Conclusion

Thus, the work carried out mathematical modeling of a ball mill on the basis of diffusion modeling, according to which the transfer function of the grinding apparatus was obtained. Using the MATLAB application package and the SIMULINK subsystem of this program, a model of the mathematical apparatus of the mill was modeled [9]. Transient and impulse characteristics of the mill were constructed using a computer model.

The simulation results confirmed the correctness of the found function and its adequacy to the described grinding process in the ball mill MShTs 75 * 55 in the GMZ 2. The developed mathematical model is used in the study of the grinding process and the improvement of grinding technology, as well as in the educational process at the department when studying the discipline "Identification and modeling technological processes" [10].

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DISCRETE CURRENT MEASURING TRANSFORMERS

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***Annotation**: Article studies control and measuring systems in which high-voltage current measuring transformers are used, which are analogue measuring converters with a number of drawbacks. In this regard, it is proposed to use discrete current transformers, the use of which leads to simplification and cheapening of structures, are reliable carriers of measuring information, as well as discrete signals from discrete current transformers can be transmitted through connecting wires of smaller cross-section.*

***Keywords**: magnetic current transformer, analog signal, discrete signal, discrete current transformer, analog-discrete converter.*

Currently, high-voltage measuring transformers are used in control and measuring systems, as well as in relay protection and automation systems, which are analog measuring current transformers.

The carrier of measuring information in the secondary circuits of the current transformer (CT) is the secondary current of the current transformer. At the same time, digital measuring instruments and discrete-action devices that receive measuring information from CT are equipped with their own analog-digital (analog-discrete) converters of measuring information signals.

In digital control and measuring systems, it seems appropriate to use measuring current transformers, which themselves are analog-digital (analog-discrete) measuring converters. Such CTs are hereinafter referred to as discrete current transformers (DCT). The use of DCT in digital control and measuring systems is expedient for a number of reasons.

Firstly, digital measuring instruments do not require the use of their own analog-discrete converters, which should lead to simplification and reduction in the cost of the designs of these instruments and devices.

Secondly, discrete signals received from DCT are very reliable carriers of measurement information, since they are less sensitive than analog CT signals to interference and to changes in the resistance of connecting wires.

Thirdly, discrete signals from the DCT can be transmitted through connecting wires of the smaller section.

The transition to discrete signals of measuring information is also advisable for the purpose of relay protection, especially in those cases when they take a power from devices that replace high-voltage measuring transformers of conventional designs.

Of the devices designed to replace conventional current transformers in high and ultrahigh voltage installations, magnetic current transformers (MCT) are the most promising.

MCT are very low-power analog measuring converter. Because of this, it is not suitable for direct power supply of current circuits of relay protection and measuring instruments of conventional design. In principle, the MCT signal can be amplified with a suitable amplifier. However, it should be taken into consideration that the maximum output signal power Smax is limited and, for a number of reasons, cannot exceed several tens of VA.

For a given load resistance, the power of the analog signal of MCT (as well as the power of the CT signal) is proportional to the square of the primary current. Therefore, for the signal power at the output of amplifier S_2, the following relation is valid:

$$S_2 = S_{н} m_1^2 \leq S_{max} ,$$

where $S_{н}$ – signal power at nominal primary current, m_1 – primary current ratio.

At primary current ratio $m_1 = m_{1max}$, corresponding to the highest value of the monitored primary current, the signal power S_2 should not exceed Smax. Hence, it follows that for a given Smax, the maximum possible power $S_{н}$ is inversely proportional to m^2_{1max}.

In the circuits of measuring instruments of a conventional type, m_{1max} is close to 1. At the same time, it is possible to provide power $S_{н}$, sufficient for measuring instruments of a conventional type.

In the schemes of relay protection and fixing devices, $m_{1max} \geq 20$ is often required. In this case, the value of $S_{н}$ is of the order of hundredths of VA, which is completely insufficient for relay protection and fixing devices produced at the present time.

