WHITE PAPER

Understanding ground-fault protective devices

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Figure 1: ABB's GFEP devices type F200 in single-phase and three-phase designs

A ground fault in a piece of electrical equipment is caused by loss of insulation between a live conductor and an exposed conductive part, causing a flow of current to the ground. Ground faults can result from deterioration, mechanical damage, and harsh enviroments. This white paper explains ground fault protective devices' standards, functionality, and applications.

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Ground-fault protective devices—known variously as residual-current devices (RCD), earth leakage circuit breakers (ELCB), ground-fault equipment, protectors (GFEP), or ground-fault circuit interrupters (GFCI)

Their primary function is protect people and equipment against the effects of ground faults by interrupting/disconnecting the defective circuit.

The general principle of these devices is the same: in an AC system, they measure and compare the currents flowing into the electrical system with the ones flowing back. If the vectorial sum of these currents is not equal to zero, the residual current makes the ground-fault device trip, interrupting the circuit.

Different standards, different devices
In the US we differentiate between two types of ground-fault protective devices, GFCIs/GFIs and GFEPs. GFCIs comply with UL 943 and can be used for personnel protection. GFEPs comply with UL 1053 and can be used for equipment protection (Figure 1).

The main difference between these two types is their sensitivity to ground-faults. GFCIs have a sensitivity of 5 mA to 6 mA, whereas GFEPs have a sensitivity of 30 mA and up. Because of their greater sensitivity, GFCIs can experience nuisance tripping in applications for equipment protection, depending on the type of load (e.g., applications with variable frequency drives or electronic devices).

Outside of the U.S., where IEC standards are used, devices with a sensitivity of 30 mA are typically used for personnel protection in addition to equipment. This is possible due to modern technology which makes the unit trip within a time frame that doesn't allow a current of 30 mA to produce incident energy at levels harmful to people. The UL standard is more prescriptive, so in this white paper we are focusing on GFEPs that are compliant with UL 1053.

Although many electrical applications in the U.S. are not required by code to have ground fault equipment protection, it's a good idea to add this level of protection since most short circuits initially manifest as ground faults.

Ground faults can cause major disruptions in industrial environments. This not only results in downtime and corresponding lost production, but also in cost for repairing or replacing damaged equipment. Faults can also result in fires when flammable materials are involved.

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The images above illustrate cable deterioration, mechanical damage, and harsh enviroments that can result in a ground fault.

Even though GFEPs are not intended to be used for personnel protection in the U.S., they do offer some protection indirectly. By creating a safer environment for the equipment, they are creating a safer environment for people, too.

How does a GFEP work?
GFEP devices comprise the three main components:

The current transformer senses the currents flowing through the conductors of an electrical system. In case of a ground-fault there is an imbalance of these currents, which creates an imbalance in the magnetic field of the transformer toroid. This imbalance creates a voltage on the secondary side of the transformer.

The electronic relay is energized by the voltage on the secondary side of the current transformer and operates the switching mechanism.

The switching mechanism opens the contacts of the GFEP and, thus, disconnects the defective circuit.

Figure 2 shows these components in a basic GFEP design and Figure 3 shows the inside of an actual device with the components visible.

