

## Range Automatic Adjusted Current Transformer Primary Winning

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**Abstract:** The article discusses the issue of introducing a correction factor for protection and control devices, as the value of the secondary current in a certain range of the auto-adjustable current transformer does not correspond to the value of the secondary current in another range determined by the difference of magnetic driving forces generated by the components of the primary current. Alternatively, an algorithm has been developed to account for the measurement error in this condition in an automatic system that controls the operating mode of the current transformer. It was also found that the output data should be transmitted taking into account the correction factor in order to ensure the proper operation of the protection and measuring devices when the current transformer is switched to another measuring range in the measuring range.

**Keywords:** range automatic adjustable current transformer, primary winding resistance, correction factor, third harmonic current filters, main harmonic current filters, logic elements, control automatic system algorithm.

### 1. Introduction

It is known that the most promising and acceptable device for switching large AC currents in control and monitoring systems are multifunction current transformers [1].

A number of scientific studies to date have focused on the development and study of current transformers (TTs), most of which are aimed at reducing TT measurement errors. These TTs can only be used within a certain defined measurement range. This in turn limits the functionality of TTs that have a certain measurement range.

To date, insufficient theoretical research has been conducted to develop broad-spectrum (universal) TTs that fully meet the requirements of modern control systems. The article describes the development of a wide range of TT with expanded functionality and automatic adjustment, as well as improved dynamic properties for control systems, and considers the introduction of a correction factor to obtain appropriate results in all measurement ranges [2].

The TTi under study consisted of metal circles with a central connector, two circular elements insulated from each other with a single axis, and a ferromagnetic closed core with a measuring coil located in the central connector and primary current inputs and outputs diametrically located along the edges of the circles (1- picture). The outputs of this TTi secondary coil are connected to the first and third current harmonic filters, and their outputs are connected to the logic elements and switching actuators installed in the circuit elements of the current transformer.

In TT, where these ranges are automatically adjustable, when the magnetic chains are saturated under the influence of a large current flowing through the primary winding while it is operating in a certain range, the automatic system transfers TT to the next range according to the third harmonic fraction in the secondary current. However, since the current  $I_2$  in the middle and upper ranges of the current transformer is generated by the opposite directional magnetic driving force (MJC), the current  $I_2$ , which corresponds to the measured value of the current  $I_1$ , differs from the operating value of the current TT in the previous range [4]. This requires consideration of the development of an algorithm to account for measurement errors in an automated system that controls the TT operating mode.

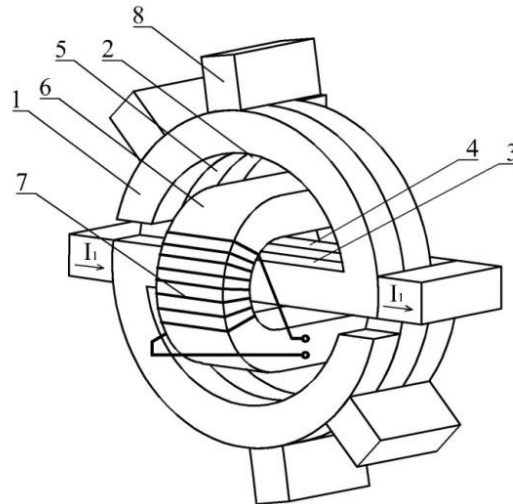


Figure 1. Automatic system block diagram for automatic adjustable range TT and protection and measuring devices: 1- and 2- single-axis circular elements; Diametrical connectors of 3- and 4-circle elements; 5- dielectric with diametrical connectors and mutual insulation of circuits; 6 ferromagnetic closed core; 7 measuring cups; 8 Primary coil outputs located mutually diametrically at the edges of the circles for different ranges.

The MYuK in the lowest range of TT is formed from 100% of the value of the primary current. In the middle and upper ranges of the TT, the components of the primary current flowing through the diametrical connectors are inversely proportional to the resistances corresponding to the lengths of the corresponding circles. Given that the value of the secondary currents in the middle and upper ranges of TT varies depending on the difference of the MUCs generated by the components of the oppositely directed primary current flowing through the diametrical connectors, the amount of TT primary currents can be expressed by the resistances of the corresponding circles.

It is known that the total resistance of a single circuit of TT is determined as follows:

$$R = R_a + R_d, \quad (1)$$

where  $R_a$  is the resistance of the circle,  $R_d$  is the resistance of the diametrical connector of that circle.

