Development of Standard Device for Resistive Current Tester for Zinc Oxide Surge Arrester

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Abstract

The topic research, standard device for resistive current tester for zinc oxide surge arrester, can be used for calibration for resistive current tester for zinc oxide surge arrester. The equip functions involve total current, resistive component of current, capacitance component of current, active power, reference voltage, phase angle, harmonic component of current. The topic introduces the working principle and the core technology of the standard device, among them; the most innovative points are the “smoothing signal generation” and “traceability design”.

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Keyword: Standard device for resistive current tester for zinc oxide surge arrester; Calibration; Verification; Standard device

1. Introduction

In preventive test and acceptance test of electrical power equipment, the zinc oxide surge arrester resistive current tester (ZOSARCT) is often used for measuring the alter parameters [1] of zinc oxide surge arrester. Main test subject involve: total current, resistive component of current, capacitance component of current etc. At present, the type of the ZOSARCT that used in electric power system is multifarious, its performance and quality are varied. Improper choosing on ZOSARCT will cause misjudgment on the running status of the zinc oxide surge arrester, and resulting in unnecessary losses. So it is necessary to be calibrated periodically on ZOSARCT in order to achieve the purpose for quality control. The electric power industry standard DL/T 987-2005 “General technical conditions of resistance
The current tester for zinc oxide surge arrester [2] is issued by National Development and Reform Committee (NDRC) in order to make progress on normalization and standardization for ZOSARCT from the different types and manufacturers, and shows the relevant requirement to the performance about it.

In traditional methods on calibrating the ZOSARCT by the most of the relevant domestic quality technology supervising departments is used by the resistance-capacitance network [2]. The deficiency of the traditional calibration methods includes: the standard resistor and capacitor in the test circuit has great influence on temperature and humidity; the internal resistance of the current meter has great influence on the measuring result; the operating procedure is complex and cumbersome, and the configuration on amplitude and phase angle are intricate. And it is difficult to generate the harmonic voltage and current. In the subject, the calibration parameters could configured conveniently to the standard device of ZOSART. Its performance is stable, high accuracy, convenient to trace to the standard, easy to operate. It can be used to calibrate them mainstream ZOSARCT legitimately and efficiently.

2. The main function and parameters of the standard device

The standard device is designed by standard resource mode. The signal of the reference voltage and the total current are supplied by the standard device to the object through the total current, resistive component current, capacitive component current, active power, reference voltage, phase angle, any harmonic component current and so on, in order to calibrate the object for all the functions by three phase; when the reference voltage and the total current are supplied by the standard device, any harmonic component current can be output synchronously by the standard device. In this way, when the standard device is calibrated by the supervising authority, all harmonic components current can be output under the background total current, it can also improve traceability of the standard device.

The main parameters of the standard device in are:
- Total current: output range from 0.1mA to 10mA, Mpc:(0.2%reading+2µA)
- Reference voltage: output range from 20V to 100V, Mpc:±0.2%reading
- Phase angle: output range from 0 to 90°, Mpc:±0.1°
- Harmonic component current: output range from 0.1mA to 10mA, Mpc:(0.2%reading+2µA)

3. The usage and principle diagram of the standard device

Figure 1 shows the working connection diagram (figure 1 is only for single phase). The terminal of the reference voltage and the terminal of the total current are connected together directly. Figure 2 shows the fundamental structure diagram. The standard device includes two parts: the host machine and the slave computer. All the parameter can be configured by the operator conveniently in the interface of host machine; the slave computer is the executive agency of the standard device. All the command parameters that set by communication interface, and turn into the reference voltage and total current. The
fundamental of the slave computer is: the sinusoidal signal unit that each DDS (Direct Digital Synthesizer) module generate amplitude, frequency, phase adjusting individually under the MCU’s controlling, it can drive the precision constant current source module and the precision voltage adapting module, thus the independent current component signal and voltage driving signal are generated, all harmonic component current are combined linearly in parallel, and final the total current signal that include all harmonic component current are output, the reference voltage signal is output by the driving voltage that driving the precision boost transformer. The total current and the reference voltage are isolated mutually.

4. The introduction of core technology

4.1. The productions of the sinusoidal signal unit

As shown in figure2, the standard device has some sinusoidal signal units, all of the sinusoidal signal unit which is designed will meet demand that amplitude, frequency, phase are stable and adjustable, the sinusoids must be very smooth without stair-step essentially. In the project, the first, the DDS chip is selected for generating all the basic differential the sinusoids signals in order to get the sinusoidal signal unit that amplitude, frequency, phase are stable and adjustable. DDS is not used in the electrical test widely, the Main Features of the DDS is based on the theory of direct digital synthesizer, and it provide the solution for the sinusoids signals that the generated about stable and adjustable amplitude, frequency, phase. The chip which is used is AD 9951 by Analog Inc in the project. high quality differential sinusoids voltage signals can be output by AD9951, the resolution of the amplitude is 14bit, the degree adjusting for phase is 14bit, the degree adjusting for frequency is 14bit, the AD9951 controlling signal level is compatible with the MCU C8051F020,and supplied by the MCU. As a result to actual work, the sinusoids signal by the circuit is also “staircase”, the refresh interval curve amplitude is less than 1µs, and the very smooth and fine linearity, the “staircase” is unseen by the common oscilloscope, so it is not necessary to use the filter-circuit, and the negative effect will be reduced by the filter-circuit.

