

Earth Tester FT6041

Akihiko Mitsugi

Back End Engineering Section

Abstract—The Earth Tester FT6041 is a multifunctional instrument for measuring grounding resistance. It features a grounding resistance measurement function based on the four-electrode method required for grounding design, as well as an MEC function for accurately measuring grounding resistance without detaching the ground wires. This paper provides an overview of the product, introduces its functions and features, and describes examples of performing measurement.

I. INTRODUCTION

Over the world, renewable energy power generation facilities are being built to help achieve a decarbonized society. Facilities such as data centers and medical institutions also need to protect devices from noise caused by lightning strikes, in order to prevent device failure and outages. Grounding design is important for the safe and stable operation of such facilities.

Periodic inspection is also required for maintaining grounding resistance below the specified value. In order to accurately measure grounding resistance, it is necessary to detach the ground wires from the equipment. However, ground wires cannot be so easily detached, as there is danger of electrocution.

The easy-to-use Earth Tester FT6041 was developed to solve these problems by using clamps for grounding resistance measurement. An overview of the instrument is illustrated in Fig. 1.

II. OVERVIEW

The FT6041 is a multifunctional instrument for measuring grounding resistance. It features various functions, such as grounding resistance measurement based on the four-electrode method required for grounding design, as well as MEC for measuring a single grounding point in a multiple grounding environment. "MEC" is a term unique to Hioki, which stands for "Measuring Earth resistance using a Clamp." In particular, the measurement range of the instrument has been improved to 300 k Ω , 100 times that of the predecessor product, which enables the instrument to be used in all types of environments, with an allowed ground potential of 30 V to enable measurement even in noisy environments.



Fig. 1. Exterior of the FT6041.

III. FUNCTIONS AND FEATURES

A. Main Specifications

- Measurable range of grounding resistance: 0.000 Ω to 300.0 k Ω
- Measurable frequencies: 94 Hz, 105 Hz, 111 Hz, 128 Hz, and 55 Hz
- Allowed ground potential: 30 V rms
- Allowed grounding resistance of auxiliary grounding electrode: Maximum 100 k Ω

B. Instrument Enclosure

The instrument features a dustproof and waterproof IP67 enclosure, as grounding resistance is often measured outdoors, in particular when measuring resistance for grounding design, where the instrument is placed directly on the ground.

C. Clamp Sensor

The clamp sensor has been designed to have a large caliber to enable measurement with a 75 mm thick grounding bar and a jaw with a small cross-sectional area to enable use in locations with crowded wiring and allow the jaw to easily engage the grounding wire.

D. Grounding Net Module

In paved urban areas, it is not possible to drive the auxiliary grounding rod required for measuring grounding resistance into the ground. The Earth Nets Module L9846 can be combined with the Measurement Cable L9845 in

¹ Development Planning Department

order to solve this problem. It allows the measurement cord to be extended so the module can be placed on concrete, which enables the grounding resistance to be measured simply by pouring water over it.

IV. PRINCIPLES

A. Grounding Resistance Measurement

Grounding resistance measurement involves applying a sine wave signal to the target, measuring the current and voltage signals, and performing a series of calculations.

In addition to the grounding resistance, which is a pure resistance component, the measurement target includes an inductance component and a capacitance component. Because the inductance component and capacitance component are not required for measurement, they are removed by measuring a voltage signal with the same phase as the current signal. The MEC function and grounding resistance measurement using two clamps have the same basic principle of measurement.

B. MEC Function

The MEC function adopts the measurement method described in BS7430, a British standard regarding the protective grounding of electrical equipment. As with grounding resistance measurement, the MEC function applies a sine wave signal to the target in order to perform measurement, but it performs calculation by detecting the current signal with a clamp sensor.

