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(54) **METHOD OF DETERMINING THE LENGTH OF THE ELECTRODES OF A SUBMERGED ARC FURNACE AND DETERMINING THE POSITION OF THE ELECTRODES RELATIVE TO THE FURNACE HEARTH, AND A SYSTEM FOR IMPLEMENTING THIS METHOD**

(57) A method for determining the length of the electrodes of a submerged arc furnace and the position of those electrodes relative to the furnace hearth, characterised in that the voltage of the electrodes is measured between the bottom of the furnace hearth and the moving terminals on the electrode casings in their upper position and the current derivatives measured on the secondary side of the transformer to determine the electrical parameters of the area immediately surrounding the electrodes, following which the length of the electrodes is calculated, with measurements being taken at the time $i_{ek}(t_k)$ at which both the electrode current $i_{ek}(t_k)$ and the desired voltage waveform on the equivalent resistance of the peri-electrode area $u_{ek}(t_k)$ take the value of zero. The invention also comprises a measuring system for determining the resistance of the electrodes (1, 2, 3) of a submerged arc furnace (4) supplied from a furnace transformer (5), characterised in that it comprises a Rogowski coil system (RC1, RC2, RC3) for measuring the current derivatives in the high-current line supplying the electrode array (1, 2, 3) and an array of voltmeters (7, 8, 9) for measuring the voltage between the counter-electrode and the predetermined moving terminal of the a given

electrode (1, 2, 3) on the electrode casing the upper position of the electrodes.

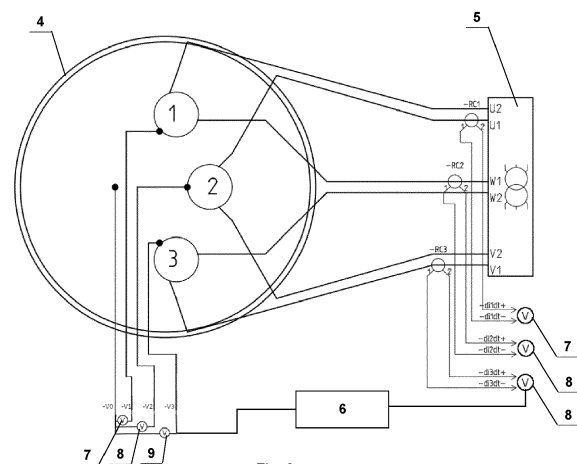


Fig. 3

Description

[0001] The invention relates to a method of determining the length of electrodes in submerged arc furnace with electrodes submerged in the charge to generate an arc in the working area, and for determining the position of the electrodes relative to the bottom of the furnace hearth. The present invention also relates to a system for implementing said method.

[0002] From the Polish patent description No. PL100928 B1, there is known a method for determining the depth of submersion of the electrodes in the charge of a submerged arc furnace (and the system for determining it) based on the measurement of the reactance determined by the measurement of the electrode current and reactive power between the electrode holder and the liquid alloy at the furnace bottom.

[0003] From the US patent description No. US5687187 A, there is known a method for determining the length of electrodes in submerged arc furnaces, in which the length of the electrodes is measured using numbered gas tanks placed intermittently in the electrode, said gas tanks being melted during operation, and the subsequent gas emission measured by spectroscopic methods. Subsequent emissions, consistently with the interval melting of the tanks and the continuous wear of the self-baking electrodes, allow the position of the tip of the electrodes in the charge to be determined relative to the bottom of the furnace hearth.

[0004] Furthermore, the European patent No. EP1099087 B1 discloses a method in which the determination of the position of an electrode tip in a charge is determined using an estimation of the maximum and minimum range of electrode positions through mathematical operations, extended by methods of manual probing, weighing of the electrodes or by measuring the vertical movement of the electrodes.

[0005] The above-mentioned documents do not take into account the variability of the arc burning parameters in the reductive atmosphere, as well as numerous additional electrode performance parameters such as self- and mutual induction of the electrode system, including the influence of the electrode casing, and therefore do not provide a satisfactory solution to the problem.