Thus, MCT as analog converters, even with amplifiers, cannot provide sufficient rated power of the measurement information signal in the relay protection circuits and fixing devices.

If we use relay protection and fixing devices with very low power consumption, designed to enter information using very low-power analog signals, then it will be necessary to place protection panels and fixing devices in the immediate vicinity of the MCT in order to avoid distortion of low-power signals by interference in the connecting wires. Such a solution is not always acceptable, and in some cases even impracticable.

The way out of the position may not be to amplify the low-power analog MCT signal, but to convert it into a discrete signal with subsequent amplification of the discrete signal. The power of a discrete signal depends little on the information carried by this signal.

Therefore, in the case of a discrete signal, the power $S_н$ is close to S_{max} practically at any multiplicity of the primary current.

Thus, the transition to discrete signals of measuring information in relay protection circuits and fixing devices should facilitate the use of cheap devices replacing modern high-voltage current transformers, and only thanks to this can a significant economic effect be obtained.

It should be noted that control and measuring systems and relay protection devices are currently not prepared for the transition to DCT. It is necessary to carry out a set of works on the reconstruction of produced digital measuring devices and the development of missing ones. A lot of work should be carried out on the development of relay protection schemes. First, technical requirements for diesel fuel should be established. Requirements should be set up taking into account the possibility of widespread use of typical elements of discrete technology and the simplest circuits of both DCT and instrumentation and relay equipment.

It seems, in particular, advisable that the DCT create a number-pulse signals arriving once or twice during a period of power frequency (assuming a sinusoidal current waveform) and displaying the effective value of the current in a number-pulse form, some of them took place in the previous half periods. In this case, measuring devices and measuring relays can be made based on counters for the number of pulses; - their speed will be about 0.5 - 1 period of industrial frequency.

The main element of a discrete current transformer is an analog-discrete converter (ADC) of alternating voltage. It is included in the monitored circuit through an intermediate analog converter (IC).

In the DCT circuit, the primary converter carries out a functional transformation of the instantaneous values of the primary current i_1 (t) into the instantaneous values of the output voltage U_2 (t), which is an input analog signal for the ADC.

The consumption of ADC from the measuring input is very small. Therefore, in the DCT circuit, very low-power primary converters without intermediate amplifiers are applicable. For example, a magnetic current transformer is used as a primary current transformer.

ADC provides receipt of four types of signals and has four outputs, denoted below $\tau_{(+)}$, $\tau_{(-)}$, $N_{(+)}$ and $N_{(-)}$.

From the outputs $\tau_{(+)}$ and $\tau_{(-)}$ signals representing the intervals $\tau_{(+)}$ and $\tau_{(-)}$ are taken. These rectangular electrical signals coincide in time with the displayed time intervals.

Signal $\tau_{(+)}$ starts at the moment when the curve U_2 (t) passes through zero in the positive direction; $\tau_{(-)}$ starts at the moment when the curve U_2 (t) passes through zero in the negative direction.

From the $N_{(+)}$ output number-pulse signals displaying the $S_{(+)}$ values are taken. Each such signal consists of $N_{(+)}$ electrical impulses, and the number of impulses in the signal is a logarithmic function of $S_{(+)}$:

or

$$N_{(+)} = aln\frac{S_{(+)}}{b} \quad (1, а)$$

or

$$N_{(+)} = aln\frac{b}{S_{(+)}} \quad (1, б)$$

where a and b – constant coefficients.

From the output $N_{(-)}$ number-pulse signals are taken, in which the number-pulses $N_{(-)}$ are logarithmic functions of $S_{(-)}$:

or

$$N_{(-)} = aln\frac{S_{(-)}}{b} \quad (2, а)$$

or

$$N_{(-)} = aln\frac{b}{S_{(-)}} \quad (2, б)$$

If linear primary converters are used in discrete instrument transformer circuits, then

$$U_{2(t)} = k_I i_{1(t)}.$$

Thus, the signal at the output $\tau_{(+)}$ coincides in time with the positive half-cycle of the primary current, and the signal at the output $\tau_{(-)}$ coincides in time with the negative half-cycle of the primary current, which allows to control the moments of the transition of the primary current curve through the zero value.