C. Two-Clamp Measurement

Two-clamp measurement enables grounding resistance to be measured in a multiple grounding environment. If the target grounding resistance to measure is given by RX and the other grounding resistance values are given by R1 to Rn, the resistance value measured is derived as expressed by (1) below.

$$R_m = R_x + \frac{1}{\sum_{i=1}^n \frac{1}{R_i}} \dots\dots\dots (1)$$

If n is sufficiently large and each Ri is a small value, (2) below can be used, and this enables the RX value to be measured because the second item of (1) can be ignored.

$$R_x \gg \frac{1}{\sum_{i=1}^n \frac{1}{R_i}} \dots\dots\dots (2)$$

With the FT6041, a sine wave signal is applied to the measurement target from the injection clamp sensor, and the grounding resistance is calculated based on the applied voltage and the current signal obtained from the detection clamp sensor.

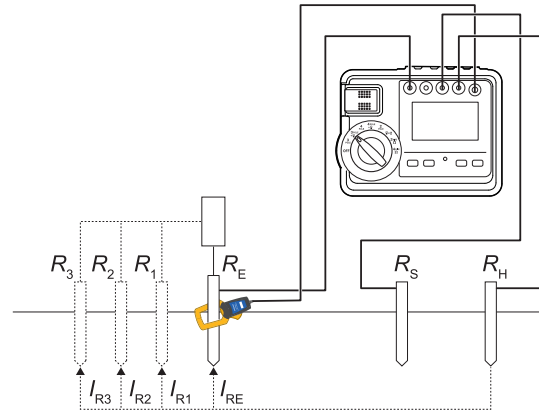


Fig. 2. Connection Diagram of the MEC Function.

D. Low Resistance Measurement

Low resistance measurement involves the same basic principles as grounding resistance measurement, but a direct current signal is applied to the target instead of a sine wave signal, and the resistance value is calculated based on the current signal and voltage signal.

V. ARCHITECTURE

A. Hardware

1) Instrument

- Four-Electrode Grounding Resistance Measurement

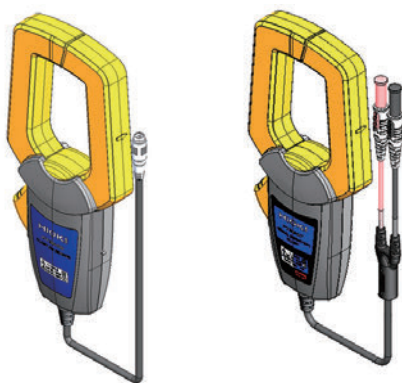
With four-electrode grounding resistance measurement, the battery voltage is boosted to generate output voltage. The output voltage is then applied between the H terminal and E terminal, and the resistance value is calculated by measuring the current flowing to the E terminal and the voltage between the S terminal and the ES terminal.

The instrument also uses synchronous detection to extract the measurement frequency and thereby improve noise resistance. Furthermore, by enabling the selection of five different measurement frequencies, the instrument can perform stable measurement that is less susceptible to noise.

- MEC Function

If the operator attempts to measure a single grounding electrode in a multiple grounding environment with the three-electrode method, the resistance value will be measured in parallel because the measurement current will also flow through the other grounding electrodes. To measure a single grounding electrode, it is necessary to detach the other grounding electrodes, but this takes a long time. It is also not possible to detach the grounding electrodes in facilities such as data centers and medical institutions, where the power cannot be shut off.

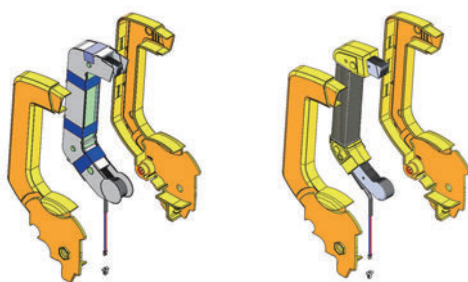
The instrument solves this problem by using a clamp sensor together with regular grounding resistance measurement in order to measure a single grounding



CT9848

FT9847

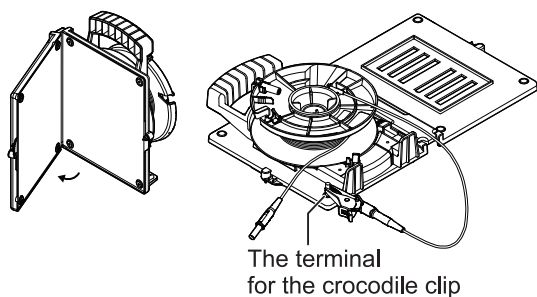
Fig. 3. Exterior of Sensor.



