The impact of mutual position of joints that generate a bipolar field on the decay of the components of the electromagnetic field's vector

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Abstract. In the article the influence of mutual position of the upper joint in relation to the lower one on the decay of the electromagnetic field was presented. Moreover, the indirect measurement method was depicted, by means of which the measurements were taken on the surface of the contact circuit. This method enables the simultaneous measurement of all the components of the vector of the electromagnetic field.

1 Methods of measurement of the electromagnetic field

The axial magnetic field generated by the coil's joints can be measured by concentrically arranged coils placed in the spaces between the joints. In these coils during the flow of the current through the contact circuit (fig.1) the tension is induced. The value of the tension measured in the particular coils allows to calculate, on the basis of relations (1) the value of the electromagnetic induction B in relation to the radius of the coil on the joint's surface [1]. Analysing the equation (1), it can be observed that the tension, or more precisely the difference of tensions between the subsequent coils, is the measure of the electromagnetic field and can be described with the formula:

$$V_n = -S_n d \frac{B_n}{dt} \tag{1}$$

where: Vn-the tension induced on the n-coil, Sn-the surface of the joint comprised by the n-coil, Bn-the density of the electromagnetic field's stream. The examples of the arrangement of the coils and measuring systems are presented in picture 1. While measuring the joints were connected with copper rod and the coils were arranged concentrically in such a way, so the field does not influence on the measured value of the tension. (fig.1a) [2] [3]. The calibration of coils was made in the field generated by the special and big enough solenoid in such a way, to obtain a homogenous field on the surface of embraced by the calibrated coil.

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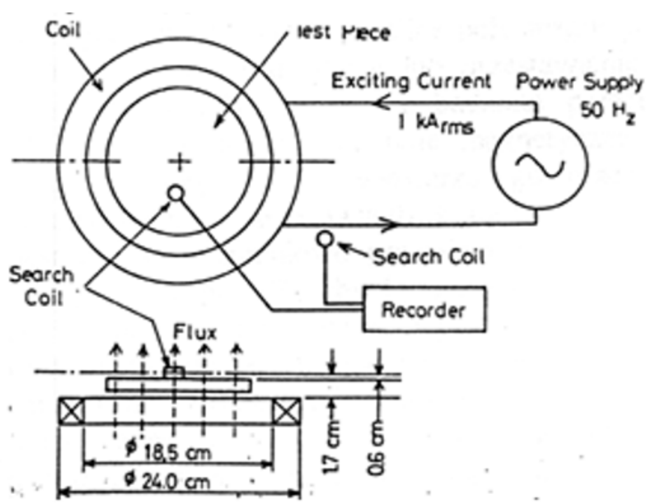

Fig 1a. The examples of measuring the electromagnetic field: with the use of concentrically placed coils.

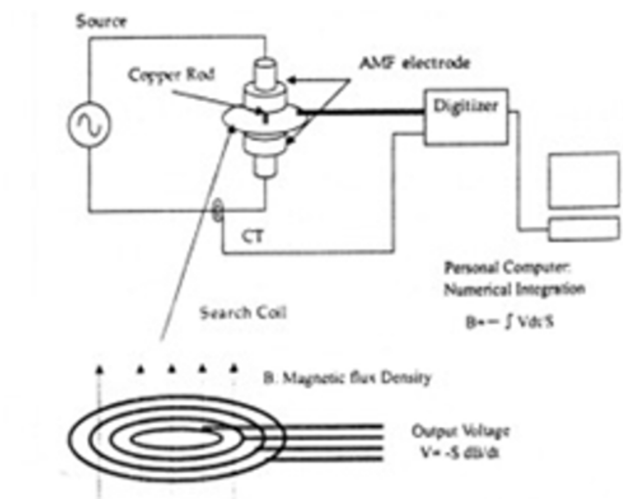

Figure 1b. The examples of measuring the electromagnetic field with the use of the so called measuring probe.