With a sinusoidal primary controlled parameter and a constant frequency, the volt-second area $S_{(+)}$ is proportional to the effective value of the primary current during the positive half-period $I_{1(+)}$, and the volt-second area $S_{(-)}$ is proportional to the effective value of the primary current during the negative half-period $I_{1(-)}$. Therefore, the numbers of pulses $N_{(+)}$ and $N_{(-)}$ display the values of $I_{1(+)}$ and $I_{1(-)}$ on a logarithmic scale.

Fig. 1 shows the combined graphs of $i_{1(t)}$ $u_{2(t)}$ and output signals when equalities (1, a) and (2, a) are true.

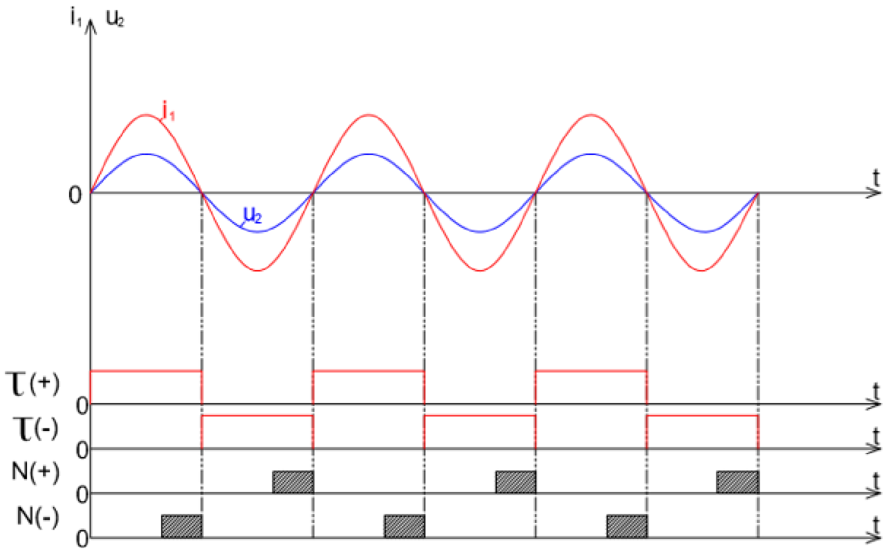

Fig. 1. ***shows the combined graphs of $i_{1(t)}$ $u_{2(t)}$ and output signals.***

Curves $i_{1(t)}$ and $u_{2(t)}$ are differ only in scale.

Signals $\tau_{(+)}$ and $\tau_{(-)}$, as already noted, coincide with the corresponding half-periods of the primary current.

Signals $N_{(+)}$ start in the middle of the intervals $\tau_{(-)}$ and end exactly at the moments of the end of these intervals.

Signals $N_{(+)}$ start in the middle of the intervals $\tau_{(-)}$ and end exactly at the moments of the end of these intervals.

If the primary current converter (PCC) operates in the mode of primary current differentiation, then

$$u_2(t) = k_I' \frac{\partial i_1(t)}{\partial t} \tag{3}$$

In this case, the signals $\tau_{(+)}$ begin at the moment when the curve i1 (t) passes through negative extremums and end when the curve $i_{1(t)}$ passes through positive extremums. Signals $\tau_{(-)}$ begin at the moment when the curve $i_{1(t)}$ passes through positive extremums and end when the curve $i_{1(t)}$ passes through negative extremums.

With a sinusoidal primary current, the signals $\tau_{(+)}$ and $\tau_{(-)}$ are ahead of the analogous signals in a circuit with a linear PCC by a quarter of a period. Correspondingly, the signals at the outputs $N_{(+)}$ and $N_{(-)}$ are shifted by a quarter of a period in advance.