[0006] On the other hand, from the Polish patent document No. PL220417 B1, there is known a method of identification of the resistance and the power of active working areas of a submerged arc furnace, especially for the production of ferrosilicon, based on measuring the instantaneous value of the current and phase voltage of the electrode, determining the value of the amplitude, phase of the current and the phases of the successive harmonic components during a measuring period of 20 ms, from which the resistances of the working area zones are calculated, including the resistances of the charge and the electric arc, using equivalent diagrams, assuming the resistance of the charge secondary circuit, the electric arc and the resistance of the sub-electrode zone to be constant values in each period of the supply voltage.

[0007] The purpose of the invention was to develop a method for determining the length of electrodes in a submerged arc furnace. Determining the electrode length values in real time is extremely difficult due to the very high operating temperatures of the furnace (>2000 K), high temperature of the arc itself and the submersion of the electrodes in the charge. Therefore, it becomes necessary to determine the operating parameters of furnace systems based on measurable values of the process input components and their correlation with the effects on the working areas using physico-technical simulation models.

[0008] Determining the active power in the electrode areas of electric furnaces requires accurate identification of the voltage waveforms at the equivalent resistances of the furnace. The starting point for determination of the voltages at the equivalent load resistances at the electrode zones of a submerged arc furnace for the production of ferroalloys are the measurements of the instantaneous values of the electrode currents $i_{e1}(t)$, $i_{e2}(t)$, $i_{e3}(t)$ and the phase voltages measured between the furnace counter-electrode and the moving terminals on the electrode casings in the upper positions of the electrodes $u_{p1}(t)$, $u_{p2}(t)$, $u_{p3}(t)$ (fig.1).

[0009] Determination of these voltages is possible if one determines the voltages induced in the measuring path, i.e. at the individual electrodes as well as at the extension of the electrode casings, under the influence of the currents of the individual electrodes and the currents of other close parts of the high-current lineduct, especially those parts that are run parallel to the electrodes in their vicinity. To solve this task, a circuit model of the system is used, taking into account the aforementioned non-linear resistances of the working charge area as well as the resistances of the electrodes and the self and mutual induction coefficients of the individual phases (fig. 2).

[0010] According to the designation of an equivalent diagram, the measurement voltage at the kth electrode is expressed by the following formula:

$$u_{pk}(t) = u_{ek}(t) + R_{ek}i_{ek}(t) + \sum_{l=1}^3 M_{kl} \frac{di_{ek}(t)}{dt} \quad ; \quad (k = 1,2,3) \quad (A)$$

where:

$R_{ek} = R_e(h_k, R_e)$ resistance of the k th electrode with the length of h_k and the diameter of De ;

M_{kl} coefficients of self-induction $k=l$ and mutual induction for $k \neq l$ electrode array, $u_{ek}(t)$ -the desired instantaneous value of the voltage on the equivalent resistance of the k th phase of the area immediately surrounding the electrode.

[0011] As shown in fig. 1, the coefficients of self-induction and mutual induction M_{kl} depend on the length of the individual electrodes h_k as well as the coordinates w_k of the position of the voltage measuring point at the extension of the electrode casing of the length h_p from the contact clamps. As the lengths of the electrodes change within certain limits during the process and the automation system changes the position of the measuring point relative to the point of reference, the inductance values M_{kl} also change. It is therefore necessary to estimate these parameters during each supply voltage period.

[0012] A simplifying assumption is introduced, $M_{12} = M_{23} = M_{31} = M$ for $k \neq l$, and the set of equations is reduced as follows:

$$u_{pk}(t) = u_{ek}(t) + R_{ek}i_{ek}(t) + L_{zk}\frac{di_{ek}(t)}{dt} \quad (k = 1,2,3) \quad (B)$$

$$L_{zk} = M_{kk} - M$$

[0013] For such a case, there is known a method for estimating the equivalent phase inductance, which consists in decomposing equation (B) at the time of t_k at which both the electrode current $i_{ek}(t)$ and the desired voltage waveform on the equivalent resistance of the area near the electrode $u_{ek}(t)$ take the value zero:

$$u_{ek}(t) = 0 ; \quad i_{ek}(t) = 0 ; \quad (k = 1,2,3) \quad (C)$$

[0014] In such a case

$$L_{zk} = \frac{u_{pk}(t_k)}{i'_{ek}(t_k)} ; \quad (k = 1,2,3) \quad (D)$$

$$i'_{ek}(t_k) = \left. \frac{di_{ek}(t)}{dt} \right|_{t=t_k}$$

where $i'_{ek}(t_k)$ - current derivative of k - phase at the moment of crossing zero value