The endings of the coil were screwed in a way to eliminate the unfavourable impact of the wires connecting the coil with the measuring system [4]. The other method to measure the decay of the electromagnetic field between the surfaces of the coils was presented in pic.1b. In this case to measure the decay of the field the probe was used. The measurement was taken by the use of the probe placed on the surface of the joint, and the measured tension was compared with the tension of the coil of the reference system, which was placed outside the measuring system [5]. In the case of measuring the field for the coil systems generating the bipolar field it is crucial to use the method from pic. 1b, the so called 'the measuring probe method'. To the laboratory measuring a recorder HIOKI type „8841/42 MEMORY HiCORDER was used. The parameters of this device allow to collect the appropriate amount of the measuring and satisfying accuracy of the measurements taken [6]. With the view to measuring the electromagnetic induction in the spaces between the joints, the measuring probe was constructed, which consisted of three coils. (fig.2).

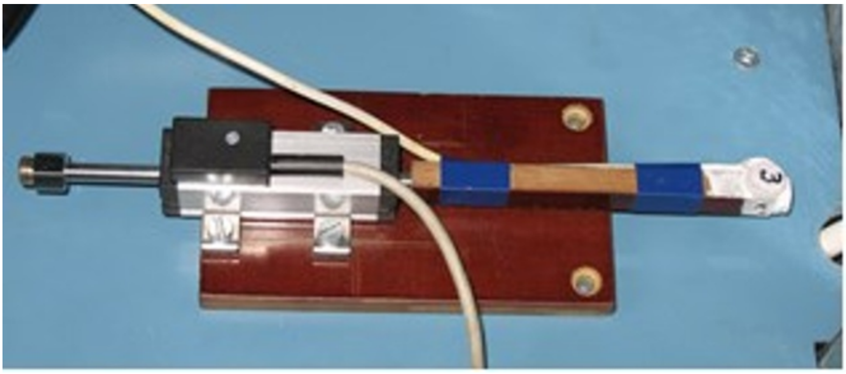

Fig 2. The measuring probe.

The measuring system with probes was placed in the Faraday's cage in order to eliminate the influences from the outside [7] [8]. In the used measuring methods, the quantity which is directly measured is the tension induced in the measuring coils. These coils, during the flow of the current through the coil system, are placed in spaces between the joints and are put from the outside to the centre of the joint plate. The measurement of the tension induced on the coil is made by HIOKI recorder with the frequency of 100 ms. It allows to get approximately 25 thousand measuring points for each position of the measuring probe. This probe in the initial phase of measuring each of the joint system is placed in the zero position (0^0) and is moved successively every 15^0 around the joint plate [9].

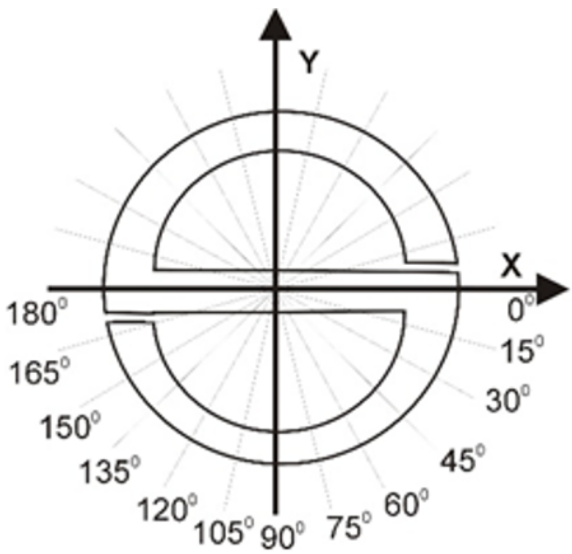

Fig 3. Diagram of contact with angles.

In case of measurements of the joint systems the measured quantity is the tension induced in the measuring coils and the desired quantity is the value of the electromagnetic induction, precisely the decay of the electromagnetic induction on the surface of the joint plate [10 -11]. While taking measurement, the frequency of the recorder was of 100 ms, which with mains power supply gives 200 samples per period. We can count the electromagnetic induction by transforming the formula 1 [12]. The final formula to calculate the electromagnetic induction measured for 50kA is presented below:

$$B = \frac{\sum_{i=1}^{200} abs(u - offset) * f_p}{4 * z * S} * \frac{\sqrt{2} * 50 * 10^3}{\max(abs(I))} \tag{2}$$

$$offset = \frac{\min_{1 \div 200}(u) + \max_{1 \div 200}(u)}{2} \tag{3}$$

Where: u- the tension measured in the measuring coils, z=50 – the number of measuring coils rolls, S=59 mm2 – the surface of the measuring coil, fp – the frequency of recorder, s sampling, I- the current flowing through the coils system.

