

# UPGRADING THE ROTOR GROUND FAULT PROTECTION ON ELECTRIC GENERATORS

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## SUMMARY

Rotor Field Ground Faults (also referred to as earth faults) can occur on electric generators without warning, causing severe damage to rotors and forcing extended outages that can be extremely costly. Often power plant operators assume they have operating protective relays that will either shut down the generator (and possibly the plant) or initiate alarms at the onset of field ground faults. But the truth is that many older generators have no protection at all or have older protective relays that are not working properly. There is nothing worse than thinking that you are protected when you are really not.

The challenge of reliably detecting ground faults is particularly difficult on brushless generators because the entire excitation system is on the rotor, and the access needed to detect ground faults is even more difficult. Fortunately, newer and more advanced rotor telemetry ground fault detection is now available for retrofit on older generators at a reasonable cost, giving operators a peace of mind. These products, not only provide fault detection, but also offer condition monitoring features. This is done by continuously measuring the insulation resistance. It is similar to performing a continuous megohm (megger) test on the rotor field winding and exciter, and tracking any degradation while the machine is running.

This paper introduces standard solutions to upgrading generators with Accumetrics' Earth Fault Resistance Monitoring System (EFREM).

## HAZARDOUS EFFECTS OF FIELD GROUND FAULTS

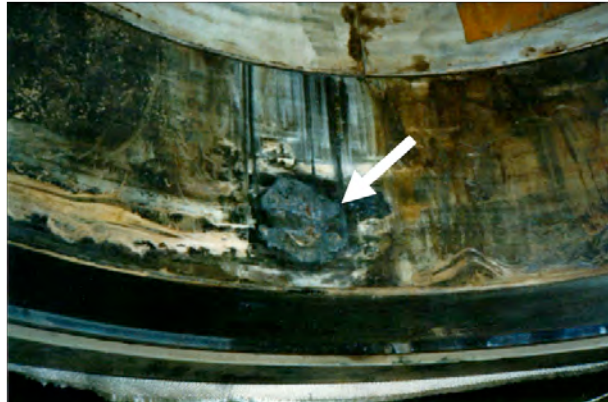
On synchronous generators, field ground faults are perhaps the most dangerous common defect that can occur on rotor windings. Insulation breakdown in the slots or end windings can cause shorts between the field winding and the rotor forging. When two grounds occur at different locations on the winding, excitation current will be diverted into the rotor forging which can lead to serious damage or even complete destruction of the generator.

A single ground fault can be equally as dangerous, because it may be the result of a coil-to-coil short or a break in the copper turns and connections, which are quite

common. Typically these faults are accompanied by severe arcing that can cause serious damage to the winding insulation as well as the rotor forgings. Figure 1 shows two examples of the damage that can occur from field ground faults.



Destroyed rotor forging resulting from undetected ground faults at two locations



Near-fatal burn damage to retaining ring inside diameter due to short between 2 coils

**Figure 1**

### **CONVENTIONAL GROUND FAULT DETECTION**

Because field grounds can result in such serious consequences, almost all larger generators have ground fault detection systems designed to activate alarms or, in some cases, trigger automatic shut down when a fault is detected. Fault detection is done by simply applying a DC injection voltage between the excitation circuit and rotor ground and measuring the leakage current that flows through that connection. Since the excitation circuit is designed to operate ungrounded, current only flows if there is a ground fault to complete the circuit. This approach yields a go/no go alarm when a fault occurs, but gives no information on the severity or location of the fault. Moreover, the severity of the fault at the threshold of alarm detection is not fixed – it is influenced by the field voltage and the fault location. With low side injection, a fault near the negative side of the winding will typically need to be an order of magnitude lower in resistance before detection occurs, than a fault near the higher DC voltage at the positive winding terminal.

The ground fault detection method described above is accomplished very easily on brush and collector ring fields where the excitation circuit is easily accessed. On brushless generators, where the exciter circuitry is entirely on the rotor, it is not as easy.

Some older brushless generators use slip rings and brushes to access the rotor. But the brushes cannot continuously contact the rotor slip ring without excessive wear and contact resistance problems, so they are often designed to operate intermittently. The ground fault detector causes a solenoid to engage the brushes into electrical contact with the rotor on a periodic basis, typically once or twice every 24 hours. But this approach only partially protects the field, as it is non-continuous and is subject to reliability issues if not constantly maintained.

First generation non-contact ground detectors became available several decades ago and replaced slip ring connections with primitive optical or radio frequency communication off the rotor, but they are still go/no go alarms and have life and reliability limitations.