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Figure 2: basic GFEP design

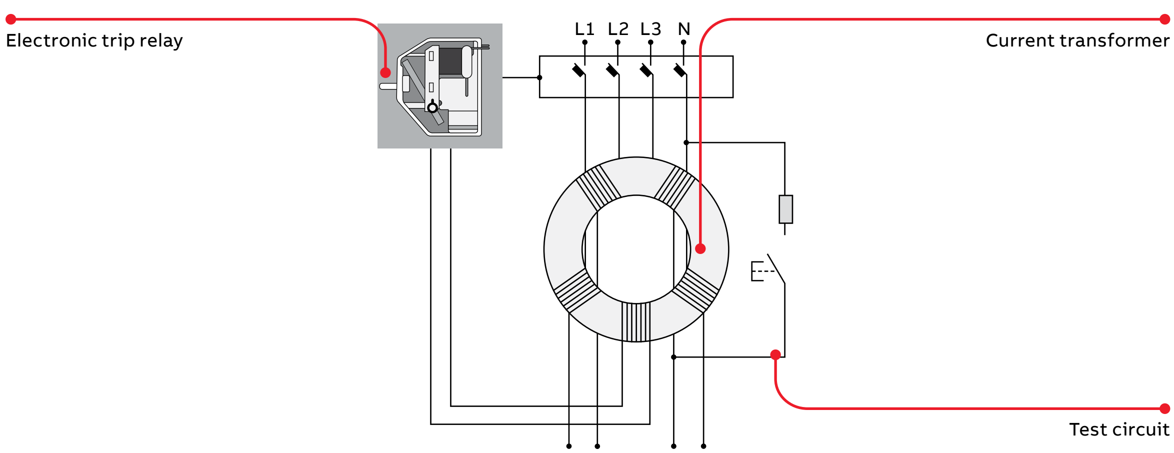

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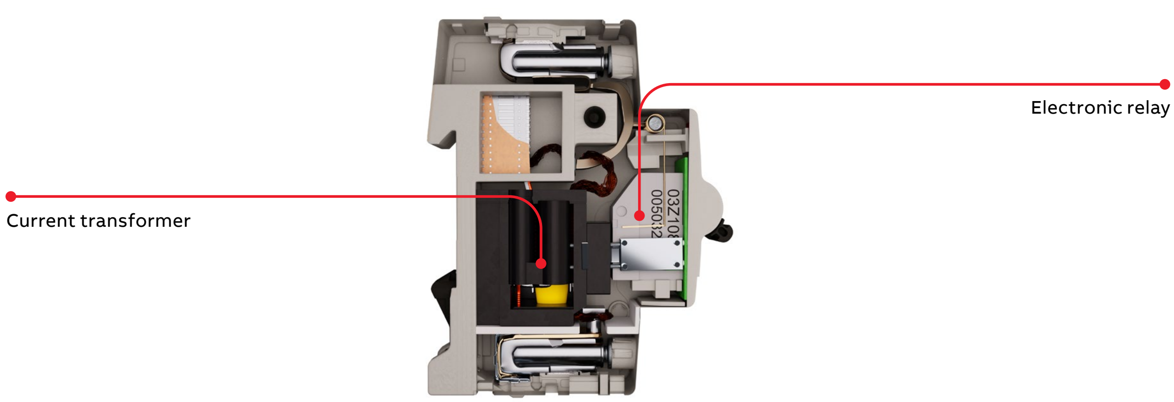
Figure 3: inside a GFEP device



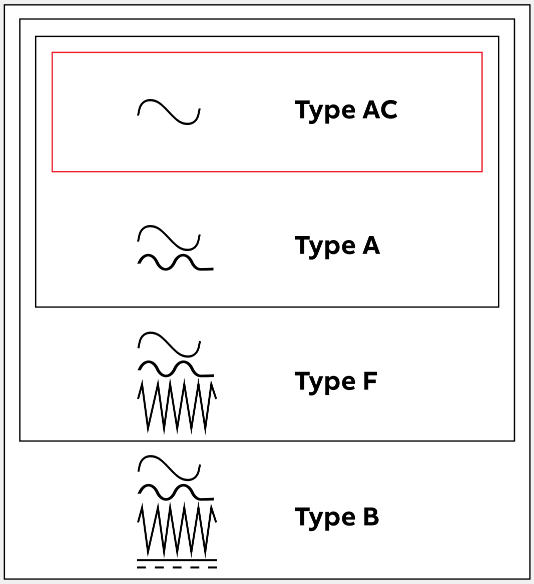


Figure 4: GFEP types

AC – Detects AC fault currents only

A – Like AC, but additionally detects pulsed DC fault currents

F – Like A, but additionally detects harmonics up to 1 kHz (e.g., for applications with VFDs)

B – Like F, but additionally detects continuous DC fault currents

There are different types of GFEPs based on the type of fault current that they can detect. They are organized along a progression of increasing capability, which Figure 4 represents in a Venn diagram.