CT9848

FT9847

Fig. 4. Exploded View of Sensor.



The terminal for the crocodile clip

Fig. 5. Exterior of the L9846.

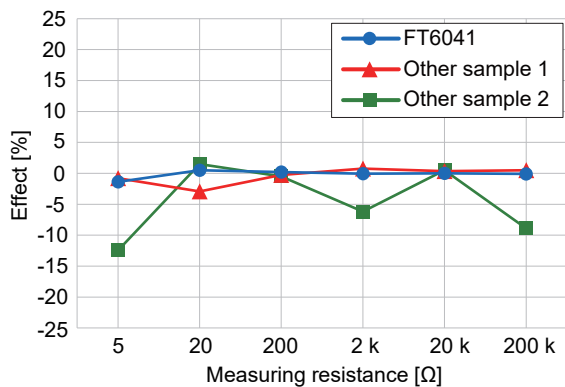


Fig. 6. Effects of Ground Potential.

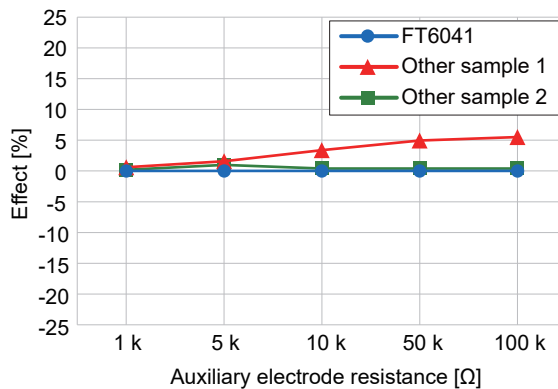


Fig. 7. Effect of Auxiliary Grounding Electrode Resistance (R_H).

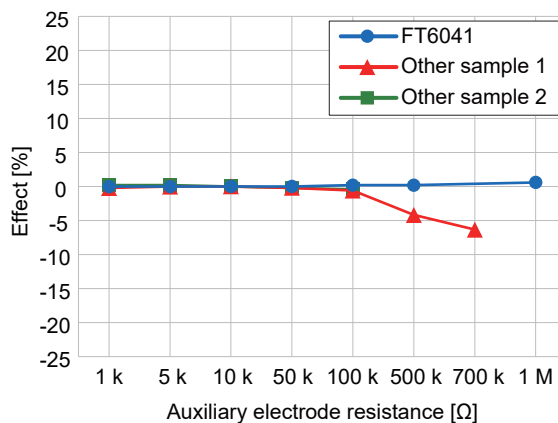


Fig. 8. Effect of Auxiliary Grounding Electrode Resistance (R_S).

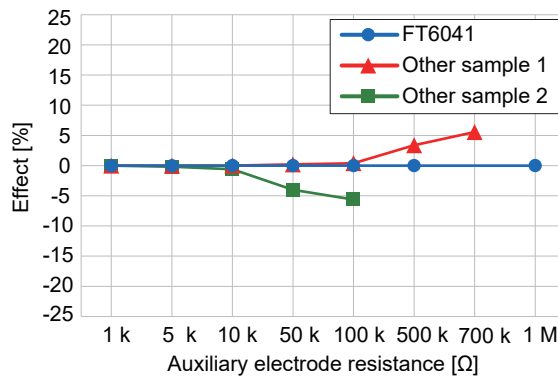


Fig. 9. Effect of Auxiliary Grounding Electrode Resistance (R_{ES}).