If the shape of the primary current curve is distorted (non-sinusoidal), then the DCT has an additional error, depending on the nature of the distortion and on the characteristics of the PCC.

In the future, the DCT will be considered as a measuring converter of the first harmonic of the primary current. If the distortion of the waveform of the primary current is caused by the presence of higher harmonics, then fewer errors are obtained in the case of using a linear primary converter. If the distortion of the shape of the primary current curve is caused by the aperiodic component of the current, then smaller errors are obtained in the case of using a PCC operating in the differential current mode. Thus, depending on the nature of the distortion of the primary current, it is advisable to use a PCC with one or another characteristic.

Enlarged block diagram of ADC (Fig. 2) has the following three channels:

1) input voltage polarity channel with outputs $\tau_{(+)}$ and $\tau_{(-)}$;
2) positive half-cycle channel with output $N_{(+)}$;
3) positive half-cycle channel with output $N_{(-)}$.

The polarity channel of input voltage consists of a polarity indicator PI. The PI is based on a trigger with two stable states, which switches at moments when the $U_2(t)$ curve passes through zero values.

The channel of the positive half-cycle of the input voltage includes an integrator of the positive half-cycle of the input voltage INT $_{(+)}$, time-pulse converter TPC $_{(+)}$ and number-pulse converter NPC $_{(+)}$.

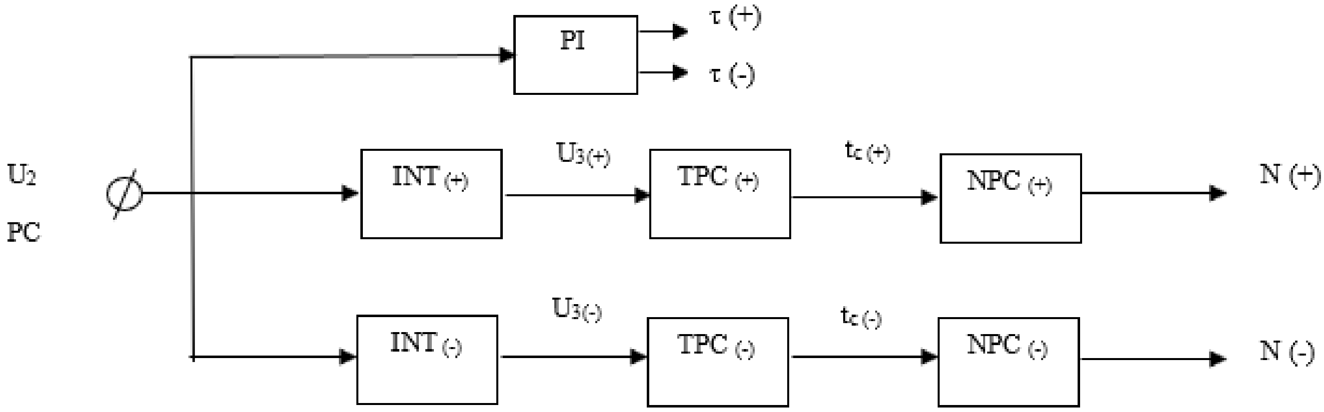

Fig. 2. ***Enlarged block diagram of ADC for PCC.***

The channel of the negative half-cycle includes an integrator of the negative half-cycle of the input voltage INT $_{(-)}$, time-pulse converter TPC $_{(-)}$ and number-pulse converter NPC $_{(-)}$. In this case, the negative half-cycle of the input voltage of the ADC is converted in the same way as it was considered for the positive half-cycle.

In the channels of positive and negative half-periods, a common multi-vibrator and some other elements are used.

In some cases, when high accuracy in the transient mode is not required from the DCT, a simplified two-channel DCT is applicable. It uses only the channel for indicating the polarity of the monitored parameter and the channel of its positive half-period. Such DCT has three outputs $\tau_{(+)}$, $\tau_{(-)}$ and $N_{(+)}$.

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