For the medium range:

$$R_1 = 0.75R_a + R_d; \quad (2)$$

$$R_2 = 0.25R_a + R_d, \quad (3)$$

For the upper range:

$$R_1 = 0.53R_a + R_d; \quad (4)$$

$$R_2 = 0.47R_a + R_d. \quad (5)$$

values are reasonable. Hence the values of the diametrical connectors are the components of the primary currents directed in opposite directions.  $I_1'$  and  $I_1''$  The following expressions are appropriate for:

$$I_1' = \frac{R_2}{R_1 + R_2} \cdot I_1; \quad (6)$$

$$I_1'' = \frac{R_1}{R_1 + R_2} \cdot I_1. \quad (7)$$

A single-wrapped blanket ( $w_1 = 1$ ) for  $F_1 = I_1$  the equation is reasonable, and for the medium range, the difference of the MUCs in the diametrically connected conductors of the primary current-generators is determined as follows:

$$\Delta F_1 = \frac{R_1 - R_2}{R_1 + R_2} \cdot I_1, \quad (8)$$

Substituting (8) into expressions (2), (3) and (4), (5), we obtain the following expressions for the middle and upper ranges, respectively:

For the medium range:

$$\Delta F_1 = \frac{R_a 0.5}{R_a + 2R_{\text{д}}} \cdot I_1, \tag{9}$$

for the upper range:

$$\Delta F_1 = \frac{R_a 0.06}{R_a + 2R_{\text{д}}} \cdot I_1. \tag{10}$$

Knowing the resistances of the TT loops and the diametrical connectors, the correction coefficient of the secondary current for each range comes from the difference of the MYuKs generated by the components of the oppositely directed primary currents in the diametrical connector [5]:

$$I_2 = \frac{\Delta I_1 \cdot w_1}{w_2}, \tag{11}$$

here:

$$\Delta I_1 = \frac{R_1 - R_2}{R_1 + R_2} \cdot I_1. \tag{12}$$

So, in all ranges  $I_2$  To get the results you need to enter the correction factor:

$$K_m = \frac{R_1 + R_2}{R_1 - R_2} \tag{13}$$

In order to check the operation of the device, when the TT magnetic circuits operating in a certain range go to saturation, we consider the state of providing the necessary control information for protection and measuring devices, taking into account the correction factor at the time of transition of the automatic system TT to the next range. .

Figure 2 shows a block diagram of an automatic system for protection and measuring devices of TT, in which the secondary circuit of TT 1; 2 automatic system consisting of main and third harmonic filters and logic elements; 3, 4, 5 executive bodies for the lower, middle and upper ranges, respectively; 6, 7- correction coefficient blocks for medium and high ranges, respectively; 8 protection and measuring devices.

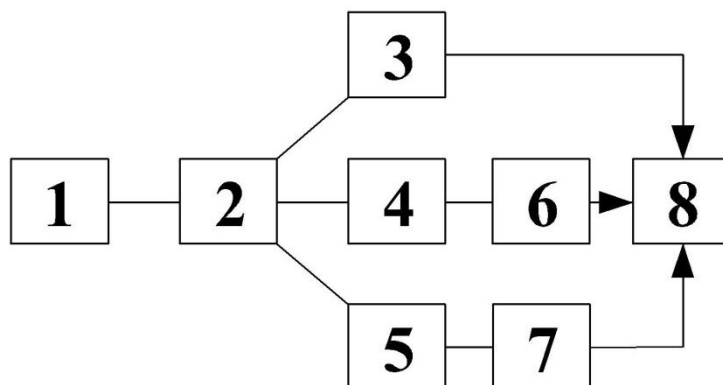


Figure 2. Automatic system block diagram for TT protection and measuring devices

In order to correctly determine the value of the primary current when the TT is transferred to the next range by the automatic system, it is necessary to transmit data to the protection and measuring devices, taking into account the appropriate correction factor.

Since the MYuK in the lowest range of TT is formed from 100% of the total current value, there is no correction factor for this range. For the medium and high ranges, blocks of correction coefficients 6 and 7 are installed, respectively, through which information on the exact values of the primary current is transmitted to the protection and measuring devices.

