Bogdan KWIATKOWSKI[1], Jacek BARTMAN[1]

University of Rzeszow, Faculty of Mathematics and Natural Sciences Department of Computer Engineering (1)

doi:10.15199/48.2019.02.13

The influence of mutual position of joints generating a bipolar field on the decay of the components of the vector of electromagnetic field

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..*

Streszczenie: *W artykule przedstawiono wpływ wzajemnego położenia styku górnego względem styku dolnego na rozkład pola elektromagentycznego. Ponadto opisano metodę pomiarową pośrednią za pomocą której pozyskano pomiary na powierzchni układu stykowego. Metoda ta pozwala na jednoczesny pomiar wszystkich składowych wektora pola elektromagnetycznego. (**Wpływ wzajemnego ustawienia styków generujących pole bipolarne na rozkład składowych wektora pola elektromagnetycznego**)*

Keywords: Electromagnetic field, bipolar switches, axial, radius and perimeter component of electromagnetic field.
Słowa kluczowe: Pole elektromagnetyczne, styki bipolarne, promieniowa, osiowa i obwodowa składowa pola elektromagnetycznego

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. Analyzing 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:

$$V_n = -S_n d \frac{B_n}{dt} \quad (1)$$

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.

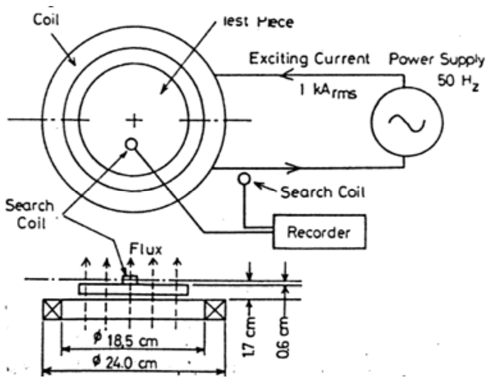

Fig. 1a. The examples of measuring the electromagnetic field: with the use of concentrically placed coils.

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) [8] [9].

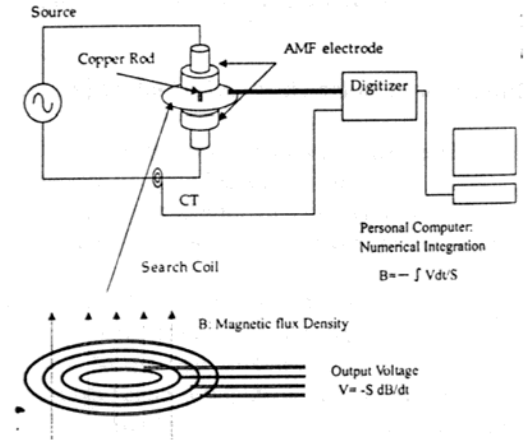

Fig. 1b. The examples of measuring the electromagnetic field with the use of the so called measuring probe

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. The endings of the coil were screwed in a way to eliminate the unfavorable impact of the wires connecting the coil with the measuring system [10]. 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. 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 [5]. 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).

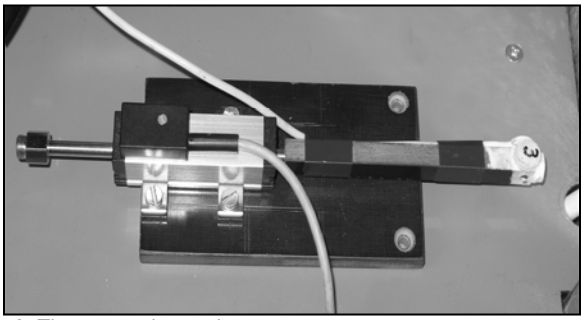

Fig. 2. The measuring probe.

The measuring system with probes was placed in the Faraday's cage in order to eliminate the influences from the outside [4] [6]. 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.

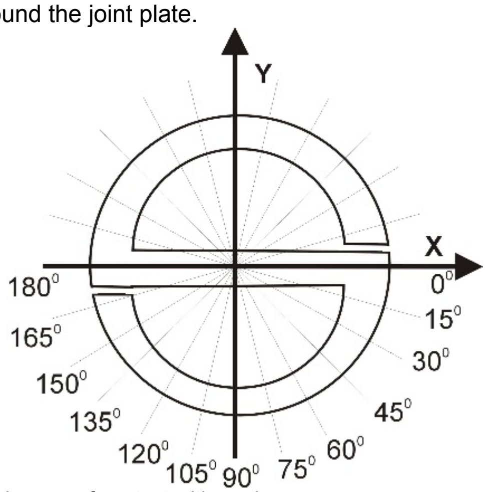

Fig. 3. Diagram of contact with angles

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 [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. Taking into account that matrixes with the values of induced tensions on the coils are enormous (25000x6 size) there is a necessity to calculate and choose very precise values to formula 1[1]. The final formula to calculate the electromagnetic induction measured for 50 kA is presented below:

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

(3) $$offset=\frac{\min\limits_{1\div200}(u)+\max\limits_{1\div200}(u)}{2}$$

where: u- the tension measured in the measuring coils, z = 50 – the number of measuring coils rolls, S = 59 mm^2 – the surface of the measuring coil, f_p – the frequency of recorder, s sampling, I- the current flowing through the coils system.