[0015] Thus, after each period of $T=20$ ms of supply voltage, the voltage waveform on the equivalent resistance of the working area $u_{ek}(t)$ of the individual phases can be reconstructed as follows:

$$u_{ek}(t) = u_{pk}(t) - R_{ek}i_{ek}(t) - \frac{u_{pk}(t_k)}{i'_{ek}(t_k)} \frac{di_{ek}(t)}{dt} \quad (k = 1,2,3) \quad (E)$$

[0016] Measurement and simulation tests have proven that this type of voltage identification on the equivalent resistances of the working areas of ferrosilicon furnaces is correct. However, such states of asymmetry on the furnace have been observed where the assumption of equality of magnetic coupling between phases is unavoidable.

[0017] It can be seen that only three electrode lengths that change during the process are unknown. As shown in fig. 1, self- and mutual inductance matrix can be considered as a function of the three length variables h_k . A formula for mutual inductance of two parallel wires with axes d_{ij} apart, lengths h_1, h_2, h_3 and two corresponding coordinates of its starting points w_1, w_2, w_3 can be introduced into the estimation calculation. This formula is the relationship of the variables described above:

$$M_{12} = M(h_2, h_1, w_2, w_1, d_{12}) \quad (F)$$

[0018] Since the current in the electrode also induces a voltage at the extension of electrode steel casing of the length of h_p to the measuring point, the mutual induction coefficient between the electrode and the corresponding rectilinear extension must also be taken into account. Function determining the coefficient of mutual induction between two rectilinear conductors of length h_k and h_p having a common end is as follows:

$$M_{kk} = M_{ep}(h_k, h_p) = \frac{\mu_0}{4\pi} [(h_k + h_p) \ln(h_k + h_p) - h_k \ln(h_k) - h_p \ln(h_p)] \quad (G)$$

$$M_{kk} = M_{ep}(h_k, h_p) = \frac{\mu_0}{4\pi} \left[h_k \ln \left(1 + \frac{h_p}{h_k} \right) + h_p \ln \left(1 + \frac{h_k}{h_p} \right) \right] \quad (G')$$

[0019] The self-induction force in the k th electrode will be determined using the formula for the inductance of a cylinder of the radius R_e and the length h_k

$$L_k = L(h_k, R_e) = \frac{\mu_0 h_k}{2\pi} \left[\ln \left(\frac{2h_k}{R_e} \right) - \frac{3}{4} + \frac{128R_e}{45\pi h_k} - \frac{R_e^2}{2h_k^2} \right] \quad (H)$$

[0020] The current of the k th phase of the high-current line duct flowing in the vicinity of this k th electrode also induces some voltages, which are taken into account in the modelling by additionally introducing the self-inductance factor dL_k . The value of this coefficient is not significant and does not depend on the length of the electrode h_k but can be determined approximately by calculation or measurement.

[0021] The essence of the invention is a method for determining the length of the electrodes of a submerged arc furnace and the position of said electrodes relative to the furnace hearth, characterised by the fact that the voltage of the electrodes is measured between the bottom of the furnace hearth and the moving terminals on the electrode casings in upper position of the electrodes and the derivatives of the current measured on the secondary side of the transformer to determine the electrical parameters of the area immediately surrounding the electrodes, following which the length of the electrodes is calculated, the measurements being made at the time h_k , at which both the electrode current $i_{ek}(t_k)$ and the desired voltage waveform on the equivalent resistance of the area immediately surrounding the electrodes $u_{ek}(t_k)$ take the value of zero.