4.2. The designing for the Precision constant current source controlled by voltage circuit

Fig 3 shows the diagram of the constant current source controlled by voltage. The main function of the circuit is responding the differential sinusoids signals that generated by the forestage circuit, and processed to generate the total current. The working principle is that the differential sinusoids signals is amplified by the instrument amplifier INA128 as a single voltage signal U1 by the DDS chip, the signal U1 is driving the voltage controlled constant current source circuit that made of operational amplifier
P1 and P2, final the mA class sinusoids current signal $I_o$ goes to the post-stage module. The circuit is “grounding load” Voltage Controlled Current Source, or called as “HOWLAND Current pump”, the circuit is made of 2 piece of precision operational amplifier OP228, the P2 is the host amplifier, combined to a differential amplifier, to detect the difference of the output signal and feedback signal, P3 is the slave amplifier. So it is easy to know when the amplifier and resistor is ideal, the circuit is satisfied with the formula (1)

$$I_o = \frac{V_o}{R_f} = \frac{V_o}{R_i} = \frac{500 \Omega}{4k \Omega}$$

In the selection of the parameter, $R_f = R_i = 4k \Omega$, $R_s = 500 \Omega$, $R_s$ is not less than $R_f$ and $R_i$ as far, so it is necessary that the amplifier P3 is exist, to provide the U3 feedback to the U3’ by voltage following loop, and it can reduce the shunt influence of the feedback circuit to $I_o$ in order to keep the integrity and matching ability to the feedback signal. The $R_f$ is matching to $R_i$ well, otherwise the linearity of the constant current source will be affected seriously, and the equivalent parallel output impedance will be reduced. The $R_f$, $R_i$ and $R_s$ are the entire precision non-inductive metal film resistor that tolerance is ±0.02%; the temperature coefficient is less than 25ppm. When the sinusoids voltage signal $U_1$ is 5V (RMS), and sinusoids current signal $I_o$ is 10mA (RMS), the destination of the design about precision constant current source by voltage controlling is achieved.

The design mentality of “module block” is applied to standard device in the total current designing, in one channel about total current involve several “precision constant current source module”, each “module” can provide several component current with different amplitude, frequency and phase according to the configuration, and the equivalent parallel output impedance based on the constant current source almost close to infinity., all those “module block” can be paralleled for outputting, in order to achieve linear superposition to all the component current, all the component current will be seen as the harmonic component current of the total current. At the same, according to the design, all the harmonic component current can be lead out when the total current output by the standard device., by this way, when the standard device traced to the supervising authority, all the harmonic component current can be lead out in background of the total current, make progress in traceability of standard device.

4.3. The designing for precision boost circuit

Fig 4 shows the diagram of the precision boost circuit, “the multi-stage” boost is applied to provide the reference voltage $U_o'$. The working principle is that, the differential sinusoids signal by DDS is amplified by the instrument amplifier INA128 as single sinusoids voltage signal $U_5$, the signal $U_5$ is adapted to sinusoids voltage signal $U_o$ by the in phase amplified circuit that made up of the high-voltage operational amplifier OP454, the amplification is 5. The forward input terminal is connected to $U_5$ that the output signal from INA128. The “multi-stage” boost mode is helpful to increase the output-offset voltage for the boost circuit. The maximum output voltage is designed as 25V (RMS) for $U_o$, the third stage amplified by the precision transformer T1, The maximum output voltage $U_o'$ is designed as 100V (RMS). T1 is the precision boost transformer which ratio is 25V/100V, the linearity is less than ±0.02%, and the magnet-core is made of Permalloy.

5. The calibration data traced to the supervising authority

All the function of the standard device is traced to the legal supervising authority (NCHVM), the calibration data by an example as follow.
Tab. 1 The calibration data

<table>
<thead>
<tr>
<th>Indication of the object (V)</th>
<th>Indication of the standard (V)</th>
<th>Relative error (%)</th>
<th>Indication of the object (mA)</th>
<th>Indication of the standard (mA)</th>
<th>Absolute error (μA)</th>
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<tbody>
<tr>
<td>100</td>
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</table>

Note: the reference instrument is 3458 multi-meter by Agilent in voltage calibration.

Tab. 2 the calibration data

<table>
<thead>
<tr>
<th>Nominal (°)</th>
<th>Indication of the standard (°)</th>
<th>Absolute error (°)</th>
<th>Nominal (Hz)</th>
<th>Indication of the object (Hz)</th>
<th>Indication of the standard (Hz)</th>
<th>Absolute error (Hz)</th>
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<td>50</td>
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<td>0</td>
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<tr>
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<tr>
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<td>0</td>
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<tr>
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<td>300</td>
<td>300</td>
<td>300</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: the reference instrument is 3458 multi-meter by Agilent Technologies in frequency calibration, and SD1000 phase-meter by AV POWER in phase angle calibration.

Tab. 3 The calibration data

<table>
<thead>
<tr>
<th>Indication of the object (mA)</th>
<th>Indication of the standard (mA)</th>
<th>Absolute error (μA)</th>
<th>Indication of the object (mA)</th>
<th>Indication of the standard (mA)</th>
<th>Absolute error (μA)</th>
</tr>
</thead>
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</table>

Note: The reference instrument is 3458 multi-meter by Agilent Technologies in current calibration. As the result shown, the character of the standard device is meeting the requirement to the design. It is legitimate and efficient that to calibrate, verify and inspect the ZOSARCT.

References

[1] The electric power industry standard DL/T 596 1996 electric power equipment preventive testing procedures, 1996,
[3] Metrological verification procedures JIG (mechanical) 198 94 zinc oxide lightning arrester leakage current tester verification regulation, 1994,
[4] Li Xiaojian etc. Zinc oxide lightning arrester leakage current verification results tester expression of uncertainty in measurement, Yunnan power technology, 2009,