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A method for overcoming thermo EMF of shunt connected meters for measuring electric energy

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Abstract: The thermoelectric potential mainly exists in the contact surface of different metal materials, from a few micro volts to dozens of micro volts, which is not easy to eliminate and the measurement is complex. It introduces large error to the calibration of the shunt connected electric energy meter. In this paper, the current reversing method is used to measure the positive and reverse power, and then the influence of the thermoelectric potential on the mV voltage of the shunt is eliminated by the software revision, so as to improve the precision of the detection of the shunt electric energy meter. The starting time is calculated by measuring the time of receiving a pulse in a positive and reverse direction to improve the accuracy of the starting test. At the same time, the low thermal potential is reduced by placing the shunt in the uniform temperature non conducting material. In the end, the improved electrical energy verification device is used for experimental testing to provide a higher precision technical means for tracing and detecting the source and detection of indirect access DC power meter.

1. Introduction

According to methods of currentmeasurement, DC Watt-hour meters usually fall into direct and indirect connected type. The shunt connected type as indirect electric energy meters are always used to measure high current while the direct connected type measures low current. For DC current measurement, a current shunt is placed in series in the current path and converts the current to a DC voltage signal. The shunt as a small but standard resistance is always applied on the measurement of series in the circuit. The voltage drop of a large current on a small resistor is measured by a voltmeter, and the actual current is expressed by the scale of the ammeter.

There is often a phenomenon of thermoelectric effect which is neglected in the measurement of DC high current by using shunt. When a large current flows through the shunt, the contact resistance between the current conductor and the two ends of the distributor causes a temperature ladder on the shunt. Even if the shunt is placed on the uniform temperature block, the distributor has its own thermal resistance and heat capacity. The relaxation time of temperature is related to the above thermal resistance and heat capacity. The larger the product of thermal resistance and heat capacity, the longer the relaxation time will be. Especially in the case of dynamic measurement, the non-uniform temperature distribution caused by the temperature relaxation in the distributor can not be ignored. Even in the state of steady state, if the partial contact between the divider and the uniform temperature block, the leakage heat of the lead will cause a certain temperature gradient in the shunt, and the temperature difference on the shunt will cause the diffusion of the carrier to produce the thermal potential[1].The thermoelectric potential is generally a few volts or even a few milli volts, which has great influence on the metering of the shunt type DC energy meter.

2. Thermoelectric potential generated by shunt-connected energy meter

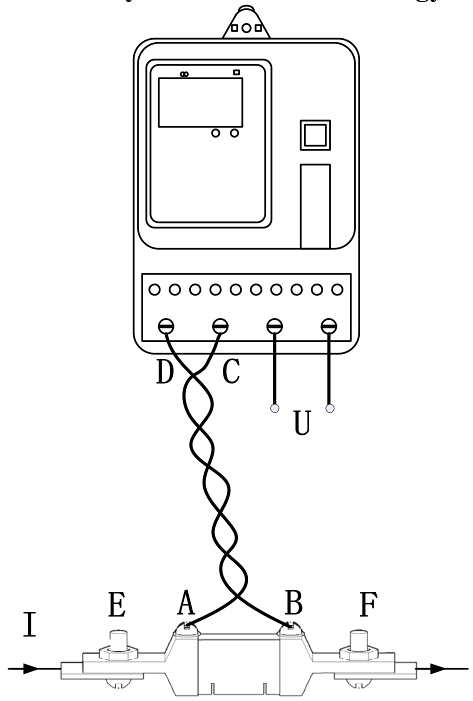

Fig 1 shunt connected to electric energy meter

When the current I flows through the shunt, the potential difference U_{AB} is generated at AB, as shown in Fig.1. The electric energy meter calculates the current through measuring the shunt U_{AB}, and carries out the current measurement. The shunt and the current conductor are tightened by screws. There is a contact resistance between the two contact surfaces E and F. When a large current flows through the conductor, the current shrinks near the contact surface. The area of the conductor shrinks and the resistance increases. When the resistance of these two places is different, the temperature ladder of the shunt exists. When the voltage of the shunting A and B terminals is different, the thermal potential is generated between the conductors AD and BC. Suppose A point temperature is T+ ΔT, B point temperature is T, C and D temperature is T1. The formula for calculating the thermoelectric potential EAD (T+ΔT, T_1) between AD is as follows[2]:

$$E_{AD}\left(T+\Delta T，\ T1\right)=e_{AD}(T+\Delta T)-e_{AD}(T1)=\frac{k(T+\Delta T)}{e}ln\frac{n_A}{n_D}-\frac{kT1}{e}ln\frac{n_A}{n_D}\ldots\ (1)$$

Similarly：

$$E_{BC}\left(T，\ T1\right)=\frac{kT}{e}ln\frac{n_B}{n_C}-\frac{kT1}{e}ln\frac{n_B}{n_C}\ldots\ (2)$$

The C and D point temperatures are almost the same, and the material used in the voltage terminal is the same, and the two points have the same thermoelectric potential.

Thermal potential difference U introduced at the two ends of the shunt voltage can be expressed as follows:

$$\Delta U=E_{AD}\left(T+\Delta T，\ T1\right)-E_{BC}\left(T，\ T1\right)=\frac{k(T+\Delta T)}{e}ln\frac{n_A}{n_D}-\frac{kT1}{e}ln\frac{n_A}{n_D}-\frac{kT}{e}ln\frac{n_B}{n_C}+\frac{kT1}{e}ln\frac{n_B}{n_C}=E_{AB}(T,T1)+\frac{k\Delta T}{e}ln\frac{n_A}{n_D}\ldots\ (3)$$

And the conductor materials of A and B point are the same, so $E_{AB}(T,T_1)=0$。

$$\Delta U=\frac{k\Delta T}{e}ln\frac{n_A}{n_D}=k_1\Delta T\ldots\ (4)$$

The formula (4) shows that the difference of the thermoelectric potential introduced at the end of the electric energy meter is directly proportional to the temperature difference between A and B. K1 is determined by metal materials, in which different materials are used in the shunt resistance structure, such as the voltage connection terminals and the material that are different from the resistance value of the material of the shunt resistance. The influence of the thermoelectric potential is further reduced by selecting materials with a low coefficient K value. The current shunt usually uses manganese copper alloy. According to the experiment, the thermoelectric potential (typical value) produced by copper and other metals at different temperature differences (typical values) is shown in the following table.

Tab.(1) Thermo EMF of copper and other metals

No.	Metal Materials	Thermoelectric potential （μV/℃）
1	Gold	0.5
2	Silver	0.5
3	Brass	3
4	Beryllium copper	5
5	Aluminum	5
6	Lead-Tin Solder	5
7	Cutting alloy （KOVAR），4J29	40
8	Silicon	500
9	Copper oxides	1000

3. Technical difficulties and solutions

Typical thermoelectric potentials of copper and some metals are described in table (1). Among them, copper, gold and silver have smaller thermoelectric potentials, and their thermoelectric potentials with copper oxides can reach 1 mV /℃. At the present stage, the electrode materials and joints of the shunt are made of stainless steel and other materials. It is difficult to calculate the thermoelectric potential by checking the table. And the thermoelectric potential of some materials can not be investigated[3]. The following is an example of a class 0.2 watt-hour meter to illustrate the impact of thermoelectric power on DC power measurement and propose a solution to eliminate thermoelectric power [4].

3.1 Technical difficulties

For the 0.2 level meter, we first assume that the watt-hour meter is 600 V, 100 A/50 mV.

①Requirements for basic error limits under reference voltage

At 0.01In current, the error limit of the meter is +0.4%, corresponding to 50 mV error = 50 mV *0.01 *0.4% = 2 V.