[0022] Preferably, when the position is determined by solving the following system of three non-linear equations due to h_1, h_2, h_3 :

$$u_{pk}(t) = u_{ek}(t) + R_{ek} i_{ek}(t) + [L(h_k, R_e) + M_{ep}(h_k, h_p) + dL_k] \frac{di_{ek}(t)}{dt} + \sum_{l \neq k}^3 M(h_l, h_k + h_p, w_1 + h_p, w_k, d_{kl}) \frac{di_{el}(t)}{dt}; (k = 1, 2, 3) \quad (1)$$

where:

$i_{ek}(t_k)$ means the electrode current

$u_{ek}(t_k)$ is the voltage on the equivalent resistance of the area immediately surrounding the electrode

$L_k(h_k, R_e)$, dL_k is the self-inductance of the electrode

$M_{ep}(h_k, h_p)$ means the mutual inductance on the steel casing of a Soderberg electrode of a fixed length of h_p

$M_{k-l}(h_l, h_k + h_p, w_1 + h_p, w_k, d_{kl})$ means the mutual inductance between the electrodes k and l

$u_{pk}(t)$ means the voltage between the counter-electrode (bottom of the furnace hearth) and the moving terminals on the electrode casings in their upper position

[0023] By breaking down the equation (1) at the time t_k such that both the electrode current $i_{ek}(t)$ and the desired voltage waveform on the equivalent resistance of the area immediately surrounding the electrodes $u_{ek}(t)$ takes the value of zero, a system of non-linear equations due to h_1, h_2, h_3 is obtained.

[0024] Newton's method can be used to solve a system of non-linear equations. The Jacobian of the system of equations (1) can be determined analytically, which is important in terms of minimising the cost of numerical calculations.

[0025] In another aspect the invention relates to a measuring system for determining the resistance of the electrodes (1, 2, 3) of a submerged arc furnace (4) supplied from a furnace transformer (5) characterised in that it comprises a Rogowski coil array (RC1, RC2, RC3) for measuring the current derivatives in the high-current line supplying the electrode array (1, 2, 3) and an array of voltmeters (7, 8, 9) for measuring the voltage between the counter-electrode and the fixed moving terminal of a given electrode (1, 2, 3) on the electrode casing in their upper position.

[0026] In order to identify the current parameters it is necessary to use modern measurement techniques allowing for synchronous recording of sampled electrode current and voltage waveforms.

[0027] The present invention solves the technical problem of determining the electrode lengths of a submerged arc

furnace without interrupting the operation of the furnace itself. The solution is to identify the electrical operating parameters of the areas immediately surrounding the electrodes ("working") areas based on a holistic approach to the furnace electrodes' operating sequence and their mutual influence on the current conditions occurring during the operation of the furnace system. Determining the values of the electrical parameters of the areas immediately surrounding the electrodes of a submerged arc furnace is based on taking measurements of the currents and voltages supplying the electrode system without interfering with the drive systems and the interior of a furnace, resulting in reducing the need for organising furnace downtimes for process control.

[0028] The object of the invention is illustrated in the embodiments, which do not limit its scope, and in the drawing wherein:

- Fig. 1 shows an illustrative furnace layout with the lengths tested in the process of measuring the lengths of electrodes in a submerged arc furnace.
- Fig. 2 shows an alternate electrical circuit diagram of a system for measuring electrode length including current variables
- Fig. 3. diagram of the measuring system generating the data necessary for equation (1),
- Fig. 4 illustrates, in a table, an example of measurement data and identification of electrical parameters for a furnace in normal operating conditions,
- Fig. 5 illustrates example voltage-current characteristics on phase resistances in the area immediately surrounding the electrodes for measurement data from the table in fig. 4,
- Fig. 6 illustrates examples of equivalent resistance waveforms in the electrode zone for the measurement data from the table in fig. 4,
- Fig. 7 illustrates in a table an example of measurement data and identification for a furnace after a failure,
- Fig. 8 illustrates exemplary voltage-current characteristics at phase resistances in the area near the electrodes after a failure for the measured data in the table in fig. 7,
- Fig. 9 illustrates examples of equivalent resistance waveforms in the area immediately surrounding the electrodes after a failure for measurement data from the table in fig. 7,
- Fig. 10 illustrates exemplary estimated electrode lengths calculated in the furnace system,
- Fig. 11 illustrates the estimated arc power - furnace,
- Fig. 12 illustrates the recorded active power - furnace.
- Fig. 13 illustrates exemplary flow of the derivation of currents.

