THE INFORMATION-ANALYTICAL CHARACTERISTICS OF THE BUSBAR FIELD PARAMETERS

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Is suggested the determining methodology of the magnetic intensity field in media around bus bar from electric current and the value current calculation as to the parameters of field in using of actuators current with the Hall elements.

The problem formulation and its connection with applied tasks. Main measuring converter applied for current production signal in power circuits, is current induction transformer having some imperfections. These imperfections accord essential influence as on the reliability of the work of control systems, so and on the safe working conditions of maintenance personnel. At the present time find applying more perfect measuring converters, in which is applied actuator current with the Hall elements [1].

Researches and publications analysis. Recommendations as to applying of the Hall actuators as the primary converters of energy there is in [1]. However in the installation of the Hall actuators appear the necessity in determining of dependence between value current measured and by the magnetic intensity field been created on definite distance from conductor with current. This dependence lets to establish necessary distance from conductor with current till actuator with purpose upturns electrical safety and the conveniences of mantling. Value characterizing the intensity of magnetic flood, is induction, consequent, is necessary to find dependence $B = f(I)$. We take into account that in the achievement of set purpose can be applicated not only actuators current with the Hall elements but also other primary converters [2].

Statement of problem. We shall determine quantitatively dependence between current value in conducto and been created the magnetic intensity field on some distance from conductor.

Results of the research. Comparing induction current transformers and current actuators with the Hall elements, follows to note following peculiarities of induction transformers:

– the necessity of the creation of breach in measured circuit for connection;

– current transformer works in conditions, close to the regime of short circuit, that is why its regime of open circuit is emergency operation [2]. Appears the hazard of the defeat of electric current service personnel, the isolation breakdown on the side of low voltage and transformer destroy;

– current transformers are used in measuring circuits and the control and automatics ones, that is why it is necessary that they corresponded to one's own accuracy class. in connection with that for current transformers exists the range of charges, in which value current measured lets to stay in the given class of accuracy. Exit for range this range brings to disorder the works of control systems and relay protection [3];

– in the exploitation process arises aging of isolation which brings to the necessity of the permanent control of its state. Failing this the high probability of the failure of current transformer connected to secondary wionding equipment, the defeats of electric current service personnel.

However actuators тока on the Hall elements also have its peculiarities [2]:

– sensitivity to voltage nonequipotentiality (the conditional by inaccurate arrangement of the Hall elements relatively of line equal potential) – is eliminated by the circuit;

– temperature instability specific sensitivity – for the modern converters can be not taken into account, because in the range of temperatures $-60^0 \ldots +60^0$C temperature coefficient composes 0,02…0,03% / degree.

For the obtained of current signal can used optoelectronic divisers, at which be absent galvanic connection between primary and secondary circuits. But their essential shortcoming is nonlinearity characteristics and the dependence of parameters from temperature, as a result what error can achieve 5…8% [2]. Such converters can be applied in low-current circuits.

There is possibly applying of quantum measuring converters allowing current measurement in range 2…100 кiloampers, with error, not exceed 0.05%. To their advantages follows ascribe noiseimmunity in broad frequency band. Follows, however, to note such their blemishes, as complexity of construction, of production and assembling, of calculation parameters. Namely such converters reasonable in currents measurement from dozens till hundreds of kiloampere.

Taking into account all aforesaid, obvious, what in current range 10…1000 ampere, in which on today's day predominate induction current transformers, rational to use current censor with the Hall elements.

The Hall element [1] presents semiconductor device (twoport scheme),available the following property: if through first pair terminal to omit direct current *I*, and self element to bestow in magnetic field with induction *B,* that on second the pair of terminal will appear voltage (Hall electromotive force) $U_{out}=kIB$. Linearity of response of the Hall element persists in the induction change from 0 till 0,7 tesla, greatest voltage on the exit of the Hall element composes 50…200 millivolt. In addition, current transformers own certain inductance which in larger speeds change current bring about visible error. The merits of current sensors with using of the Hall elements consist in possibility current measurement without the breach of measured circuit in absence galvanic connection with one, in the possibility of measurement larger current, including in installations with high voltage. Current sensor (Fig. 1) presents embracing strip 1 twisted multisection magnetic conductor from cold-rolled steel with two air gaps, in which are placed turbonit fillers. Changing the thickness of fillers, can be changed current force, in which is achieved maximal induction (0,7…1 tesla), thereby having restructured sensor on another nominal current value. In fillers make pricks, in which are disposed the Hall elements 2. Shown on Fig. 1 sensor is appointed for curents from 1.6 till 6.3 kiloampere, whereat gap must change from 2 till 6 millimetre. In necessity measurement larger currents use of core with larger dimensions or will divide wireway on a few strip, and disposed on its current sensors include by parallel.