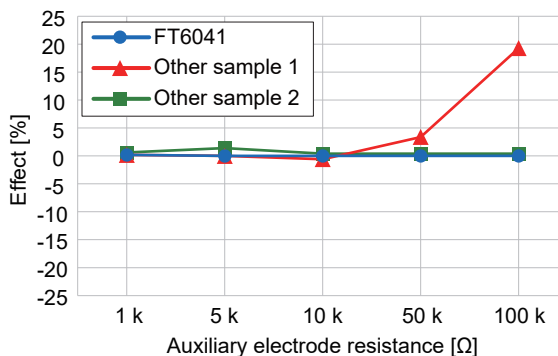


Fig. 10. Effect of Auxiliary Grounding Electrode Resistance (R_E).

Earth Tester FT6041

electrode. A connection diagram is illustrated in Fig. 2. If the measurement voltage and clamp sensor measurement current are given as V and IR_E , respectively, the resistance of a single electrode in a multiple grounding environment (R_E) is derived as expressed by (3) below.

$$R_E = V/IR_E \dots \dots \dots (3)$$

- Two-Clamp Measurement

Two-clamp measurement is a function that uses the injection clamp sensor and detection clamp sensor to perform the simple measurement of one grounding electrode in a multiple grounding environment. By applying voltage to the injection clamp sensor, voltage corresponding to the winding ratio of the primary and secondary sides of the clamp sensor is applied to the target for measurement. The resistance value is then calculated by using the detection clamp sensor to measure the current corresponding to the resistance value.

- Low Resistance Measurement (Conductivity Check)

This function applies battery voltage to the target for measurement, then measures the voltage and current in order to calculate the resistance value. The constant current measurement circuit detects the current using an I-V converter and controls the measurement current to ensure that a constant current of 200 mA is maintained. The instrument also features a safety mechanism to protect the measurement circuit by blowing a fuse if the connection cord is accidentally connected to a live part.

B. Software

1) Automatic measurement

The automatic measurement function enables the operator to simply press the measurement key once to automatically measure the ground potential, auxiliary grounding resistance, and grounding resistance.

When measurement starts, the function automatically checks whether the ground potential is within the allowed range. The grounding resistance of each auxiliary grounding electrode is then measured to automatically check whether the auxiliary grounding resistance value is within the allowed range. If the auxiliary grounding resistance value exceeds the allowed range, measurement stops and the instrument indicates which auxiliary grounding electrode exceeded the allowed range. This enables the operator to easily check the auxiliary grounding electrode that exceeded the allowed range. If the ground potential and auxiliary grounding resistance are within the allowed range, the grounding resistance is automatically measured. The displayed range is also automatically selected according to the level of grounding resistance.

2) Terminal guide display area

When the rotary switch is set to the function to measure, the terminals to use are displayed on the top of the screen.

This helps prevent mistakes because the operator can follow the guide when connecting the cables. When measurement starts, the instrument automatically performs a connection check, and if any unconnected terminals are found, those terminals flash in the guide display area to inform the operator.

3) Comparator function

When measurement is complete, an alarm sound and LED inform the operator if the measured resistance value exceeds the threshold set in advance. The threshold can be set to a value of 1 Ω to 500 Ω . This enables the operator to not only check the measured value but also identify if the value is within the normal range, which helps improve the efficiency of measurement work.

4) Wireless communication

By attaching the optional Wireless Adapter Z3210 to the FT6041, the instrument can perform **Bluetooth**[®] communication to use GENNECT Cross, which is application software for a mobile terminal. GENNECT Cross enables the operator to easily create reports, view and save measured values, and transfer measured values to a smartphone.

GENNECT Cross can also be used to upgrade the firmware of the instrument. This means that with future functional improvements, firmware upgrades can be performed on-site, without the need to return the instrument to Hioki.

C. Design

1) Instrument

The design concept of the instrument is a user-friendly grounding resistance meter that provides new styles of measurement. In order to provide intuitive operations, the instrument adopts a rotary switch and a MEASURE key.

The rotary switch enables the operator to immediately access the intended function from among the various measurement functions that the instrument provides. The OFF position is horizontal (in the 9 o'clock direction), and the various functions are, in clockwise order: 3 pole \rightarrow 4 pole \rightarrow 2 pole \rightarrow 2 clamp \rightarrow low resistance measurement. This order was determined based on the likely frequency of use of each function.