2. The results of measuring of particular coil systems

The main goal of the measuring is to point that there is a possibility of improving the evenness of the decay of the electromagnetic field thanks to the choice of construction and placing the joints to each other in the vacuum chamber of the off switch in a way to get possibly the best conditions of the decay of the electromagnetic field as well as the conditions of extinguishing of the arc [13]. Three components of the field were measured: axial component, perimeter component and the radius component, measuring them by three probes simultaneously from the outside edge of the joint to its center. Picture 3 shows the joints constructions which had undergone the research.

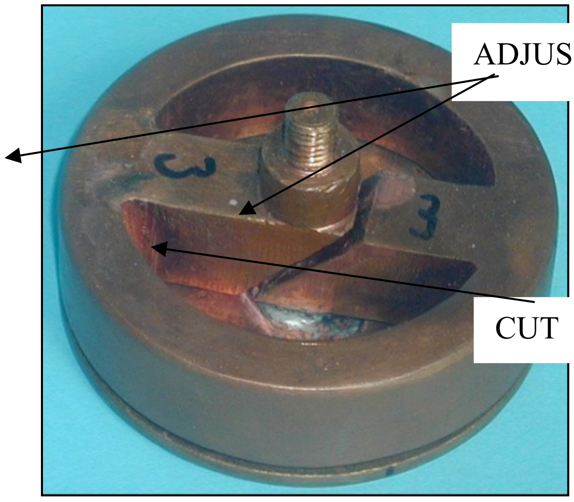

Fig 4. The joint constructions used in the research the bipolar joint no.1.

For the joint in picture 4 there was a measurement taken for four positions. In picture 5 there are presented the positions of joints in which the channeling of the upper joint is precisely above the channeling of the lower joint.

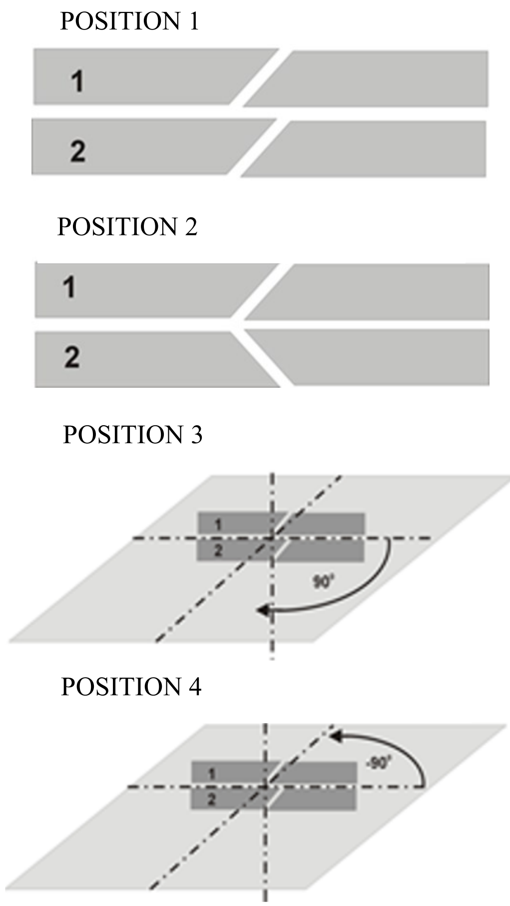

Fig 5. The positions of the joint system for which the measurements were taken.

Position 1. The highest values for this position is reached by the radius component, and the smallest by the perimeter component of the electromagnetic induction B. The axial component of the induction has an even decay on the surface of the joint. The highest values are reached for the central angles of measurement, that is from 60^0 to $120^{0.}$ The smallest values are reached by the angles of 0^0 and $180^{0.}$ While the values of the maximum courses increase, these points (maxima) come to the central part of the joint plate. The courses for the perimeter component are increasing when moving to the centre of the joint plate. In the central part of the measured area the value of the induction are slightly smaller and they create something like a ‘saddle’. On the external part of the joint plate from 30 to 20 mm, the values of the induction increase in the course of moving from 0^0 to $180^{0.}$ In the central part of the joint the system is changing and the highest values are reached by the angles from 0^0 to 30^0. It was also observed that the smallest differences between the values on the outer side of the joint occur for the angles from 90^0 to 180^0. The highest values are for the course of 180^0, that is from 100 mT on the outer part of the joint to 300 mT in the central part of the joint.

