

# 300 AND 310 SERIES LEAKAGE CLAMP-ON TESTERS

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*To meet the great demand of the maintenance and service field, we have developed the 300 and 310 Series Clamp-on Testers for live-line current. The 300 and 310 series consist of miniature- and medium-sized clamp-on testers. There are six models including AC and AC/DC types that are mostly leakage clamp-on testers. This report introduces the leakage clamp-on testers.*

*Four models of leakage clamp-on testers (including miniature- and medium-sized models) were developed to meet the wide variety of user's applications. The miniature-sized models are of single function type. The 300-30 handles current ranges of 30/300 mA and 30/300 A. The 300-31 handles current ranges of 3/30 mA and 30/60 A. The medium-sized models are of multi-function type that handles five current ranges between 30 mA and 300 A (310-30 RMS value model and 310-31 average value model). Improvement in the basic performance, operability, and durability were sought for both series of testers. In particular, the basic performance of the 300-31 was improved drastically from the conventional CL Series, to allow it to accurately measure a leakage current of 1 mA which conforms to the Technical Standards for Electric Facilities. This improvement is due to the adoption of a new circuit technique that electrically cancels the influence received from external magnetic fields.*

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## INTRODUCTION

There has been increasing demand for measuring insulation on live lines and thus for an applicable smart leakage clamp-on tester. This demand results from the necessity to observe Chapter 1, Section 3, Article 14 of the Technical Standards for Electric Facilities enforced on June 1, 1997. The article defines that "When measuring insulation is difficult because an applied voltage on the cable way is extremely low ... the leakage current must be kept to 1 mA or lower." In measuring insulation of low-voltage cable ways, in particular commercial 100-V cable ways for domestic use, the conventional means where an insulation resistance tester is used after turning off the power, is giving way to live-line measurement with a leakage clamp-on tester. This

trend has lead to demand for a leakage clamp-on tester that can measure the leakage current more accurately.

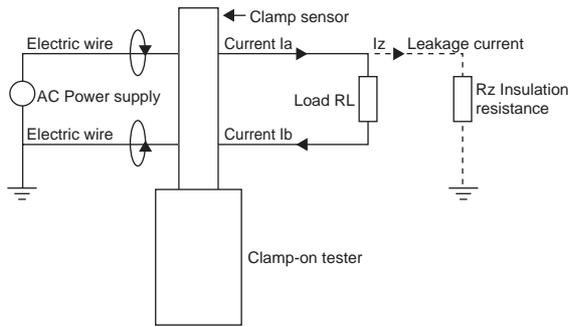
To meet demand, Yokogawa M&C has developed clamp-on



Figure 1 300 and 310 series leakage clamp-on Testers

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**Figure 2** Measurement Principles

testers with main units of two sizes: miniature-sized 300 series and medium-sized 310 series (see figure 1). Their main specifications and functions are as follows:

- Basic accuracy:  $\pm 1\%$
- Maximum thickness of measured cable:  $\varnothing 40$  mm
- Can measure from a small current to a load current with a variety of ranges :
  - 30/30 mA, 30/300 A (model 300-30)
  - 3/30 mA, 30/60 A (model 300-31)
  - 30/300 mA, 3/30/300 A (310 series)
- Influence of external magnetic field (against 100 A of adjacent electric cable):
  - 0.5 mA typical (model 300-31)
  - 5 mA or less (310 series)
  - 10 mA or less (model 300-30)
- Equipped with noise filter (model 300-31 and 310 series)
- RMS value detection, frequency measurement, min./max./average value recording, voltage measurement, and recorder output. Optional AC adapter (310 series).
- Auto power-off
- Withstand voltage: 5550 V (310 series), 3700 V (300 series)
- Conforms to EN 61010 safety standard: CAT III 600 V (310 series), CAT III 300 V (300 series)
- Conforms to EN 61010 EMC standard