The MEASURE key enables the operator to easily perform single measurement by pressing the right side of the key, or continuous measurement by pulling the key up. The instrument has a live wire warning indicator that lights red when performing grounding resistance measurement or low resistance measurement.

The instrument is covered in a protector (in Product Blue, the Hioki corporate color) that provides an easy-to-grip surface. The protector also reduces impacts to the

instrument in the event of a fall and enables it to be securely installed on the ground.

The exterior is comprised of an upper case, lower case, and battery cover, and each part is appropriately sealed to achieve a dustproof and waterproof enclosure.

2) Clamp sensors

The external appearances of the Clamp on Sensor CT9848 and Signal Induction Clamp FT9847 are illustrated in Fig. 3.

These two clamp sensors were developed to achieve two-clamp measurement, with the FT9847 used for signal injection and the CT9848 used for signal detection.

The FT9847 and CT9848 share most of the same parts, and have the same external appearance except for the output cable.

To enable the two sensors to be visually identified as Hioki products, their handles and instruction plates share a similar design with existing current sensors.

The FT9847 injection sensor is designed to prevent magnetic saturation caused by the injection signal.

The CT9848 detection sensor adopts a core material suitable for detecting microcurrents, as the detection of microcurrents is required. When performing two-clamp measurement, a constant signal is injected to the measurement line from the FT9847 and detected by the CT9848, so the two sensors have been designed to prevent the injection signal from being directly detected (Fig. 4).

3) Grounding net module

The external appearance of the Earth Nets Module L9846 is illustrated in Fig. 5. The module is integrated with a winder for improved convenience. The Earth Nets Module L9846 also has a sponge, which retains water to provide more stable measurement.

VI. EXAMPLES OF MEASUREMENT

A. Effects of Ground Potential

Grounding resistance measurement is sometimes performed at power generation systems. In order to ensure accurate measurement values in such noisy environments, the FT6041 allows a maximum ground potential of 30 V. Fig. 6 illustrates a graph indicating the effect of grounding resistance measurement when a ground potential of 30 V AC at 60 Hz is applied. This demonstrates how the effect of grounding resistance is lower than in competitor products.

B. Effect of Auxiliary Grounding Electrode Resistance

Grounding resistance measurement requires auxiliary grounding rods to be inserted into the ground. Therefore, measurement is performed with resistance at each auxiliary grounding electrode. In particular, the four-electrode

method is used for grounding design, so it is desirable for auxiliary grounding electrodes to have a wide range of allowed resistance values but a low effect of resistance. Fig. 7 through 10 illustrate graphs indicating the effect of resistance for each auxiliary grounding electrode. This demonstrates how the range of resistance values allowed is wider and the effect of resistance is lower than in competitor products.

VII. CONCLUSION

The FT6041 is a grounding resistance meter with a wide range of measurement that is also resistant to noisy environments. It features an MEC function and two-clamp measurement function to enable grounding resistance measurement in locations that were difficult to check in the past. The addition of the L9846 also makes it easy to perform grounding resistance measurement in locations where auxiliary grounding rods cannot be inserted into the ground.

Over the world, renewable energy power generation facilities are being built to help achieve a decarbonized society, and grounding design is important for the safe and stable operation of such facilities. It is hoped that the FT6041 will find use among a broad customer base in the fields of grounding design and inspection and maintenance work.

Manabu Senda², Akihiro Nagai², Takeaki Mijazawa², Koji Morishita², Nao Wada³, Takahiro Ogawara⁴, Hiroki Nagasawa⁵

TRADEMARKS

- The Bluetooth[®] word mark and logos are registered trademarks owned by Bluetooth SIG, Inc. and any use of such marks by Hioki E.E. Corporation is under license. Other trademarks and trade names are those of their respective owners.

² Development Planning Department

³ Sensing & Storage Unit

⁴ Source & Measure Unit

⁵ Manufacturing Department