In the sensor head is established printed-circuit card, on that are mantled elements as to scheme Fig. 1.

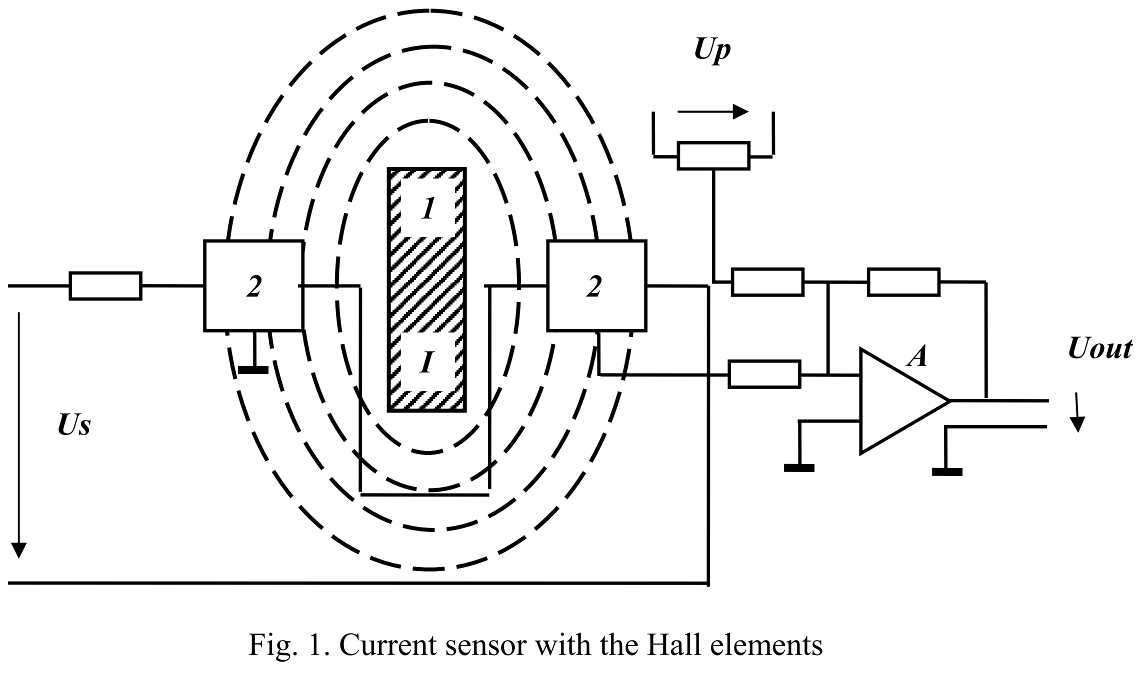

Fig. 1. Current sensor with the Hall elements

For protection from magnetic fields the printed-circuit card is bestowed in steel trunk. We shall note that in that case, when current sensor is disposed proximately from the control cabinet, this printed-circuit card can be established in the control cabinet. In order to decrease stray pick-up, current sensor has the own feed of amplifiers (+12.6 volts) from balancers in integral execution. Both Hall element are connected by series, and its output voltage supply on input of operational amplifier in integral execution. With the help of potentiometer establish the zero of amplifier, than is recompensed remaining voltage of the Hall element. The deficiency of such sensor – necessity in special stabilised current source feeding the element input. In applying of several sensors for the feed of it inputs maybe applicated general source.

Follows to note that for ensuring high accuracy measurement should be withstanded definite distance from current sensor till return strip. It is for example, as tocurrent force 5 кA and permissible errors 0.5% this distance should be not less 400 millimeters.

Because the Hall sensor is disposed on some distance r_0 from conductor with current (busbar rectangular cross-section) that is necessary to know dependence the magnetic field strength on any distance from this conductor. We will take busbar rectangular cross-section, transversal section of that has dimensions *d* and *h*, and third size *L*, what lets to consider such conductor as totality direct currents. In the system of coordinates portrayed on Fig. 2, we shall distinguish elementary direct current with section *dxdy* and shall determine using Ampere's circuital law, the magnetic field strength that been created by this element in point with coordinates x_0, y_0. Value of elementary current $di = \frac{idxdy}{hd}$, consequent

$$dH_{полн} = \frac{x_0 - x}{r} = \frac{idxdy}{2\pi rhd},$$

and composing dH_1 and dH_2 are determined by formulae (1) and (2)