### **THE ACCUMETRICS' EFREM**

In 2005, Accumetrics introduced the [EFREM](#), an innovative new condition monitoring field ground fault detector. This system differs from the earlier field ground detectors in that it provides continuous monitoring and trending of insulation resistance, as well as field voltage. The measurement is achieved by injecting a low frequency pulse signal between rotor ground and the field circuit and precisely measuring leakage current. Insulation resistance may be calculated as  $\Delta v/\Delta i$  and is not influenced by the DC currents resulting from the excitation voltage at the location of the fault. If a fault is detected by diminishing resistance, the system will also report a location factor providing information about the location of the fault along the field winding.

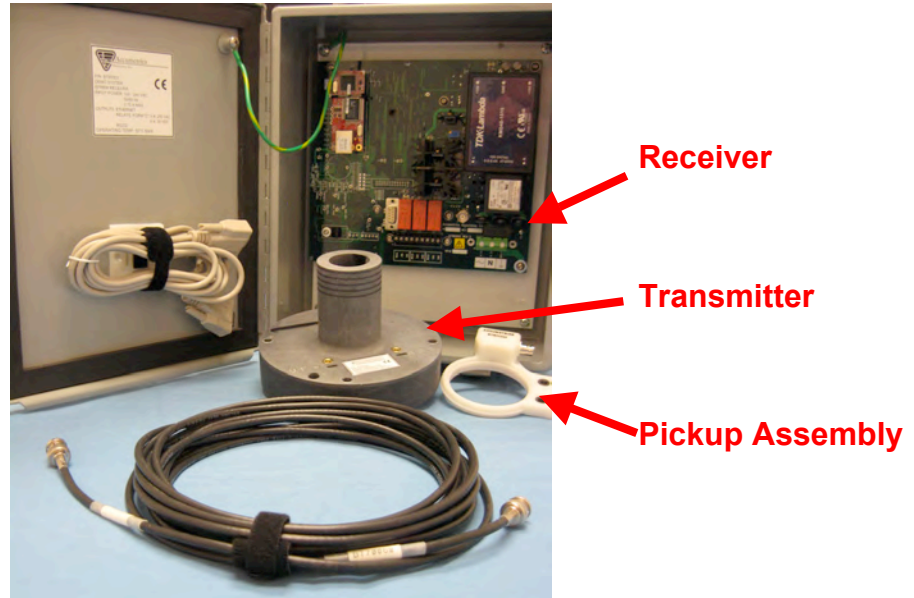
Two ground fault alarms are provided, allowing operators to be alerted at two different levels of fault severity, as the insulation resistance falls below their respective, user selected insulation resistance thresholds. Trending data is available in both digital and analog output formats for monitoring purposes. In the unlikely event that the EFREM starts to malfunction in any way, that condition will be detected and a system malfunction alarm will be asserted, notifying operators that the machine is no longer properly protected from rotor ground faults.

The EFREM is supplied to a number of major OEMs for installation on new machines and is also supplied to utility operators as upgrades to their existing fleet of generators. The system is currently operating on hundreds of machines worldwide.

### **STANDARD RETROFIT PACKAGES**

The most common form of the EFREM is the end-of-shaft version, which is designed to mount adjacent to overhung brushless exciters mounted at the non-drive-end of

generators. Figure 2 is a photo of the EFREM components. This version consists of a rotor mounted transmitter, a non-rotating pickup assembly that mounts adjacent to the transmitter, a coaxial cable that connects the pickup to a remote receiver unit that recovers rotor measurements and provides user interfaces.



**Figure 2 – Standard EFREM Components**

This product can be adapted to mount on most brushless generators. Accumetrics can supply standard installation kits for several GE generators with brushless exciters.

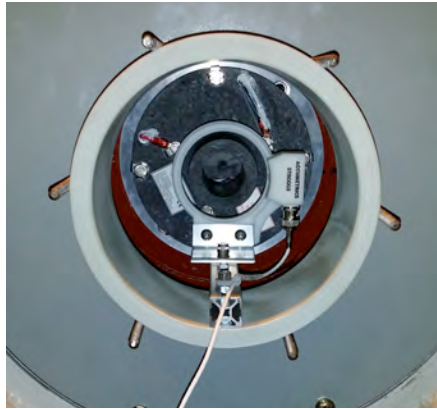
Please contact the factory for kits.

Figures 3 and 4 show typical installations on 7A6 and 9A4 generators, respectively.

Accumetrics will support electric utility upgrades on these units, including a review of requirements, supply of the EFREM unit and installation kits.



**Figure 3 – Installations of EFREM on GE 7A6 units**



**Figure 4 – Installations of EFREM on GE 9A4 units**

On other types of generators, where Accumetrics does not have prepared installation kits, a site visit by an Accumetrics Field Engineer is generally recommended to make necessary inspections and measurements. This usually only takes a few hours and is typically done during an outage, when full access to the machine is available. Accumetrics will then make an offer to the utility for a customized mounting kit and any design changes that are necessary to install the EFREM on the intended generator. Although these customized installations take a little more time, they are still cost effective means of upgrading generators to a modern field ground detector.



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