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 [9]. 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.

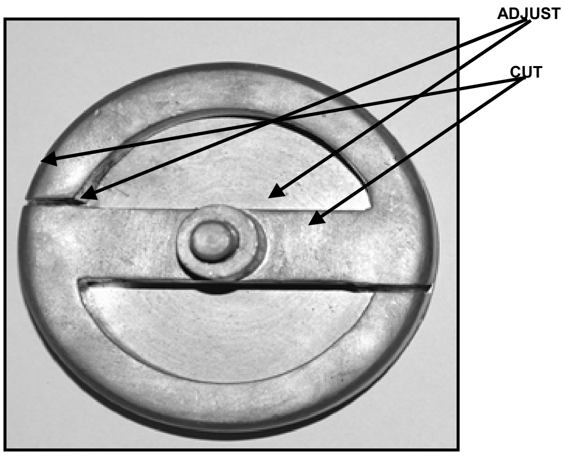

Fig. 4. The joint constructions used in the research a) the bipolar joint no.1.

For the joint in picture 4 there was a measurement taken for the two arrangements. The first is with the supply placed pararerlly to each other and the second is with the supply of the lower joint moved with 90^0 (fig.5). The results for the first arrangement.

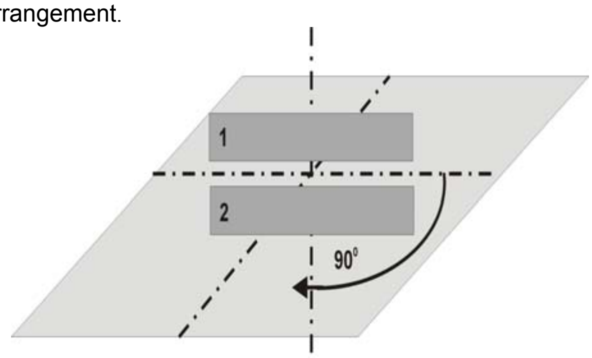

Fig.. 5: mutual arrangement of the joints moved with 90^0.

As it could have been suspected the axial component of the vector of the electromagnetic field is increasing alongside with reaching the middle point of the contact circuit. The values of the perimeter component of the electromagnetic induction are increasing with the increase of the measuring angle. The highest values are reached for the angles from 135^0 to 180^0 and in the central part of the joint plate where they are of 580 mT.

Figure 7 shows some waveforms for electromagnetic field for selected measuring angles at setting 1 according to figure 3.

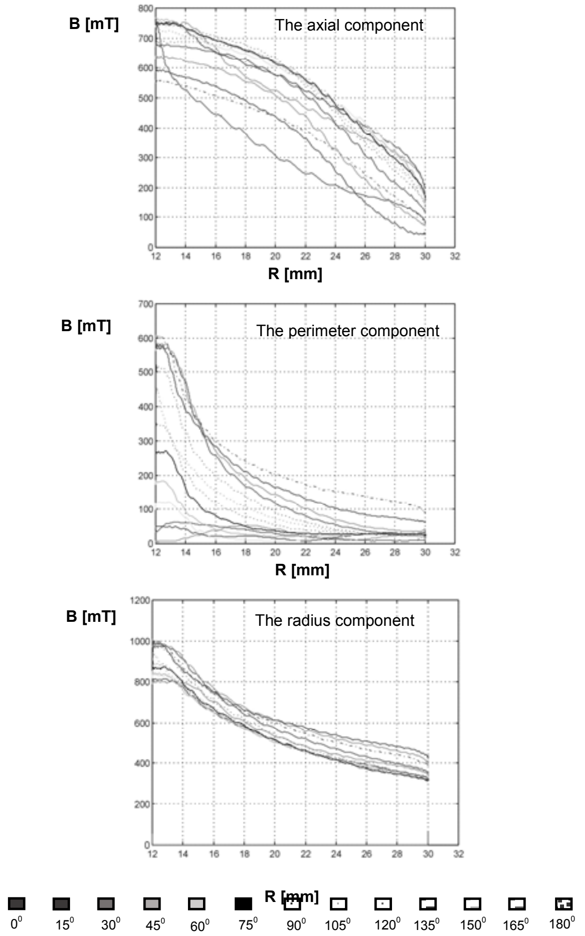

Fig.6. The course of the components of the vector of electromagnetic induction for all the measurement angles – joint fig.4, arrangement 1.

