies. As such, it fails to conduct noise away from this point.

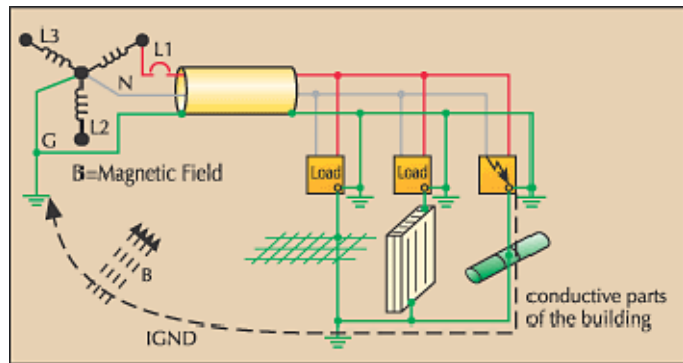


As you can see, a filter or surge suppressor circuit does not prevent disturbances from entering the device. Often sensitive electronic devices are connected to a reference ground. The problem above results from the devices' grounding conductor connected to the conduit (which is also serving as a ground) rather than to a dedicated reference grounding system tied to the main grounding point.

Sometimes the shield of the communication or data cable connects to conductive parts of the building. Now, part of the disturbance current in the grounding conduit (which is also connected to the building's conductive parts) goes through the signal reference ground conductor to ground. Because of this, the ability to attenuate noise is reduced. You must monitor the separation of the signal reference ground and the safety grounding conduits.

Watch out for magnetic field interference. In a normal electrical system, ground current produces a low frequency (60 Hz) magnetic field. At this frequency, a clean electrical system has a magnetic field between 0.1 mGaus to 45 mGaus. In an industrial working environment the magnetic flux density can be much higher, anywhere from 20 mGaus to 15 Gaus. Normal sources of stray magnetic fields are transformers, large motors, and various industrial production machines. However, the major significant cause for magnetic stray fields is often a faulty grounding connection or an equipment failure in an electrical system.

Fig. 3 (right), shows how magnetic field interference is generated. In the electrical system shown, there's a neutral-to-ground connection someplace in the facility. As a result, part of the neutral conductor's return current flows through the conductive parts of the building back to the service entrance. This produces a large current loop without having a current balance. This generates the magnetic interference field B , which can have a density almost 10 times greater than a "clean" electrical system.



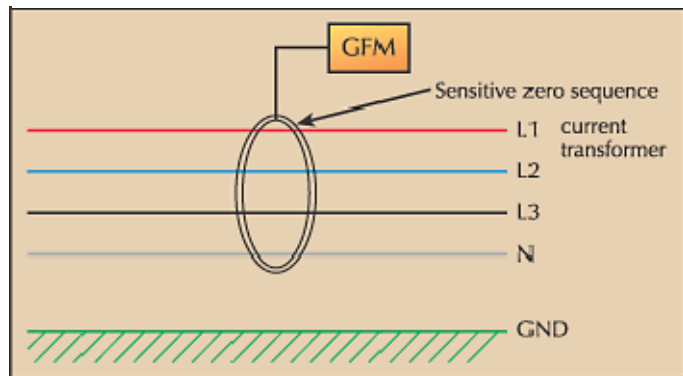
Relatively small magnetic fields cause disturbances to sensitive electronic devices. For example, fields higher than 13 mGaus can disturb a computer monitor.

In the U.S., definitive standards on electric magnetic fields aren't yet established. However, in Europe, the Cenelec (European Committee for Electrotechnical Standardization) EMC Standard EN-50082-1 gives limit values for residential, commercial, and light industry environments. The maximum value of magnetic flux density is 38 mGaus for industrial situations and 13 mGaus for computer monitoring locations. In a facility's electrical system, you may see very high peaks of magnetic flux density during starting current impulse. These peaks can directly effect the circuits of sensitive devices.

How do you monitor ground leakage current to avoid problems? To prevent electronic noise from disturbing electronic devices, you can use different kinds of noise attenuation circuits, such as filters, isolation transformers, photo-couplers, etc. But one of the most important aspects in preventing electronic noise from disturbing electronic devices is to evaluate the wiring and grounding systems first. This can often be expensive and time consuming. The simplest and most economical method is to continuously monitor leakage current of the whole electrical system or the most critical parts of electrical system.

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A sensitive current transformer connected to a monitoring device can measure leakage current. The procedure for measuring ground fault current flow is to place the phase conductors and the neutral conductor through a current transformer (CT) as shown in Fig. 4 (right). The purpose of the CT is to measure the instantaneous sum of the phase and neutral currents. This type of CT is usually a closed-core type, however, you can also use a split-core type. (You can also wrap flexible CTs around the conductors, but they lack sensitivity in the low current ranges.)



If your electrical system has a separate grounding conduit or a separate dedicated ground conductor, it should stay outside the CT. The CT should be connected to a ground fault monitor (GFM), or any type of meter that can accurately measure current.

If there's no leak to ground, the sum of the current as detected by the CT should be close to zero. If the three phase conductors aren't balanced (as far as current flow), then the current difference will be flowing through the neutral. With this situation (and because the neutral is run through the CT with the phase conductors), the total current flow as seen by the CT will be close to zero, under ideal conditions. Normally, electrical systems have some minor leakage that's caused by insulation resistance and capacitance to ground.

