Advancements in Integrity Testing

An Overview of Recent Improvements in Earthing System Integrity Testing.

Until recently, condition monitoring of power system earthing systems required testing that was costly and inefficient, in part because it relied on non-ideal instruments designed for different, or generic purposes. Recent developments have resulted in the availability of test instruments specifically designed for earthing systems, making integrity testing more effective and affordable.

Introduction

Earthing systems are an important element of high voltage power systems. The condition of earthing systems is crucial to the safe and reliable operation of the power system, especially during fault events, where the earthing system is one of the primary measures in managing the risk to staff, plant and the general public.

Perhaps surprisingly, the difference between an effective, and ineffective earthing system could be as small as a few mΩ of additional resistance in a key connection. For example, a 1kA fault current level through a 10mΩ joint results in 10kW of heat dissipation in the joint, which could almost immediately destroy the connection.

Without an effective earthing system management plan and ongoing maintenance, deterioration or latent failures (e.g. from poor installation practices, corrosion, mechanical damage from vehicles/earthworks, or electromagnetic forces and thermal cycling during faults) might remain undiagnosed until the earthing system fails to perform adequately during a fault event.

Fortunately, recent technological improvements have led to advanced DC continuity meters that make regular integrity testing sufficiently accurate and cost-effective to allow pre-emptive detection and repair of earthing system failures.

Integrity Testing Challenges

One significant complication in Earthing Integrity Testing is the fact that the majority of the earthing system is buried, making inspection difficult, and as previously discussed differences in the order of a few mΩ can be quite significant, so a precision instrument is required for effective testing. Further, it is often not feasible to isolate the power system during the test, and so the high levels of electrical noise that are always present in a live substation can make precision measurement extremely difficult.

Effective instruments for integrity testing need a combination of high noise immunity, and appropriate measurement range and accuracy. However, there are some additional requirements for an instrument to be a truly cost-effective tool. It must be robust and reliable to deal with the realities of site-work (as opposed to a 'lab' setting); it should be

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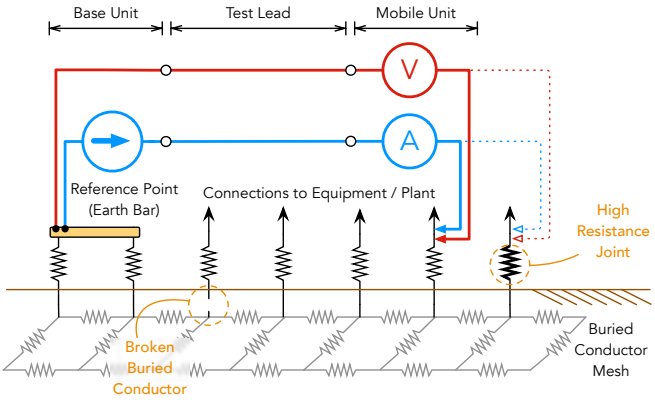
easily portable, with a large 'test range' to cover an entire installation; and the battery should last for multiple tests to maximise testing time while in the field. Until recently, the combination of these features in a single instrument was unachievable.

Traditionally, integrity testing may have been performed using a micro-ohmmeter to measure the resistance across joints in the earthing system. These instruments are specifically designed to accurately measure very small resistances, and typically use the four-wire resistance measurement technique (see picture below) pioneered by Kelvin over 150 years ago, to eliminate the impact of test lead resistance on the measurement, which can be significant when the target resistance is in the mΩ range.



Earthing System Integrity Testing with the 4-wire Test Method as implemented in Safearth's new CS3 Continuity Meter

The majority of the commercially available instruments used to perform this type of testing on-site are not specifically aimed at earthing integrity testing, but testing a single joint or connection, such as determining the resistance across circuit breaker contacts, and as such, they suffer a range of limitations.

They are often a single self-contained unit with both signal generation and measurement capabilities, which in the context of earthing system integrity testing, limits the extent of the system that can be assessed before the 'reference point' must be moved. They are not typically designed for testing operational earthing systems, and might not have the required noise immunity. In some cases, they require a large test current (e.g. 10-100A) for accurate measurement, and the additional energy requirements can mean shorter testing time (or battery life), or higher weight and larger test leads.

Recent Advancements In Integrity Assessment

The advancement of technology has made it feasible to produce instruments designed specifically to meet the requirements of earthing system integrity testing, with the right combination of high precision electronics, and signal processing capability to overcome the challenges of accurately measuring the resistance between earthing system elements in a live substation.

These purpose-built instruments extend on the generic micro-ohmmeters, by using the same 4 wire measurement technique, but separating the signal generation, and measurement portions of the device so a 'base unit' with the power electronics may be located at a reference location such as a transformer earth bar, and measurements may be taken across the entire installation with a mobile 'handheld unit'.

The best instruments use a 'dual polarity' measurement technique that can overcome both AC and DC noise. This technique is common in the 'integrated style' micro-ohmmeter devices, but is less common in the 'split system' style devices due to the difficulty of coordinating the signal generation and measurement functions.

Earthing-system specific instruments can also be tailored to the expected resistances

between points of a large substation earthing system (e.g. 1 – 100mΩ) by using relatively small test currents (e.g. 1A) and precision measurement electronics to achieve the required measurement resolution to distinguish between a 'good bond' and a bad one.

By using a smaller test current, the maximum distance between the reference point, and the measurement location can be increased, with some instruments capable of accurate measurement over more than 200m of test lead.

Of course, a substation yard is not the most forgiving environment for a test lead, and one potential weakness of these instruments is that damaged test leads may manifest as incorrect measurements (for example a broken voltage lead may appear as a very low resistance measurement). Safearth's CS3 employs a unique method to overcome this issue using the patent-pending LeadSURE® technology, which verifies the test leads are intact before, and during, every measurement and displays an error message if damaged leads are identified.

Summary

Regular earthing system integrity testing forms a vital part of a responsible earthing system management plan, and recent advances have produced instruments that make effective, regular integrity testing more achievable.

The best instruments for earthing integrity testing provide a combination of high noise immunity, measurement range and accuracy, portability, useable test lead length, robustness and reliability, and battery life to enable measurements across an entire installation to be made while the power system is live, with results accurate enough to identify poor or deteriorating connections, even though the difference between 'good' and 'bad' may only be a few mΩ.

With appropriate training and familiarity, these instruments can be used to perform a rigorous and highly effective integrity test upon an in-service major substation in just a few hours. This means asset owners now have a cost-effective means to regularly test the integrity of their power system earthing installations.

CS3 Site Continuity Meter

The most effective device for earthing system integrity testing. Using patent-pending advanced technology, the CS3 allows you to quickly and reliably prove all your connections and find poorly made or deteriorating joints before they fail.

- 4 times faster than traditional methods
- Accurate in live substations
- Robust and reliable
- Switched polarity DC for high noise immunity Test leads up to 200m
- LeadSure® damaged lead detection

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