To determine the temperature error of the current distribution in the elements of the TT circuit, the range of which is automatically adjustable, we determine the value of the currents, taking into account the normal and high

ambient temperatures and the increase in conductor temperature as a result of current flow. For the mid-range TT medium range, the currents in the circuit elements are as follows:

$$I'_{11} = \frac{0.25R_a + R_\delta}{R_a + 2R_\delta} \cdot I_1, [A]; \quad (14)$$

$$I''_{11} = \frac{0.75R_a + R_\delta}{R_a + 2R_\delta} \cdot I_1, [A]; \quad (15)$$

here,  $R_a$  – the resistance of the circle, [Om];  $R_\delta$  - the resistance of this circular diameter connector, [Om],  $I_1 = 1000 A$ .

$$R_a = \rho_{\alpha 1} \frac{l_a}{S}, [Om]; \quad (16)$$

$$R_\delta = \rho_{\alpha 1} \frac{l_\delta}{S}, [Om]; \quad (17)$$

here,  $l_a$  – circle length,  $l_a = 1,41195 m$ ;  $l_\delta$  – the length of the diametrical connectors of this circular element,  $l_\delta = 0,41144 m$ ;  $S$  – cross-sectional area of circular elements,  $S = 134,1149 mm^2$ ;  $\rho_{\alpha 1}$  – specific electrical resistance of aluminum material,  $\rho_{\alpha 1} = 0,028 \frac{Om \cdot mm^2}{m}$ .

Determine the resistance of the elements of the circle using the initial data given for the auto-adjustable TT for the range:

$$R_a = 2,947 \cdot 10^{-4} Om;$$

$$R_\delta = 0,8589 \cdot 10^{-4} Om.$$

Using the values of the resistance of the elements of the circle, we determine the value of the current flowing through each element of the circle:

$$I'_{11} = 342,051 A;$$

$$I''_{11} = 657,948 A.$$

The difference in currents in the TT circuit elements whose range is automatically adjustable  $\Delta I_1 = I''_{11} - I'_{11} = 315,896 A$ .

We use the following expression to determine how much the temperature of the circular elements increases as a result of the increase in the value of the currents flowing through them:

$$\Delta T' = \frac{I'_{11}{}^2 \cdot (0.75R_a + R_\delta)}{K \cdot F'}, [K]; \quad (18)$$

$$\Delta T'' = \frac{I''_{11}{}^2 \cdot (0.25R_a + R_\delta)}{K \cdot F''}, [K]; \quad (19)$$

here,  $K$  – total heat transfer coefficient for aluminum material,  $K = 25 \frac{Bm}{m^2 \cdot K}$ ;  $F$  – cooling surfaces of circular elements,  $F' = 0,17544 m^2$  and  $F'' = 0,09121 m^2$ .

According to the given initial data, the increase in temperature in the circular elements as a result of an increase in the value of the currents flowing through them  $\Delta T' = 8,1842 \text{ }^\circ K$  and  $\Delta T'' = 30,2983 \text{ }^\circ K$  equal to the values.

The effect of the temperature increase of the circular elements on the value of the specific electrical resistance of the material can be determined by the following expression:

$$\rho'_{\alpha 1} = \rho_{\alpha 1} (1 + \alpha_{At} \cdot \Delta T'), \left[ \frac{Om \cdot mm^2}{m} \right]; \quad (20)$$

$$\rho''_{\alpha 1} = \rho_{\alpha 1} (1 + \alpha_{At} \cdot \Delta T''), \left[ \frac{Om \cdot mm^2}{m} \right]; \quad (21)$$

here,  $\alpha_{At}$  – average temperature coefficient of aluminum material,  $4,3 \cdot 10^{-3} \frac{1}{K}$ .

According to the above information  $\rho'_{\vartheta 1}$  and  $\rho''_{\vartheta 1}$  We obtain the following values for:

$$\rho'_{\vartheta 1} = 0,02898 \frac{Om \cdot mm^2}{m},$$

$$\rho''_{\vartheta 1} = 0,03164 \frac{Om \cdot mm^2}{m}.$$

Above  $\rho'_{\vartheta 1}$  and  $\rho''_{\vartheta 1}$  We determine the resistance values for TT circle elements whose range is automatically adjustable according to the values of:

$$R'_a = 3,05161 \cdot 10^{-4} Om,$$

$$R''_a = 3,33186 \cdot 10^{-4} Om,$$

$$R'_\delta = 0,88923 \cdot 10^{-4} Om,$$

$$R''_\delta = 0,97090 \cdot 10^{-4} Om.$$

We use the following expressions to determine the current distribution in the circular elements using the resistance values obtained by increasing the temperature of the circular elements.:

$$I'_{12} = \frac{0.25R'_a + R'_\delta}{R'_a + 2R'_\delta} \cdot I_1, [A]; \quad (22)$$

$$I''_{12} = \frac{0.75R''_a + R''_\delta}{R''_a + 2R''_\delta} \cdot I_1, [A]. \quad (23)$$

Above  $I'_{12}$  and  $I''_{12}$  We determine the value of the currents for the elements of the TT circle, the range of which is automatically adjustable according to the expressions:

$$I'_{12} = 342,051 A,$$

$$I''_{12} = 657,948 A.$$

The difference between the currents obtained from the increase in the temperature of the circular elements as a result of the increase in the value of the currents in the circuit elements of the TT circuit, the range of which is automatically adjustable  $\Delta I_2 = I''_{12} - I'_{12} = 315,896 A$ .