[0029] The embodiment shown in fig. 1 depicts the furnace system with the lengths tested in the process of measuring the lengths of the electrodes in submerged arc furnace. The lengths w_1, w_2, w_3 constitute the distance between the top of the electrode casings and the roof of the furnace placed at a fixed height from the bottom of the furnace hearth h . The length h_p defines a fixed characteristic length of the electrode casings above the electrode contact clamps. The lengths h_{e1}, h_{e2}, h_{e3} represent the unknown length of the electrodes below the contact clamps, while d_1, d_2, d_3 represent the distance of the edge of the electrode from the bottom of the furnace hearth. The distances d_{12}, d_{23} and d_{31} represent the distance between the individual electrodes. The electrode voltages are u_{p1}, u_{p2}, u_{p3} , and i_{e1}, i_{e2}, i_{e3} , while i_{e1}, i_{e2}, i_{e3} determine the current supplied to the electrodes.

[0030] Fig. 2 shows an equivalent electrical circuit diagram for measuring electrode lengths with current variables. Equation (X) is used to determine the length of the electrodes based on data from the measuring system shown in figure 3 (V_0 - counter-electrode signal source; V_{1-2-3} - electrode voltage signal sources, RC_{1-2-3} - Rogowski coils; di_{1-2-3}/dt - current derivatives, 1-2-3 - electrodes, $U/W/V_{1-2}$ - terminals of the secondary side of the furnace transformer supplying the electrode system).

$$u_{pk}(t) = u_{ek}(t) + R_{ek}i_{ek}(t) + [L(h_k, R_e) + M_{ep}(h_k, h_p) + dL_k] \frac{di_{ek}(t)}{dt} + \sum_{l \neq k}^3 M(h_l, h_k + h_p, w_1 + h_p, w_k, d_{kl}) \frac{di_{el}(t)}{dt}; (k = 1, 2, 3) \quad (X)$$

where:

- $i_{ek}(t_k)$ means the electrode current
- $u_{ek}(t_k)$ is the voltage on the equivalent resistance of the area immediately surrounding the electrode
- $L_k(h_k, R_e), dL_k$ is the self-inductance of the electrode
- $M_{ep}(h_k, h_p)$ means the mutual inductance on the steel casing of a Soderberg electrode of a fixed length of h_p

$M_{k-l}(h_l, h_k+h_p, w_l+h_p, w_k, d_{kl})$ means the mutual inductance between the electrodes k and l

$\frac{di_{ek}(t)}{dt}, \frac{di_{el}(t)}{dt}$ means the derivatives of the current of a given electrode

$u_{pk}(t)$ means the voltage between the counter-electrode (bottom of the furnace hearth) and the moving terminals on the electrode casings in their upper position

[0031] In order to determine the length of the electrodes using equation (X), it is necessary to select the time t_k when both the electrode current $i_{ek}(t_k)$ and the desired voltage waveform on the equivalent resistance of the area immediately surrounding the electrodes $u_{ek}(t_k)$ take the value of zero. By solving the resulting system of non-linear equations due to h_1, h_2, h_3 one arrives at the lengths of the electrodes at time t_k .

[0032] In order to verify how the calculated values of h_1, h_2, h_3 relate to the actual electrode lengths, an experiment was carried out, whereby the electrode lengths were measured mechanically with some accuracy, following which the results were substituted into a mathematical model of the system and, successively, such corrective inductances dL_1, dL_2, dL_3 were selected that will ensure that the phase currents of the electrodes and the voltages at the equivalent resistances pass through zero simultaneously.

[0033] In an embodiment, the measuring system for determining the resistance of electrodes 1, 2, 3 of an electric submerged arc furnace 4 fed from a furnace transformer 5 includes an array of Rogowski coils RC1, RC2, RC3 connected to a sampling circuit 6. The aforementioned Rogowski coil array RC1, RC2, RC3 is used to measure the current derivatives in the high-current line path feeding the electrode array 1, 2, 3 and the voltmeter array 7, 8, 9 to measure the voltage between the counter-electrode and the fixed moving terminal of the respective electrode 1, 2, 3 on the electrode casing in their upper position. This method was tested on a test bench on a submerged arc furnace. An exemplary identification of the parameters of the area immediately surrounding the electrodes in normal operating conditions is shown in fig. 5 and 6 and the measurement data and identification of the furnace parameters are shown in the table in fig. 4, while fig. 8 and 9 and the table in fig. 7 show these characteristics after an emergency.