②Requirements for starting current value of watt-hour meter

The starting current value of the 0.2 level indirect access DC energy meter should be less than 0.001In, the voltage value corresponding to 50 mV = 50 mV x 0.001 = 50 V.

When the gold, silver and copper are connected with low thermoelectric potential, according to the table (1), when the 1.2 point is ΔT=5℃, the error of the thermoelectric potential about 2.5uV has exceeded the 0.01In current, and the thermoelectric potential can not be ignored.

3.2 Solution

1) Eliminating the influence of thermoelectric potential on the measurement of basic error of electric

energy

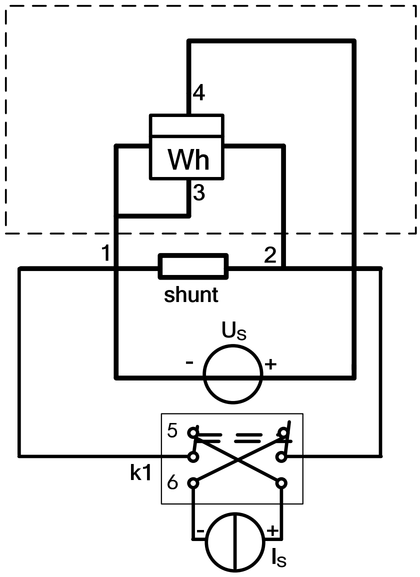

Fig2. Verification principle block diagram of current commutation method

The verification process should be carried out in a constant temperature chamber, and a large current relay K_1 with a small thermoelectric potential should be selected. The thermoelectric potential has nothing to do with the material of the conductor, the material of the shunt, the contact resistance and so on, and is independent of the direction of the current I.

In figure (2), the relay K_1 is first hit in the 6 position current source output forward current I through the shunt R, and the output rated voltage of the shunt is connected to the electric energy meter current terminal. At the same time, the voltage terminal of the meter is connected to the voltage source U_S, and the power E_1 is measured through time T, and the unit W.s.

$$E_1 = U \times \frac{(U_n + e_r)}{R} \times T .... \quad (5)$$

When the temperature of the shunt voltage terminal is restored to room temperature, the K_1 will be controlled to fifth in figure 2 and the current will be commutated. The power E_2 will be measured in time T and the unit W.s.

$$E_2 = U \times \frac{(U_n - e_r)}{R} \times T .... \quad (6)$$

The average value of the two measurements is taken to offset the thermal potential.

$$E_0 = \frac{E_1 + E_2}{2} = U \times \frac{U_n}{R} \times T .... \quad (7)$$

$$\gamma = \frac{E_0 - E}{E} \times 100\% .... \quad (8)$$

In the form:

E_0 - the electric energy value of the test table to eliminate the heat potential, W.s

E—the standard meter electrical energy value，W.s

e_r-thermoelectric potential，V

2) starting test

Assuming bidirectional counters change one word, the starting time is t_1 and t_2 respectively.

$$U \times \frac{(U_n + e_r)}{R} \times t_1 = U \times \frac{(U_n - e_r)}{R} \times t_2 .... \quad (9)$$

Time error introduced by thermoelectric potential

$$\gamma_t = \frac{e_r}{U_n} = \frac{|t_2 - t_1|}{t_2 + t_1} \times 100\% .... \quad (10)$$

The starting time should eliminate the error introduced by the thermoelectric potential.

$$t_Q{}' = (1 \pm \gamma_t) \times t_Q \ldots \quad (11)$$

In the form:

t_Q- starting test time, min；

$t_{Q'}$-start test time eliminate the thermal potential, min；

3) Other measures

The distributor is placed between the uniform temperature blocks and connected with a conductive silver paste with good heat conduction. The voltage measurement leads should be connected with smaller diameter wires to reduce the error caused by thermal relaxation. A good thermal contact is established between the voltage measuring conductor and the uniform temperature block to avoid the external heat flowing through the electrode lead to the shunt[5].