## MEASUREMENT PRINCIPLES OF LEAKAGE CLAMP

Figure 2 illustrates the measurement principle of a leakage clamp. It is a circuit where load  $R_L$  is connected to an AC power supply and two electric wires are clamped. If insulation resistance  $R_z$  is high enough to prevent leakage current  $I_z$ , current  $I_a$  and  $I_b$  flowing through the two wires have the same value of  $180^\circ$  and are out of phase with each other. Thus magnetic fields formed by the currents on two wires are zero ( $I_a - I_b = 0$ ) as they cancel each other out, resulting in no leakage current. On the other hand, if insulation resistance  $R_z$  is low and there is some leakage current  $I_z$ , the magnetic field amounts to  $I_z$  [ $I_a (I_b = I_a - (I_a - I_z) = I_z$ ] and the leakage clamp measures a current of  $I_z$ . Consequently, the leakage clamp can detect a leakage current when the insulation resistance is low.

## DESIGN CONCEPTS AND BASIC CONFIGURATION

Our design concepts for the 300 and 310 series were basically operability and robustness of the clamp sensor. In particular, we aimed at minimal influence of the external magnetic field by adjacent electric wires, downsizing and lightweighting, and greater durability. The following introduces the main configuration.

### (1) Clamp Sensor

The clamp sensor for detecting current has a mechanically strong structure as it only opens from one side. The long opening lever facilitates opening and closing. It is designed so as to conform to safety standards by, for example, providing a barrier between the sensor and main unit.

### (2) Key Switches

All the operation switches are mini, reliable embossed key switches that give better click-touch action. Use of membrane switches allows operation with one hand for improved workability.

### (3) Range Switch

The conventional model used mechanical rotary switches or slide switches to change ranges. For the 300 and 310 series, we selected a low-resistance power MOSFET to incorporate full autoranging for increased operability and reliability.

### (4) Components Miniaturization

We adopted surface-mount components for electric circuits, one-fifth the size of the conventional model. Surface mounting of printed circuit boards has greatly contributed to increased density of components and downsizing.

### (5) Longer Battery Life

With the 300 series, we replaced the two conventional alkaline button batteries with an advanced coin-shaped lithium battery, reducing the number of batteries and tripling battery life of the 300-30 compared to the conventional CL613.

### (6) Increased Durability

In response to user's requests for improved durability for the 300-31, we checked opening and closing of the clamp sensor 70,000 times, which is a substantial increase from the norm of 10,000. We then successfully performed visual and functional inspections.

## CONFIGURATION

### Clamp Sensor

To accurately measure a leakage current of 1 mA using the 300-31, we had to reduce the influence of external magnetic fields from adjacent electric wires to less than one-fifth that of the conventional model. Thus we thoroughly reviewed configuration of the conventional model to optimize it, as well as devised a new circuit for electric correction to stabilize product performance (see figure 3).

In figure 3, when measuring the current flowing through wire F within the clamp sensor, the current forms a magnetic field that

causes currents with the same phase to flow through coils C1, C2, C3, and C4. The sum of four current outputs is measured as the output from an adder. Due to the influence of a magnetic field formed by current flowing through measured wire G outside the clamp sensor, the following relationship exists: currents flowing through coil C1 and C3 have the same phase, coil C2 and C4 the same phase, currents flowing through coil C1 and C2 have the opposite phase, and coil C3 and C4 the opposite phase. This means the output from the adder is theoretically zero. In fact, each output amplitude generally differs as the clamp cores and coils are asymmetrical. To correct each unbalanced output, we used trimmer potentiometers R1, R2, and R4 to eliminate the influence of external magnetic fields.

**Electric Circuit**

Figure 4 is a block diagram of the 310-30. In figure 4, the output from clamp sensor is converted to a voltage by a shunt resistor, and to a DC signal through an amplifier and an AC/DC converter. There is a filter circuit between the amplifier and the AC/DC converter, use of which can be switched. The filter removes unnecessary frequencies other than those of the power supply. The DC signal from the AC/DC converter is then converted to a digital signal with a full-scale count of 3200 and displayed on the LCD after various computations by CPU. There is also an isolated output for a recorder and an isolated input from an AC adapter.

