Technical Note 262

GFCI circuit breakers with ABB drives

Improving compatibility with VFDs and high frequency (HF) rated Class A GFCI devices

Document summary

VFDs (AC drives) use high-frequency switching to control motor speed and torque. This switching can create common-mode (CM) noise and high-frequency leakage currents that may cause nuisance tripping when a conventional Class A GFCI is installed on the line supply power feeding a drive. This technical note explains the cause, outlines mitigation practices, and summarizes recent UL developments that recognize “HF” designed Class A GFCIs evaluated for improved immunity to high-frequency differential current.

Question

Can a GFCI circuit breaker be installed on the input side of a drive, or will the drive cause the GFCI to trip?

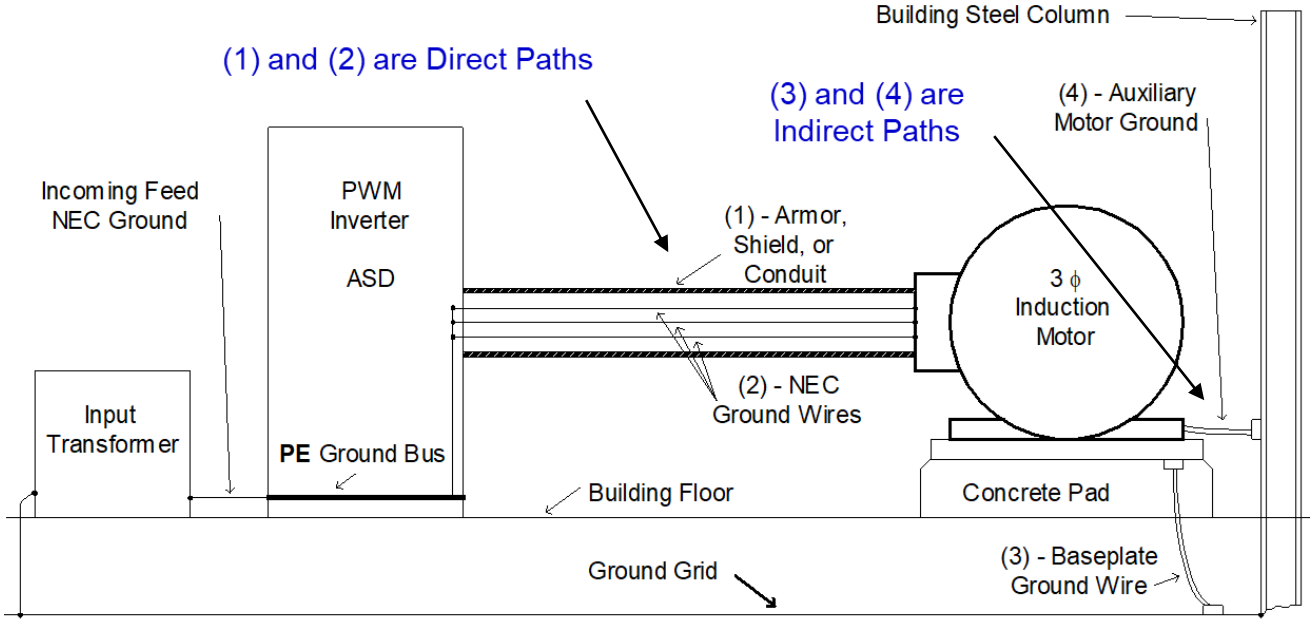
Short answer

- A conventional Class A GFCI may trip when supplying a VFD because the drive and motor system can generate high-frequency common-mode leakage currents/noise.
- If Class A GFCI protection is required by NEC, consider Class A GFCI evaluated and designed for HF (UL 943 Supplement SB) for improved immunity/compatibility with inverter-based loads.
- Regardless of device selection, correct grounding/shielding, cable practices, and EMC installation details are essential to reduce nuisance tripping.

Why do GFCIs sometimes trip on VFD systems

VFDs switch IGBT power devices at relatively high frequencies (typically in the kHz range). The pulse-width-modulated (PWM) output has fast rising voltage edges (high dV/dt), which charge and discharge parasitic capacitances in the drive, motor cable, and motor. This switching creates common-mode electrical noise. Common-mode noise is current that appears on conductors with respect to ground, returning through parasitic capacitance in the drive, motor, and cable, as well as through the facility grounding system. See Figure 1.

Figure 1. illustrates typical indirect (capacitive) return paths for common-mode current in a VFD system.