Depending on its sophistication, a monitor can initiate alarms, take a recording of the current for trend purposes, etc. Many monitors have settings for initiating action at a current amplitude. Some are specially built for just determining ground fault measurement, while others can take power and additional measurements. Some monitors have single- or multi-channels for measuring a number of readings from various CTs. Each channel can have an independent alarm setting. Some monitors have a delay setting that helps avoiding nuisance alarms, with settings to 60 sec.

If there's a wiring error in a system, the reading will be few amps. Usually, the sensitivity of a monitor is from 5mA to 30mA and can go up to 10A.

Continuous monitoring offers advantages. Continuous monitoring of ground fault leakage conditions is a relatively inexpensive method to increase power quality. You can measure various points throughout your electrical system or you can focus on just that part of the system crucial to production or function.

Spot measurements to find intermittent disturbances are difficult and time consuming. However, continuous measuring will easily detect these disturbances. Continuous measurement can generate an alarm immediately when a fault occurs or when insulation resistance someplace in the system decreases. With multiple CTs and a GFM with several channels, you can locate the problem.

Usually a fault occurs during maintenance or renovation of an electrical system. When this happens, the GFM looks at the magnitude of the ground fault current and recognizes it as a solid fault. Usually, you can find these immediately.

Most common faults are:

- Wiring errors,
- Neutral-to-ground faults,
- Load wired between phase and ground,
- Insulation damage or degradation, and
- Defective device connected to the system.

Recent studies show that 60% to 80% of power quality problems are due to an incorrect connection of an electrical system made during the design, installation, or maintenance stage. By using CTs and monitors, you can check an electrical system during acceptance testing of the installation and also during maintenance and renovation of the system. And, by taking continuous measurements of the ground leakage current, you can instantly recognize a change in the condition of electrical system. This helps ensure no faulty connections are left undetected, no faulty equipment is connected to the electrical system, and helps predict insulation faults before the circuit breaker trips. It also provides a warning that sensitive devices connected to the electrical system may start to malfunction.

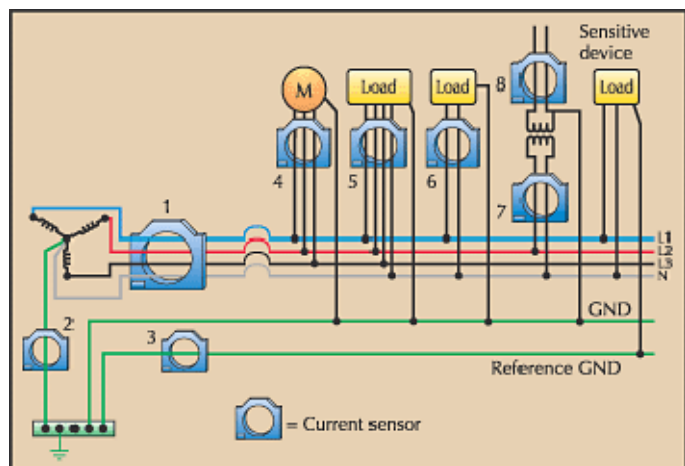
Helpful hints in determining placement of CTs.

Fig. 5 (right), shows where to locate CTs for measuring critical points in an electrical system. The numbers before each explanation below relate to the location shown.

1. Current measurement of feeder and neutral conductors. This arrangement is sufficient for small electrical systems having few devices. In large systems, a more involved arrangement is recommended because the tracing of a fault is time consuming. Also, small changes of the leakage current are not detected (e.g. weakening of the insulation level in a network section).

2. Measuring the current in the ground conductor that connects a transformer's neutral point and the main ground terminal. The leakage current measurement will be the same here as the measurement taken using the previous method. This arrangement, however, takes a direct reading; the previous measuring method relies on the summation of currents flowing in the phase and neutral conductors. If it's possible to use the ground conductor for simple electrical systems, this method (No. 2) is recommended because you can use a smaller and less expensive CT.

3. Measuring the reference-grounding conductor. This method is for an electrical system having a separate reference-grounding conductor (the Reference GND in Fig. 5, which is a separate grounding conductor used





mainly for sensitive electronic devices). Using a CT as shown, is a way of measuring the current flow through the Reference GND. Note you must monitor this conductor. This measurement detects the current flow through the connections between the cable shields of data cables and the grounding conductor. These connections may have large ground currents flowing in the cable shield. Also, measurements of leakage currents using the Reference GND can indicate wiring errors as well as the weakening of the insulation level in the conductors and devices connected to the Reference GND.

4. Supervision of a 3-phase motor or other 3-phase devices. It's possible to monitor the insulation level of a device or a section of the electrical system with this form of monitoring. Degraded insulation would initiate an alarm even before a circuit breaker or short-circuit protector trips. As such, you can avoid unexpected power or process breaks.

5. Measuring a riser circuit or the supply serving an individual device. This is a good method for small networks.

6. Monitoring a single-phase system (one branch circuit or an individual device). The tracing of a fault is easy. If it's a question of a branch circuit with several wall outlets or various other connected loads, you can use a sensitive clamp-on current meter for tracing a fault.

7. Measuring the primary circuit of a transformer, UPS, or other device. This measurement monitors the insulation level of the device.

8. Measuring the secondary circuit of an isolation transformer or a noise suppression transformer. You would use this method when measuring programmable controllers or other sensitive electronic devices. It monitors the insulation level or the wiring of circuits or devices connected to the secondary circuit. A defective device often disturbs other devices in the same circuit. It is easy to locate a device impaired by a connection to the ground system when the device is connected to the secondary circuit of a transformer by using CTs connected to a monitor. This kind of a fault would normally be difficult to locate. When using this measuring point you must make sure that one of two secondary conductors should be connected to ground.