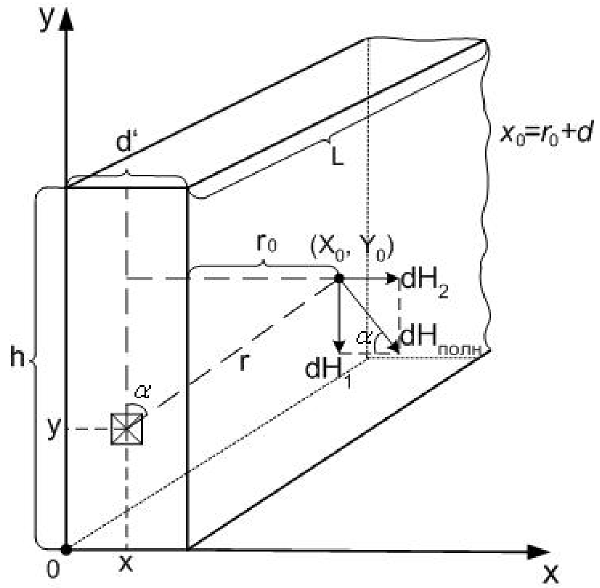

Fig. 2. Computative scheme for determining of the tension of magnetic field

$$dH_1 = dH_{полн} \sin\alpha = dH_{полн} \frac{x_0 - x}{r} = \frac{i(x_0 - x)dxdy}{2\pi rhdr^2}; \tag{1}$$

$$dH_2 = dH_{полн} \cos\alpha = dH_{полн} \frac{y_0 - y}{r} = \frac{i(y_0 - y)dxdy}{2\pi rhdr^2}; \tag{2}$$

Magnetic field strengthes H_1 and H_2, been created busbar, shall receive by integrating of expressions (1) and (2), accordingly as to area *D* – transversal cross-section of conductor

$$H_1 = \iint_D \frac{i(x_0 - x)dxdy}{2\pi r \cdot h \cdot d \cdot r^2} = \frac{i}{2\pi hd} \iint_D \frac{i(x_0 - x)dxdy}{r^2} = \frac{i}{2\pi hd} \int_0^h dy \int_0^d \frac{x_0 - x}{(x_0 - x)^2 + (y_0 - y)^2} dx =$$

$$= -\frac{i}{4\pi hd} \int_0^h dy \cdot \ln\left[(x - x_0)^2 + (y - y_0)^2\right]\Big|_0^d = -\frac{i}{4\pi hd} \int_0^h \left\{ \ln\left[(d - x_0)^2 + (y - y_0)^2\right] - \ln\left[x_0^2 + (y - y_0)^2\right] dy \right\}.$$

Last integral maybe calculated by portions:

$$\ln\left|a^2+t^2\right|dt = t\ln\left|a^2+t^2\right| - 2t + 2a\cdot arctg(t)\,. \qquad (3)$$

As a result applying of formula (3) shall receive:

$$H_1 = \frac{i}{4\pi hd}\cdot\Bigg[2x_0\left(arctg\frac{h-y_0}{x_0} + arctg\frac{y_0}{x_0}\right) - 2\left(d-x_0\right)\cdot\left(arctg\frac{h-y_0}{d-x_0} + arctg\frac{y_0}{d-x_0}\right) -$$

$$-y_0\cdot\ln\frac{\left(d-x_0\right)^2+y_0^2}{x_0^2+y_0^2} - \left(h-y_0\right)\cdot\ln\frac{\left(d-x_0\right)^2+\left(h-y_0\right)^2}{x_0^2+\left(h-y_0\right)^2}\Bigg]\,.$$

Analogously:

$$H_2 = \int\limits_D \frac{i\left(y_0-y\right)}{2\pi hdr^2}dxdy = -\frac{i}{2\pi hd}\int\limits_0^d dx\int\limits_0^h \frac{\left(y-y_0\right)dy}{\left(x-x_0\right)^2+\left(y-y_0\right)^2} =$$

$$= -\frac{i}{4\pi hd}\int\limits_0^d\left[\ln\left(\left(x-x_0^2\right)+\left(h-y_0\right)^2\right) - \ln\left(\left(x-x_0^2\right)+y_0^2\right)\right]dx =$$

$$= \frac{i}{4\pi hd}\Bigg[2y_0\left(arctg\frac{d-x_0}{y_0} + arctg\frac{x_0}{y_0}\right) - 2\left(h-y_0\right)\cdot\left(arctg\frac{d-x_0}{h-y_0} + arctg\frac{x_0}{h-y_0}\right) - x_0\ln\frac{x_0^2+\left(h-y_0\right)^2}{x_0^2+y_0^2} -$$

$$-\left(d-x_0\right)\ln\frac{\left(d-x_0\right)^2+\left(h-y_0\right)^2}{\left(d-x_0\right)^2+y_0^2}\Bigg].$$