In addition to these types there are short-term delayed (AP-R) and selective types (S) available that are used in applications that can experience nuisance tripping of a type AC or type A device. Nuisance tripping can be caused by all kinds of devices and incidents such as inverters/converters, surge voltage (atmospheric and operational discharges), transient impulses from capacitive or inductive load switching, fluorescent lamps with electronic ballasts, and transient impulse currents from electronic devices (EMC filters).

GFEPs are also classified as voltage-independent or voltage-dependent GFEPs. As the names suggest, the latter require a voltage to operate the tripping mechanism while the former do not.

Each GFEP is equipped with a test button (test circuit) to check the correct function. The test circuit simulates a ground-fault and the device will trip if it is working properly. It’s important (and recommended by manufacturers) to check the function of a GFEP regularly. In the US, GFEPs are tested and approved according to UL 1053, and carry the mark for UL-recognized components shown in Figure 5.

Figure 5: UL-recognized label

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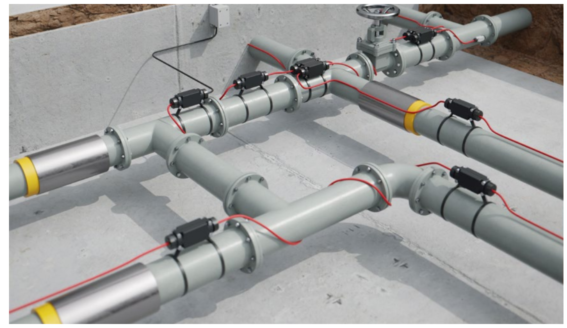

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Figure 6: GFEP with integrated miniature circuit breaker

Figure 7: Outdoor de-icing / snow melting system

Applications
GFEPs can generally be used in any kind of application to protect any kind of equipment.

They can be installed in branch circuits together with a corresponding branch circuit protective device, such as a miniature circuit breaker (MCB) or molded case circuit breaker (MCCB) as indicated by UL 489. They can be placed in supplementary circuits together with a corresponding supplementary protector (e.g., an MCB according to UL 1077). There are also GFEPs available with integrated circuit protective devices. Figure 6 shows a 2-pole (single phase) GFEP with an integrated supplementary protector (MCB) as required by UL 1077.

Besides these examples, there are some applications for which the U.S. National Electric Code (NEC) requires the use of GFEP. Following are some examples shown by the corresponding NEC regulation.

Article 426.28: Ground-fault protection for equipment shall be provided for fixed outdoor deicing and snow-melting equipment (e.g., roof-heating systems in buildings, Figure 7).

Article 427.22: Ground-fault protection for equipment shall be provided for heat tracing and heating panels for pipelines and vessels.

Article 517.17: In health care facilities, an additional level of GFPE (with selectivity) is required downstream.

Article 553.4: The main overcurrent protective device for a floating building/structure shall have ground fault protection not exceeding 100 mA.

Article 555.3: The main overcurrent protective device for a marina or boat yard shall have ground fault protection not exceeding 100 mA.

Articles 690.5 and 690.35 describe ground-fault protection for equipment in solar installations (PV arrays).

These are just a few of the many applications where GFEPs are used. These devices are present in a wide array of facilities (see gray box below). In many cases, there is no NEC mandate for GFEPs, but they are often employed to protect critical assets that are expensive and time consuming to repair or replace in the event of a ground fault.

Ground-fault equipment protection is a critical part of a comprehensive solution for circuit protection. It avoids costly downtime and the cost of damaged or destroyed equipment. More importantly, it also creates an environment that is safer for people.

GFEPs in the field
Ground-fault protection devices can be found in a wide variety of applications and industries, including:
- Roof heating/deicing systems
- Semiconductor manufacturing
- Heat trace systems
- EV charging stations
- Power distribution for marinas
- Pharmaceutical manufacturing
- Food and beverage production
- Solar and wind power installations
- Data centers

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