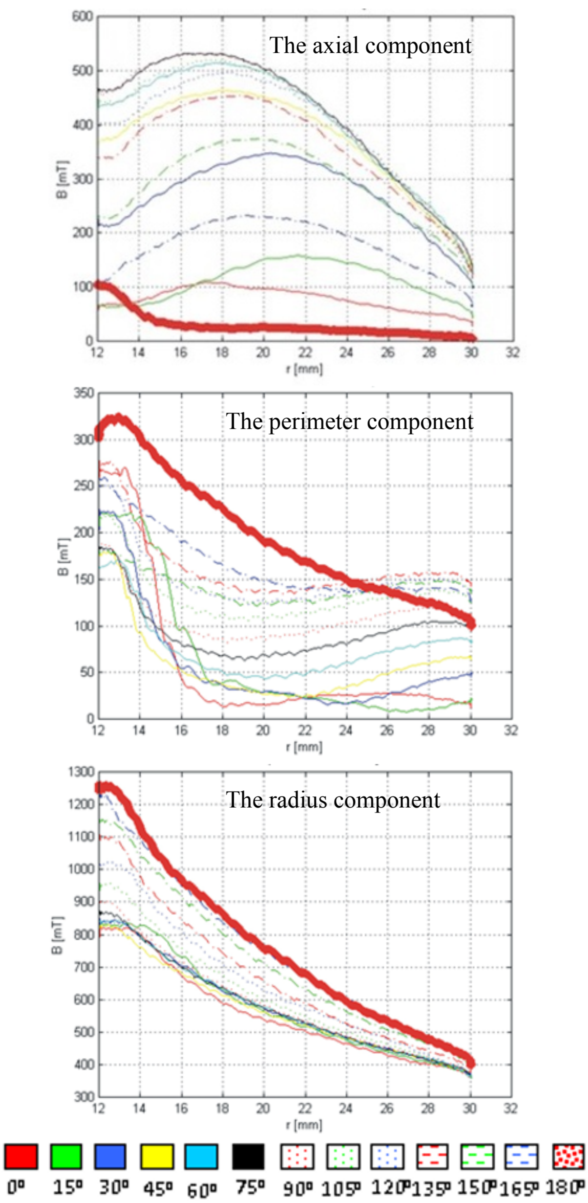

Fig. 6: The course of the components of the vector of electromagnetic induction for all the measurement angles – joint pic.3a, arrangement 1.

As it was mentioned before the axial component of the induction reaches the highest values. The courses for all the measuring angles begin with almost one and the same point. The values of induction have their increasing character (almost linear) in the direction from the outer to the central part of the joint. The value of the induction is increasing alongside with the measuring angle from 0^0 to 180^0.

Position 2. All the courses for the axial component start with the same value of the induction (approx. 25-30 mT). The highest values are observed for the 135^0 angle. When crossing this point, the courses subsequently decrease in their values. In the range of measurement, which is 12 mm to 30 mm (pic. 3), in the courses for the starting measuring angles – 0-75^0 – there is a point of inflexion. For the bigger angles the inflexion points are of increasing character.