Passing on to induction and introducing more convenient parameter $r_0 = x_0 - d$, finally gain:

$$B_1 = \mu_0\frac{i}{4\pi dh}\Bigg[2\left(r_0+d\right)\cdot\left(arctg\frac{h-y_0}{r_0+d} + arctg\frac{y_0}{r_0+d}\right) - 2r_0\cdot\left(arctg\frac{h-y_0}{r_0} + arctg\frac{y_0}{r_0}\right) -$$

$$-y_0\cdot\ln\frac{r_0^2+y_0^2}{\left(r_0+d\right)^2+y_0^2} - \left(h-y_0\right)\cdot\ln\frac{r_0^2+\left(h-y_0\right)^2}{\left(r_0+d\right)^2+\left(h-y_0\right)^2}\Bigg]\,; \qquad (4)$$

$$B_2 = \mu_0\frac{i}{4\pi dh}\Bigg[2y_0\cdot\left(arctg\frac{r_0+d}{y_0} - arctg\frac{r_0}{y_0}\right) - 2\left(h-y_0\right)\cdot\left(arctg\frac{r_0+d}{h-y_0} - arctg\frac{r_0}{h-y_0}\right) -$$

$$-\left(r_0+d\right)\cdot\ln\frac{\left(r_0+d\right)^2+\left(h-y_0\right)^2}{\left(r_0+d\right)^2+y_0^2} + r_0\ln\frac{r_0^2+\left(h-y_0\right)^2}{r_0^2+y_0^2}\Bigg]\,. \qquad (5)$$

Then the value of the complete induction of field in point with coordinates $\left(x_0, y_0\right)$:

$$B_{полн} = \sqrt{B_1^2+B_2^2}\,.$$

It is evident, what if measurement is performed in point with ordinate $y_0 = h/2$, that

$$B_1 = \mu_0\frac{i}{4\pi dh}\Bigg[4\left(r_0+d\right)\cdot arctg\frac{h}{2\left(r_0+d\right)} - 4r_0\cdot arctg\frac{h}{2r_0} - h\cdot\ln\frac{4r_0^2+h^2}{4\left(r_0+d\right)^2+h^2}\Bigg],\ B_2 = 0 \text{ и } B_{полн} = B_1\,.$$

Owing to the presence of this dependence becomes the possible determining of current value in conductor on given distance from the Hall sensor. Maybe decided opposite task – as to known current value and distance from conductor maybe determined induction. Specifically, as to this provided Ingulet's ore-dressing and processing enterprise, as to expressions (4), (5) was performed calculation, results which are led below. The initial data: *d=5* millimeters, *h=35* millimeters, r_0*=2* millimeters, *i=4* kiloampere. As a result calculation induction composed $B=116$ gauss or $B=0{,}0116$ tesla. In deciding of opposite task having accepted induction equal $B=135$ gauss, in the same basic data current value is received equal *i=1,63* kiloampere. For these basic data qualitative understanding picture of the magnetic field strengthes round busbar with current, mentioned on Fig. 3.

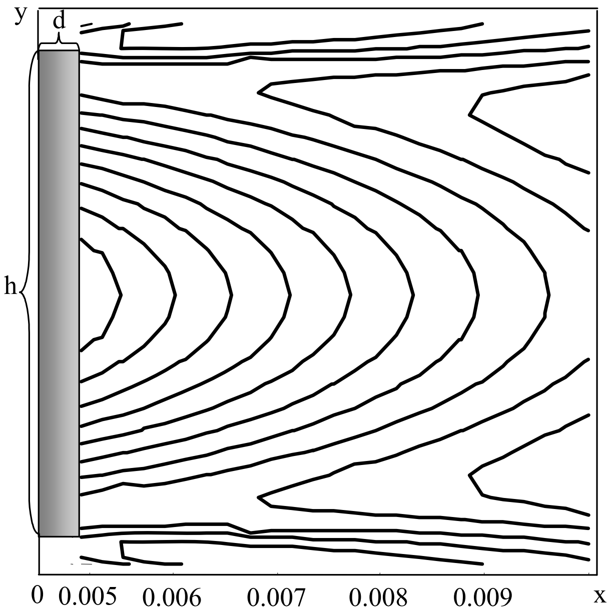

Fig. 3. The distribution of the magnetic field strengthes round busbar with current

Conclusions. From the comparative analysis of the characteristics of induction current transformers and the Hall sensors evident, that the last have the row of advantages in given current range. Characteristics that adduced by manufacturing plants are received for definite distance from conductor till sensor which not always acceptably in circumstances of manufacturing. But owing to dependences (4) and (5), is we received the possibility of the quick calculation of current value in conductor as to the indications of sensor situated on arbitrary distance.

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