There are “indirect” paths because the HF current does not return through the intended line conductors; it returns through parasitic capacitances to grounded metal and the facility bonding/grounding system, creating residual current seen by the GFCI.

- Motor cable and motor winding-to-frame capacitive coupling allows currents to flow through the motor frame to ground.
- Drive RFI/EMI filter capacitors (line-to-ground and/or DC-bus-to-ground, depending on design) intentionally provide a path to PE/ground at high frequency.
- Bonded shields, conduit/armor, and mounting plates provide additional HF return paths back to the source ground network. (Bonded Shields, conduit or cable armor would usually be considered among the preferred return paths for high frequencies.)

A line-side GFCI monitors differential current (imbalance between outgoing and returning current). High-frequency components and transient behavior associated with VFD systems can be interpreted as differential leakage and cause nuisance tripping. The noise can also propagate and interfere with other equipment (for example, sensors, PLCs, computers, and communications devices).

What has changed over the years

- More inverter-based loads (drives, vehicle charging stations, high-efficiency appliances) are common in buildings and industry, increasing the high-frequency content of leakage current.
- UL 943 introduced Supplement SB — Optional High Frequency (HF) Rating — a supplemental evaluation addressing GFCI immunity/compatibility in the presence of high-frequency differential current.

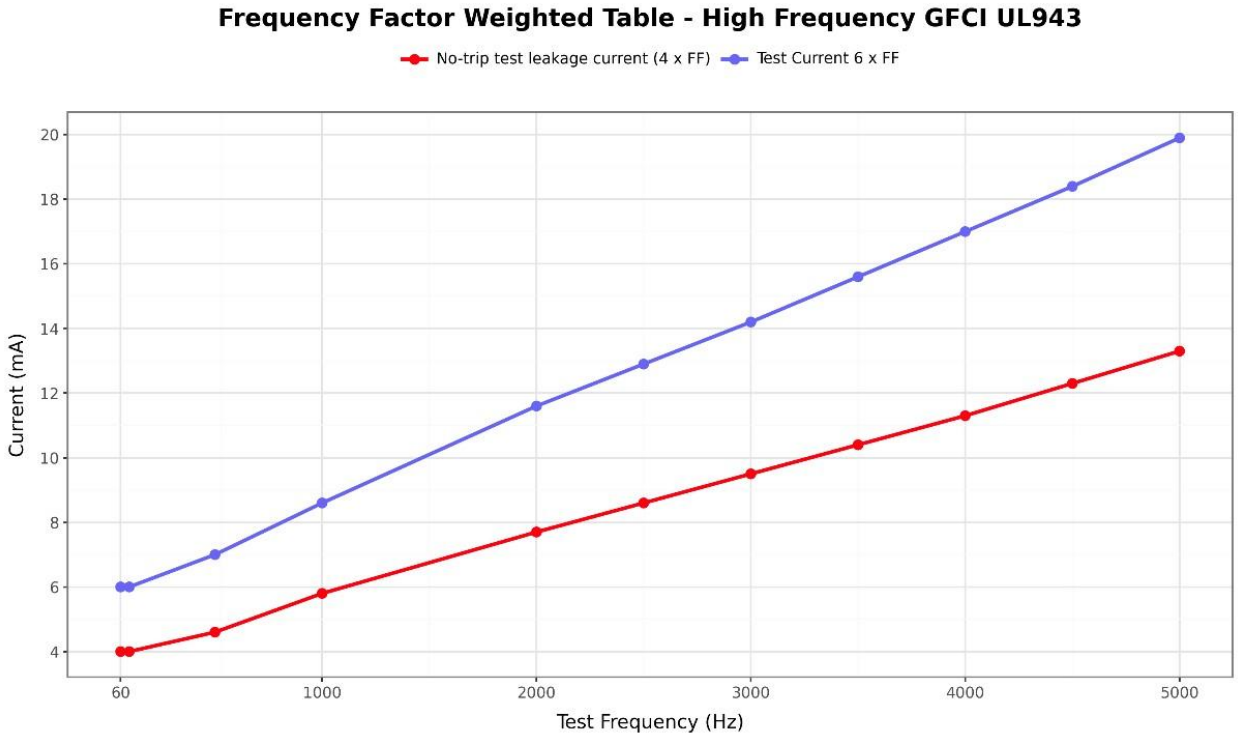
- The 2026 NEC recognizes HF Class A type GFCIs for use with loads that have modern high-frequency leakage currents such as variable speed drives and inverters (confirm local adoption and AHJ requirements).