[0034] The results obtained confirmed that the developed method for determining the position of the electrode tips is capable of estimating this position with an accuracy of more than ± 10 cm in successive estimation steps.

[0035] The calculations resulted in the exemplary electrode lengths over time shown in fig. 10-12

[0036] An exemplary waveform of the derived currents is shown in fig. 13

Claims

1. A method for determining the length of the electrodes of a submerged arc furnace and the position of those electrodes relative to the furnace hearth, **characterised in that** the voltage of the electrodes is measured between the bottom of the furnace hearth and the moving terminals on the electrode casings in their upper position and the current derivatives measured on the secondary side of the transformer to determine the electrical parameters of the area around the electrodes, following which the length of the electrodes is calculated, the measurements being made at time t_k , at which both, the electrode current $i_{ek}(t_k)$ and the desired voltage waveform on the equivalent resistance of the area immediately surrounding the electrodes $u_{ek}(t_k)$ assumes the value of zero.
2. The method according to claim 1, **characterised in that** the position is determined by solving the following system of equations:

$$u_{pk}(t) = u_{ek}(t) + R_{ek}i_{ek}(t) + [L(h_k, R_e) + M_{ep}(h_k, h_p) + dL_k] \frac{di_{ek}(t)}{dt} + \sum_{l \neq k}^3 M(h_l, h_k + h_p, w_l + h_p, w_k, d_{kl}) \frac{di_{el}(t)}{dt}; (k = 1, 2, 3) \quad (X)$$

where:

$i_{ek}(t_k)$ means the electrode current

$u_{ek}(t_k)$ is the voltage on the equivalent resistance of the area immediately surrounding the electrode

$L_k(h_k, R_e), dL_k$ is the self-inductance of the electrode $M_{ep}(h_k, h_p)$ means the mutual inductance on the steel casing of a Soderberg electrode of a fixed length of h_p

$M_{k-l}(h_l, h_k+h_p, w_l+h_p, w_k, d_{kl})$ means the mutual inductance between the electrodes k and l

$u_{pk}(t)$ means the voltage between the counter-electrode (bottom of the furnace hearth) and the moving terminals on the electrode casings in their upper position

3. A measuring system for determining the resistance of the electrodes (1, 2, 3) of a submerged arc furnace (4) supplied from a furnace transformer (5), **characterised in that** it contains a (6) Rogowski coil system (RC1, RC2, RC3) for measuring the current derivatives in the high-current line feeding the electrode array (1, 2, 3) and a voltmeter array (7, 8, 9) for measuring the voltage between the counter-electrode and the predetermined moving terminal of a given electrode (1, 2, 3) on the electrode casing in the upper position of the same.