The ambient temperature below is below normal  $\Delta T_2 = 30^\circ K$  We perform calculations on the effect of the increase in the value of the currents on the elements of the circuit TT automatically adjustable to the currents obtained from the increase in the temperature of the elements of the circuit.

The ambient temperature is above normal  $\Delta T_2 = 30^\circ K$  The specific electrical resistance of the circular elements as a result of the increase is determined as follows:

$$\rho'_{\vartheta 12} = \rho'_{\vartheta 1} \left( 1 + \alpha_{Ai} \cdot (\Delta T' + \Delta T_2) \right), \left[ \frac{Om \cdot mm^2}{m} \right]; \quad (24)$$

$$\rho''_{\vartheta 12} = \rho''_{\vartheta 1} \left( 1 + \alpha_{Ai} \cdot (\Delta T'' + \Delta T_2) \right), \left[ \frac{Om \cdot mm^2}{m} \right]. \quad (25)$$

We determine the value of the specific electrical resistances for the TT circuit elements whose range is automatically adjustable according to expressions (24) and (25) above:

$$\rho'_{\vartheta 12} = 0,033745, \left[ \frac{Om \cdot mm^2}{m} \right];$$

$$\rho''_{\vartheta 12} = 0,039853, \left[ \frac{Om \cdot mm^2}{m} \right].$$

Above  $\rho'_{\vartheta 12}$  and  $\rho''_{\vartheta 12}$  We determine the resistance values for TT circle elements whose range is automatically adjustable by values:

$$R'_{a2} = 3,55273 \cdot 10^{-4} Om,$$

$$R''_{a2} = 4,19576 \cdot 10^{-4} Om,$$

$$R'_{\partial 2} = 1,03526 \cdot 10^{-4} \text{Om},$$

$$R''_{\partial 2} = 1,22263 \cdot 10^{-4} \text{Om}.$$

The ambient temperature is above normal  $\Delta T_2 = 30^\circ K$  We use the following expressions to determine the current distribution in the circular elements using the values of resistance to the currents obtained from the increase in the temperature of the circular elements as a result of the increase in the value of the currents in the circular elements TT.

$$I'_{13} = \frac{0.25R'_{a2} + R'_{\partial 2}}{R'_{a2} + 2R'_{\partial 2}} \cdot I_1, [A]; \quad (26)$$

$$I''_{13} = \frac{0.75R''_{a2} + R''_{\partial 2}}{R''_{a2} + 2R''_{\partial 2}} \cdot I_1, [A]. \quad (27)$$

We determine the current value for the TT circuit elements whose range is automatically adjustable according to expressions (26) and (27) above:

$$I'_{13} = 342,051, [A];$$

$$I''_{13} = 657,948, [A].$$

The ambient temperature is above normal  $\Delta T_2 = 30^\circ K$  increase The difference between the currents obtained by the effect of an increase in the temperature of the elements of the circuit as a result of an increase in the value of the currents in the circuit elements of the range TT automatically adjustable  $\Delta I_3 = 315,896 \text{ A}$ .

For automatic adjustable range TT  $\Delta I_1$ ,  $\Delta I_2$  and  $\Delta I_3$  We determine the error due to the increase in temperature by the following values:

$$\Delta I_1 - \Delta I_2 = 0 \text{ A},$$

$$\Delta I_2 - \Delta I_3 = 0 \text{ A},$$

$$\Delta I_1 - \Delta I_3 = 0 \text{ A},$$

The range of results obtained does not change in the value of currents flowing through them due to the parallel connection of the elements of the circuit TT primary windings, which are automatically adjustable, both at high ambient temperatures and as a result of large currents passing through the elements. It also has very small values that the range can be adjusted automatically without taking into account the error in the special design of the TT primary coil.

As a result of the study of the range-adjustable TT, it was found that the output data should be transmitted taking into account the correction factor in order to ensure the proper operation of the protection and measuring devices when the TT switches to another measuring range in the measurement range. Proper transmission of data ensures the correct operation of protection and measuring devices in various harmonics, as well as further increases the reliability of the automatic system.

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