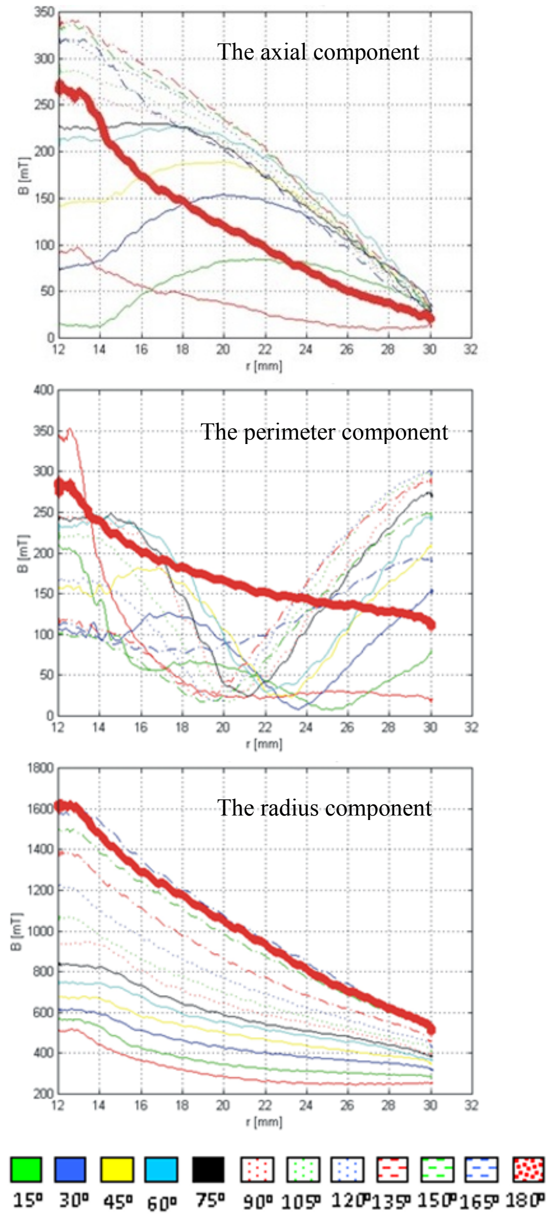

Fig. 7: The course of the components of the vector of electromagnetic induction for all the measurement angles – joint pic.3a, arrangement 2.

For the majority of the measuring angles the perimeter component of electromagnetic induction reaches its minimal value in the central part of the measuring area, in the distance of 19 to 22 mm. However, there are exceptions for angles of 0^0 and 180^0. The majority of courses will reach their maximal value on the external part of the joint plate. The radius component, just as in the previous cases reaches its highest values in comparison with the rest of the components of this position. The lowest values are for the 0^0 angle, later with the increase of the angle, the courses reach higher values. The maximal are for the angles of 180^0.

Position 3. The courses for the axial component reach maximal values in the central part of the measuring area. The highest are for the initial measuring angles; 0^0, 15^0 and 30^0. The lowest course was for the 90^0 angle. From 0^0 to 90^0 the courses were gradually decreasing their values, to increase again when crossing the point of 90^0 angle.

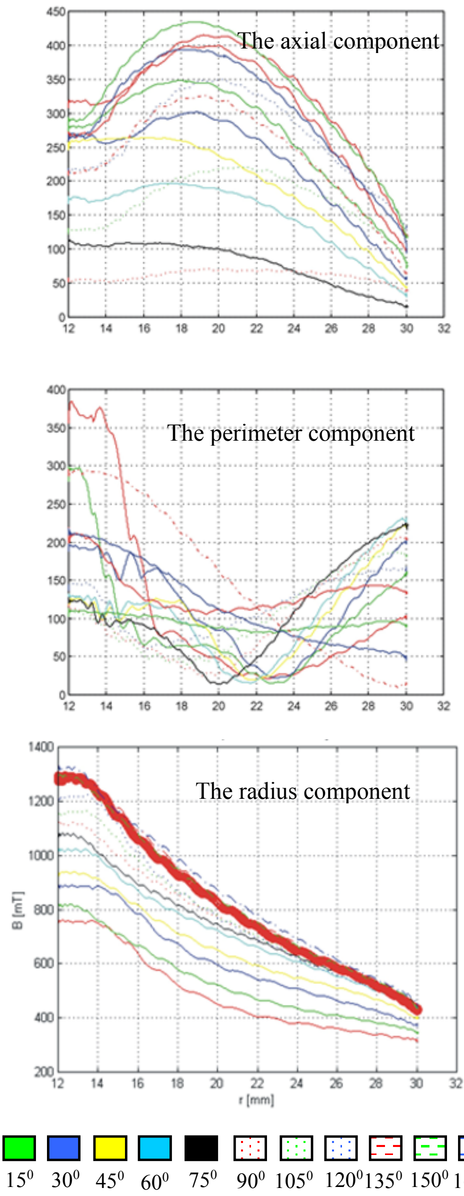

Fig. 8: The course of the components of the vector of electromagnetic induction for all the measurement angles – joint pic.3a, arrangement 3.