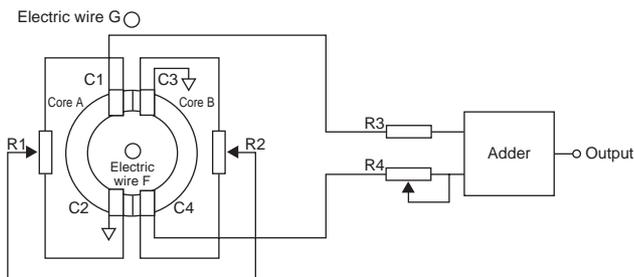
**STRUCTURE**

For the 300 and 310 series, we have newly designed two types of main unit casing and four types of clamp sensor. Our first priority was usability; we pursued operability of the clamp sensor, the placement of switches, and readable display. We designed the 300 series a size larger than the conventional CL series to enhance the robustness and operability. On the contrary, we made the 310 series smaller than the conventional 2343 series with the emphasis on portability. As for the styling, we adopted a corporate color for the clamp sensor to separate it from the main unit, as a dangerous part that might cause an electrical shock.

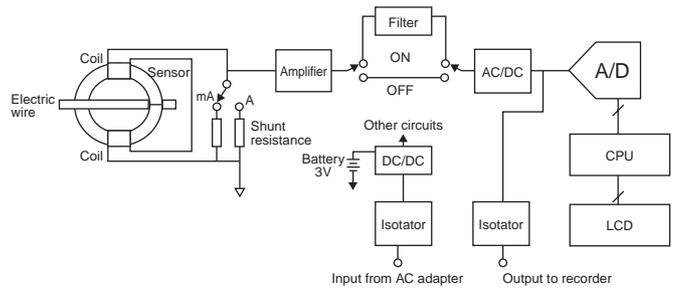
**CHARACTERISTICS (MODEL 300-31)**

**Influence of External Magnetic Field**

There are the following two means of measuring the degree of



**Figure 3** Basic Configuration



**Figure 4** Block diagram

influence from external magnetic fields outside the clamp sensor:

- Placing the clamp sensor in the center of a magnetic field of 400 A/m and measuring the influence (with a general measuring instrument)
- Measuring the influence of a magnetic field formed by a current flowing through an adjacent electric wire outside the clamp sensor (with the clamp tester, see figure 5)

**Residual Current**

The clamp sensor usually measures a leakage current by clamping two wires for a single-phase power and three wires for a three-phase power to detect the total of the small amount of currents. If there is no leakage current, it is theoretically zero. However, the sensor sensitivity varies depending on the position of wires against the clamp sensor. For this reason, we evaluated the performance of the clamp sensor by running two currents with the same amplitude and the opposite phases through two wires and measuring the residual current (see figure 6).

**Influence of Conductor Position**

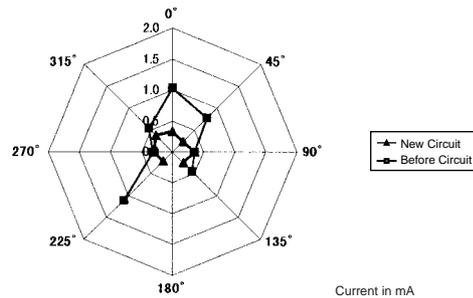
This means a current deviation when moving the wire along the inner circumference of the clamp, from the standard current value measured at the center of the clamp sensor. The influence is  $\pm 0.1\%$  or less at 10 A.

**Linearity Characteristics**

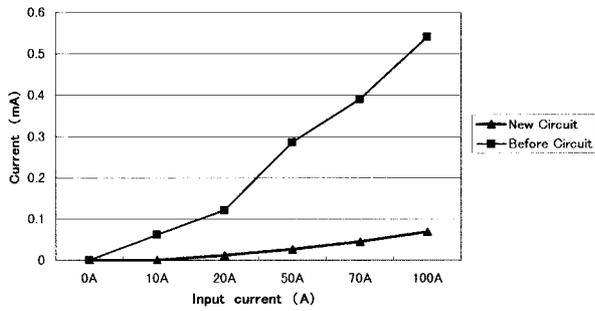
We measured the errors in each current value (see figure 7).