Understanding Class A GFCIs designed for "HF" (UL 943 Supplement SB)

The UL 943 Optional HF rating is intended to evaluate a GFCI's resistance to false tripping when high-frequency differential currents are present. The evaluation uses a weighted measurement concept (Interoperability Indication Unit, IIU) and assesses immunity across a wide frequency range. In practice, HF designs are aimed at improving interoperability for inverter-based equipment that can generate HF leakage components while maintaining electrical safety for personnel.

The HF evaluation applies frequency-dependent limits from 60 Hz to 150 kHz, expressed in Interoperability Indication Units (IIU), with a no-trip leakage level of 4 × FF (below red line) and a test (trip) current level of 6 × FF (per UL 943 Table SC2.2 frequency factor weighted table).

Figure 2. provides a quick reference to 5 kHz for the UL 943 Supplement SB frequency-factor weighting (FF) used to evaluate Class A-HF GFCIs.



- HF rating is optional for Class A GFCI devices that are designed and evaluated to the supplemental requirements.
- HF designs improve compatibility but do not eliminate the need to correct wiring errors, neutral-to-ground faults, and insulation failures.
- Always select and apply protective devices in accordance with the product listing/marking, manufacturer instructions, NEC, and Authority Having Jurisdiction (AHJ) direction.

Application guidance for VFD installations with required Class A GFCI protection

- **Confirm why Class A GFCI is required**
  - Verify the NEC article and local amendments driving the requirement (location, receptacle type, equipment, etc.).
  - Confirm whether a breaker-type or receptacle-type GFCI is needed and any special AHJ conditions.
- **Choose the right GFCI for inverter-based loads**
  - Where permitted and appropriate, use an HF designed Class A GFCI to improve immunity to VFD-related HF leakage components.
  - Avoid combining many EMI-filtered loads on one device; cumulative leakage can exceed Class A thresholds even with improved HF immunity.
- **Implement VFD installation best practices (reduces leakage and noise at the source)**
  - Grounding and bonding: Ensure the motor frame, drive enclosure, and equipment grounding conductor (EGC) are properly bonded. Terminate motor cable shields by carefully following the drive instructions so HF return current is controlled.
  - Motor cable: Use VFD cables where applicable and keep motor leads as short as practical. Long motor leads increase capacitive coupling and common-mode current.
  - Wiring layout: Keep sensitive control wiring separated from power wiring and do not route input and output wiring together.
  - RFI/EMC filtering: Install and configure RFI/EMC filters per the drive manual.
- **Consider isolation/decoupling when required by the installation**
  - An isolation transformer installed between the GFCI and the VFD can help reduce transfer of common-mode noise and may reduce nuisance tripping in challenging installations.

Common symptoms and corrective actions

Use Table 1 below as a quick diagnostic starting point. Always rule out real ground faults and wiring errors first.

Table 1

Observed behavior	Likely contributors	Recommended actions
Trips immediately on drive enable/start	High transient HF leakage; filter configuration; wiring/shield termination	Check grounding/shield termination; verify filter configuration; consider HF-marked GFCI where applicable; reduce motor lead length where possible
Trips intermittently during speed changes	PWM mode changes; switching frequency changes; cumulative leakage variations	Correlate trips to drive events; isolate loads; improve cable/shield practice; can try different switching frequencies to troubleshoot nuisance trips
Trips when multiple electronic loads are connected	Cumulative leakage current	Split circuits; reduce number of filtered loads per GFCI; verify no neutral-ground faults
Trips persistently with no VFD running	Wiring error or real ground fault	Inspect downstream neutral/ground separation maintaining a single bonding point; test insulation; inspect cables and terminations

Troubleshooting checklist

- Verify line/load wiring, neutral routing (if applicable), and neutral and ground are only bonded at one point.
- Correlate trip timing with drive operation (start, accel/decel, switching frequency changes, EMI filter enablement).
- Isolate contributors: disconnect parallel loads and accessories to identify cumulative leakage contributors.
- Inspect motor cable condition, moisture ingress, conduit fill, and terminations; test motor insulation if a fault is suspected.
- If GFCI protection is required and installation is correct, evaluate whether an HF designed Class A GFCI is appropriate for improved immunity to VFD-related HF leakage components.

Disclaimer

This technical note is intended as general application guidance. Requirements vary by installation, product listing, and local code adoption. Always follow the applicable NEC edition adopted by the jurisdiction, the product listing/marking, ABB installation manuals, and AHJ requirements.