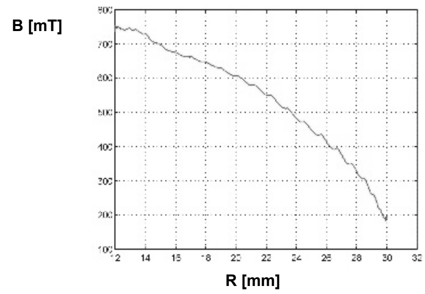

Fig.7a. The course of the components of the vector of electromagnetic induction for the selected measuring angle the axial component angles 45^0.

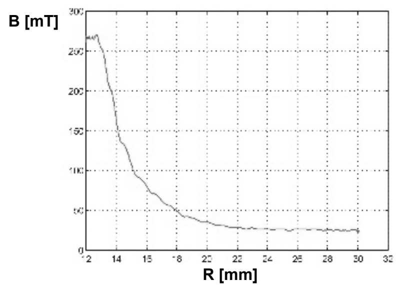

Fig..7b. The course of the components of the vector of electromagnetic induction for the selected measuring angle the perimeter component angles 75^0.

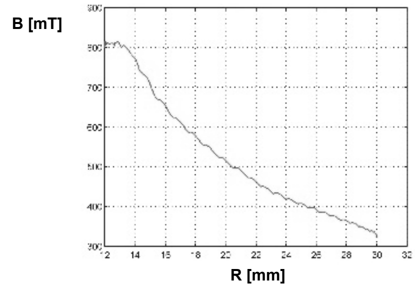

Fig. 7c. The course of the components of the vector of electromagnetic induction for the selected measuring angle the radius component angles 30^0.

The results for the second arrangement of joints. The axial component of the induction reaches similar values when compared with the arrangements described above. The highest values are for the angles of 45^0 and 135^0, which is the central part of each of the quarters of the contact circuit. In some characteristics it has been observed a flattening, bending of the courses towards the center of the contact circuit. It is connected with the mutual arrangements of the joints. The perimeter component is similar in its character in comparison with the arrangements described above, however, the value of induction it can reach are considerably higher.

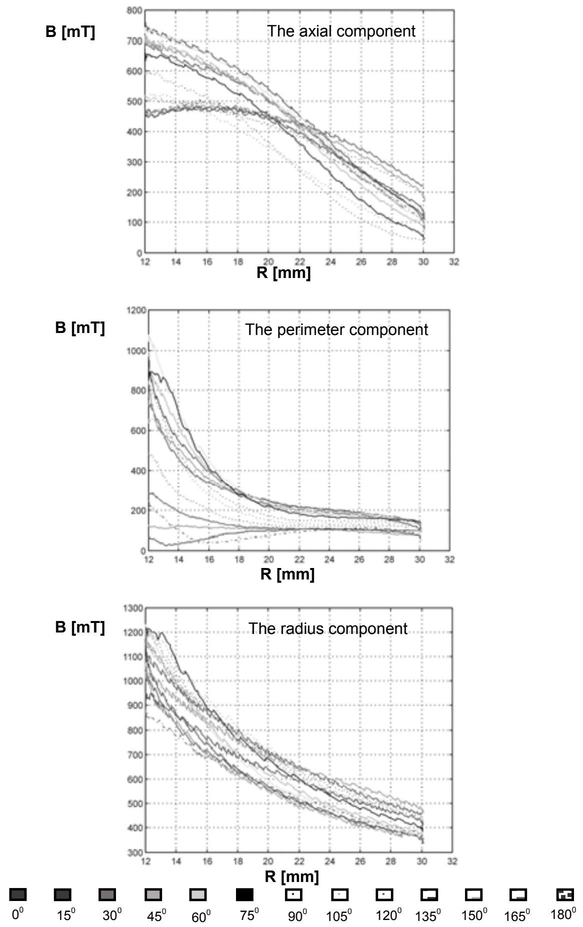

Fig.8: The course of the components of the vector of electromagnetic induction for all the measurement angles – joint fig.4, arrangement 2.

The highest values are for angle of 45^0, the lowest for 180^0. The radius component reaches the highest values in comparison with different arrangement presented for this joint. The highest are for angles from 75^0 to 105^0. For the arrangement, where the joints are moved with 90^0 to each other, the perimeter and radius component of the electromagnetic field increased. Figure 9 shows some waveforms for electromagnetic field for selected measuring angles at setting 2 according to figure 3.