4. The improved shunt access electric energy meter verification system

After setting up the parameters in the man-machine interface, the computer passes the command through the RS232 line to the central console. After receiving the command, the central control console controls the output voltage of the voltage source to the electric energy meter, and the current source outputs the current to the shunt, and the shunt voltage is connected to the electric energy meter to measure[6]. Within the time T, the power error module is used to calculate the device and the power error of the checked table. When the current is zero, when the terminal of the shunt is restored to the normal temperature, the current reverse output current is controlled by the central control table to the shunt, and the output value is kept constant to measure the electrical energy value of the checked table again[7]. The power error is calculated according to formula (5) ~ (8). When starting the experiment, we measure the time of receiving a pulse in reverse direction and calculate the revision time according to formula (10) ~ (11). Then the test data is transmitted to the computer by the central console, and the operation such as display, save, print and so on is completed by the computer [8].

This system is applied to verify the 0.5 stage shunt access watt hour meter.

（1）Energy meter parameters：600V 100imp/kWh，matching the parameters of 0.1 stage shunt：100A/50 mV

(2) test environment: constant temperature chamber temperature: 25 C; humidity: 80%R.H. Test data such as table (1) power error comparison table, table (2) positive and negative changes in the starting time of a word and the starting time comparison after counteracting the thermal potential.

Tab.2 The comparison of the error between the positive electric energy and the elimination of the thermoelectric potential

Test point	Forward electric energy error	Correction of thermoelectric potential error	Introduction error of thermoelectric potential
(Un In)	0.54%	0.5%	0.04%
(Un 0.01In)	1.2%	0.9%	0.3%

Tab.3 Starting time comparison

Positive time (s)	Reverse time (s)	Correction time (s)	Theoretical starting time (s)
64	72	65.8	70

From the data analysis of the above table, it can be found that the error of the watt hour meter is

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reduced after the effect of the software revision to eliminate the influence of the thermoelectric potential, and the test result is passed from the unqualified to the qualified, and the starting test time is reduced accordingly.

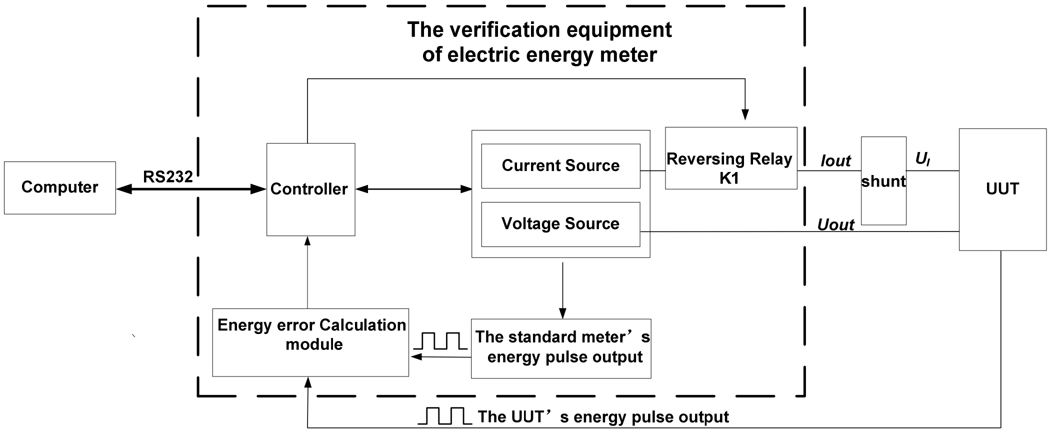

Figure 2 verification principle block diagram of shunt-connected meters for measuring electric energy

5. Conclusion

The current commutation method proposed in this paper is to repair the positive and negative electrical energy of the large current reversing measurement by adding a low voltage relay to the current source circuit and to eliminate the influence of the thermoelectric potential on the mV voltage of the shunt. This method improves the accuracy of the measurement of DC power, provides a basis for the tracing and detection of the quantity value of the DC meter, and provides more accurate test data for the producers of the electric energy meter.

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