Similarly to the position depicted above, here the perimeter component has the most irregular courses. In the central part of the measuring area, the majority of courses reach their minimums. The highest values for this position were reached by the radius component, however these are still lower than in position 2. The lowest values are for the course of 0^0, then with the increase of the measuring angle the value of induction rises, to reach its maximum in 180^0 angle.

Position 4. The axial component for this position is similar as in position 3. The values reaches by this component are slightly higher in comparison with position 3. Thus in this case the perimeter component of the electromagnetic induction has its minimum point in the centre of the measuring sphere.

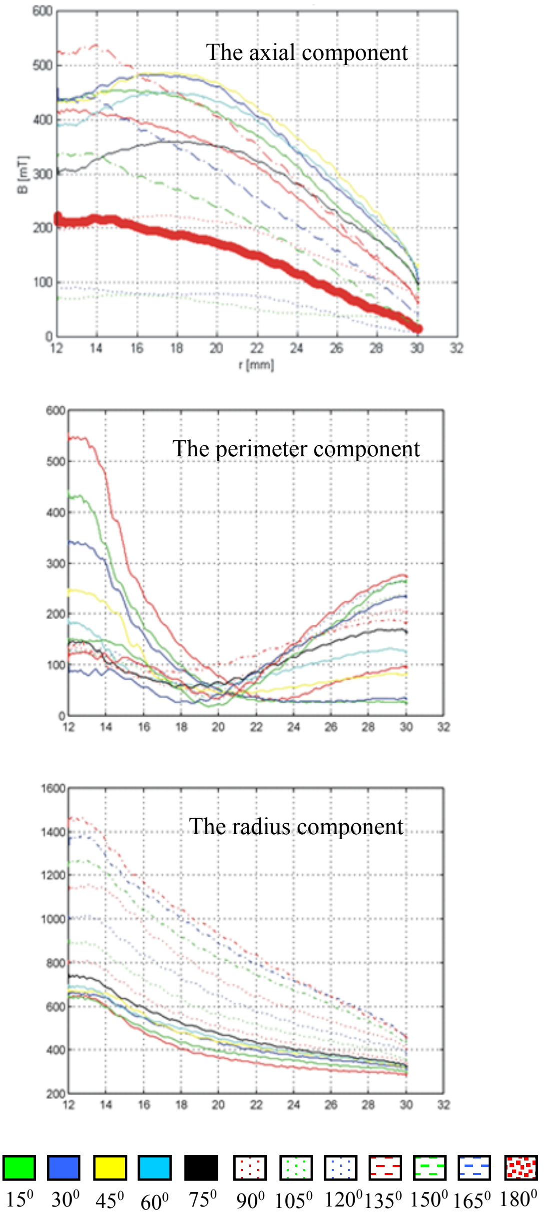

Fig. 9: The course of the components of the vector of electromagnetic induction for all the measurement angles – joint pic.3a, arrangement 4.

The radius component behaves likewise as in position 3. In the whole measuring area it is increasing. The values taken by the particular measuring points on the joint plate increase alongside with the increasing measuring angle. Thus it can be concluded that for both position 3 and 4 the axial component of induction has even decay on the whole surface of joint and reaches its maxima at the moment when perimeter component has its minimal values.

3. Remarks and conclusion

The results of the measurements taken on particular joints used in the off switches of vacuum chambers proved that there is a considerable influence of the arrangement of joints among each other on the decay of the components of the electromagnetic field among the joints. In case of bipolar joints, the influence if the joint's arrangement is visible and there is a possibility to choose the decay of the electromagnetic field in the post favourable way. The bipolar joints (acc.pic. 3). The measurements were also taken for their arrangement 'supply-supply', and 'supply-supply+90^0'. It was unanimously agreed that the arrangement of the joints among one another, especially of such a construction, has a crucial impact on the decay of the vector of the electromagnetic induction. It was also observed in the courses of the axial component of the electromagnetic field. In the further research it is hoped to carry out measurements for other contact circuits, e.g. from pic. 3b, contact circuits generating SADE field and other new constructions.

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