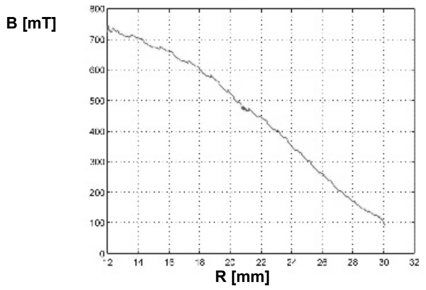

Fig.9a. The course of the components of the vector of electromagnetic induction for the selected measuring angle the axial component angles 45^0.

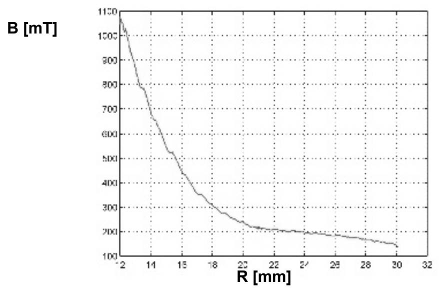

Fig.9b. The course of the components of the vector of electromagnetic induction for the selected measuring angle the perimeter component angles 45^0.

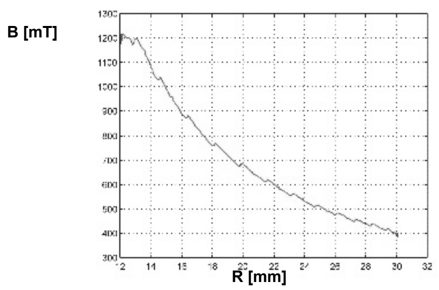

Fig..9c. The course of the components of the vector of electromagnetic induction for the selected measuring angle the radius component angles 75^0.

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 chose 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.

***Authors**: dr inż. Bogdan Kwiatkowski, University of Rzeszow, Faculty of Mathematics and Natural Sciences Department of Computer, ul. Pigonia 1, 35-959 Rzeszow, E-mail: bkwiat@ur.edu.pl; dr inż. Jacek Bartman, University of Rzeszow, Faculty of Mathematics and Natural Sciences Department of Computer, ul. Pigonia 1, 35-959 Rzeszow, E-mail: jbartman@ur.edu.pl.*

LITERATURA

[1] Sikora R.: Teoria pola elektromagnetycznego, *Wydawnictwo Naukowo-Techniczne*, Warszawa 1985.
[2] Harald Fink, Marcus Heimbach, Wenkai Shang: Vacuum Intrerrupters with Axial Magnetic Field Contact Based on Bipolar and Quadropolar Design, *IEEE 19 International Symposium on Discharges and Electrical Insulation in Vacuum, Xian-2000*.
[3] Brandt S.: Analiza danych. Metody statystyczne i obliczeniowe, *Wydawnictwo Naukowe PWN, Warszawa 1998*.
[4] C.E. Bouwmeester, M.B.J. Leusenkamp (Holec Medium Voltage) and R.W.P. Kerkenaar, W.F.H. Merck and G.C. Damstra (Eindhoven University of Technology): Investigation of vacuum circuit breakers for high currents, *IEEE 19 International Symposium on Discharges and Electrical Insulation in Vacuum, Xian-2000, China.*
[5] Dahlquist G., Björck A.: Metody numeryczne, *PWN, Warszawa 1993.*
[6] B. Fenski, M. Lindmayer: Vacuum Interrupters with Axial Magnetic Field and Contacts, 3-d. Finit Element Simulation and Switching Experiments, *IEEE Transaction on Dielectrics and Electrical Insulation Vol.4 1997 pp. 407.*
[7] Grodziński A., Szymański A., Sibilski H., Dzierżyński A., Borowski P., Hejduk A., Krasuski K., Badania styków z osiowym polem magnetycznym w rozbieralnej komorze próżniowej. *Elektronika Konstrukcje, Technologie, Zastosowania, nr 8 (2011), 42-44.*
[8] Sibilski H., Dzierżyński A., Hejduk A., Krasuski K., Grodziński A., Szymański A., Badanie właściwości magnetycznych styków komór próżniowych, Materiały konferencyjne - *Łączniki 2010, 7-16.*
[9] Sibilski, H. Dzierżyński, A. Berowski, P. Błażejczyk, T. Hejduk, A. Krasuski, K. Grodziński, A. Szymański, A. : Badanie styków dla łączników próżniowych średniego napięcia, *Przegląd Elektrotechniczny 2012, 193-196*
[10] J. Bartman, Accuracy of reflecting the waveforms of current and voltage through their spectrum determined by the standards regulating measurements, *in Revue Roumaine des sciences techniques - Serie Electrotechnique et Energetique, vol 61/4, 2016, pp. 355-360.*
[11] A. Koziorowska, J. Bartman, The influence of reactive power compensation on the content of higher harmonics in the voltage and current waveforms, *Przegląd Elektrotechniczny, vol 90/1, 2014, pp. 136-140.*