**Frequency Characteristics**

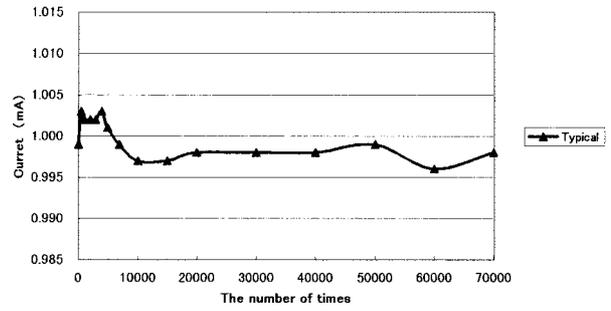
We measured the levels for each frequency, and for 100 Hz or more, filtering circuit characteristics (see figure 8).



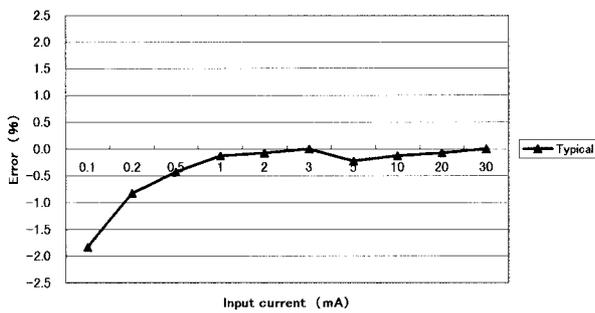
**Figure 5** Effects of external Field (Adjoining electric wire currents 100A)



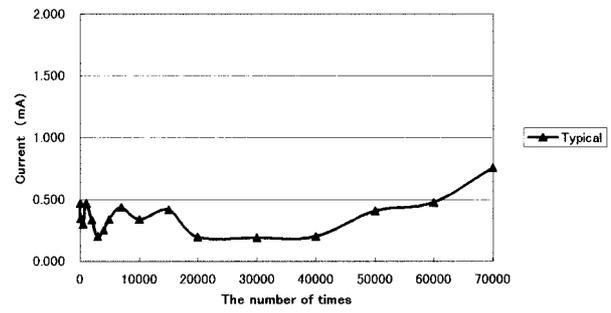
**Figure 6** Residual current



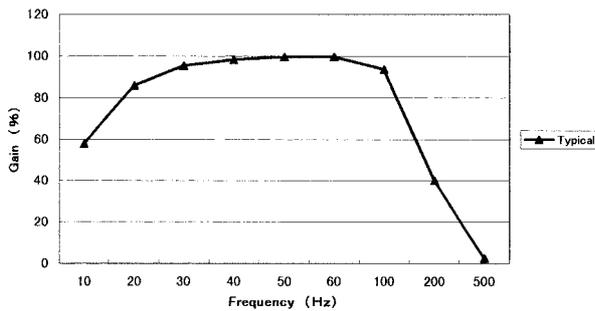
**Figure 9** Clamp sensor opening and closing test (Accuracy)



**Figure 7** Linearity curve



**Figure 10** Clamp sensor opening and closing test (Influence of external magnetic fields)



**Figure 8** Frequency response

### Clamp Sensor Opening and Closing Tests

We performed opening and closing tests of the clamp sensor to measure the characteristic changes with regard to the accuracy and influence of external magnetic fields (see figures 9 and 10).

### CONCLUSION

In this report we have introduced the aim of development, benefits, features, configuration, and characteristics of the newly developed 300 and 310 series clamp-on testers. Their performances are satisfactory enough to meet the targeted values. In particular, the miniature-sized 300 series has won sufficient recognition for its performance and durability to be adopted by the Electric Maintenance Associations throughout Japan. We expect the 300 and 310 series will be advantageous to more users in a wider range of applications. ♦