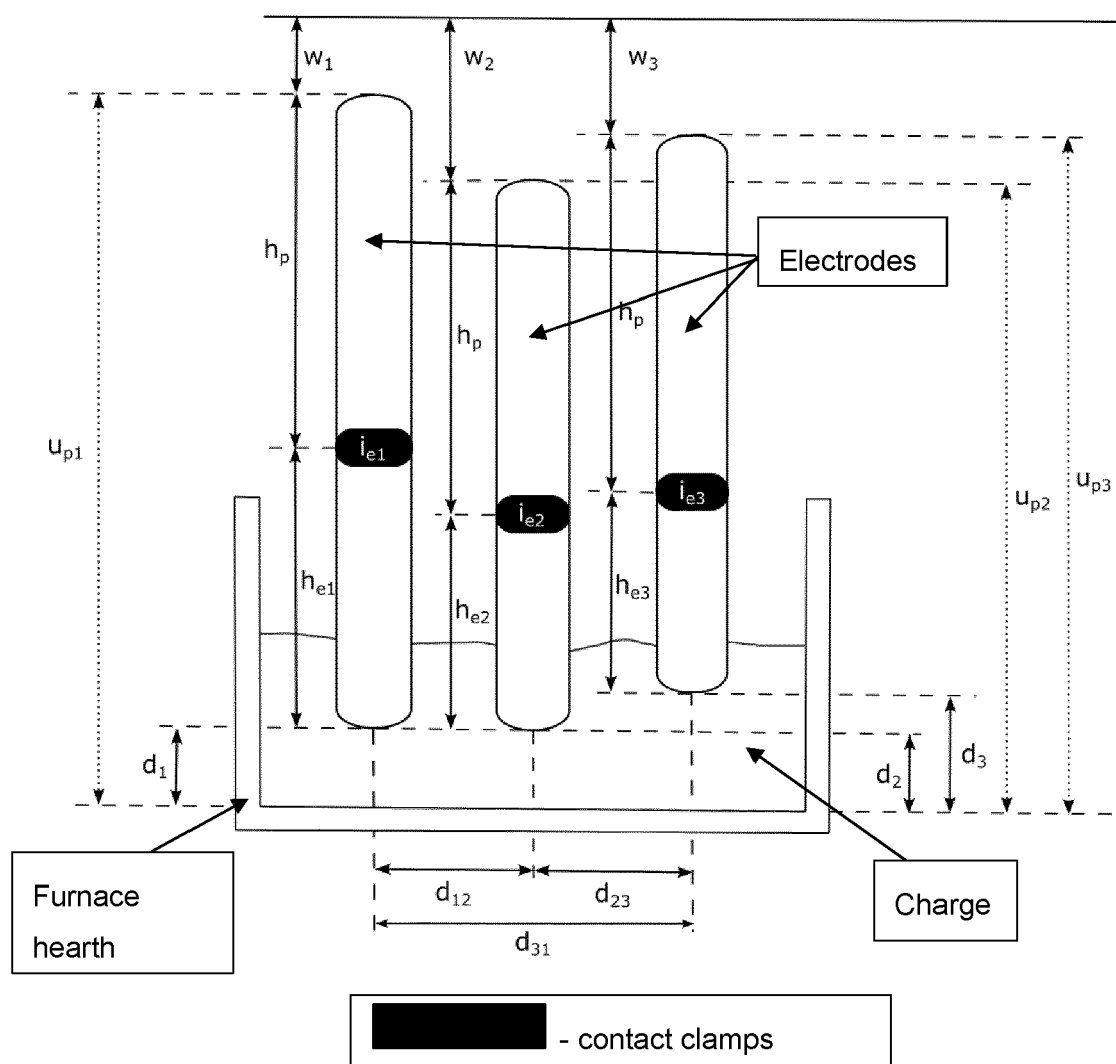


Fig. 1

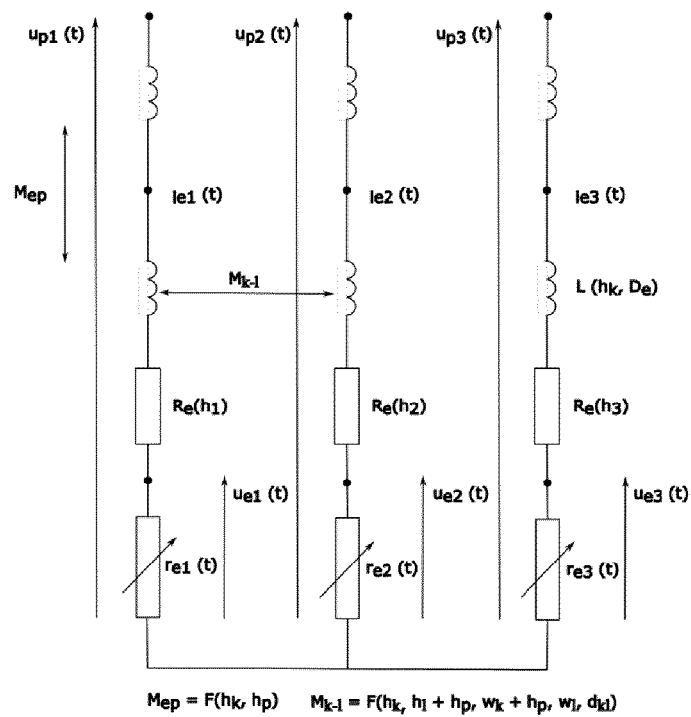


Fig. 2

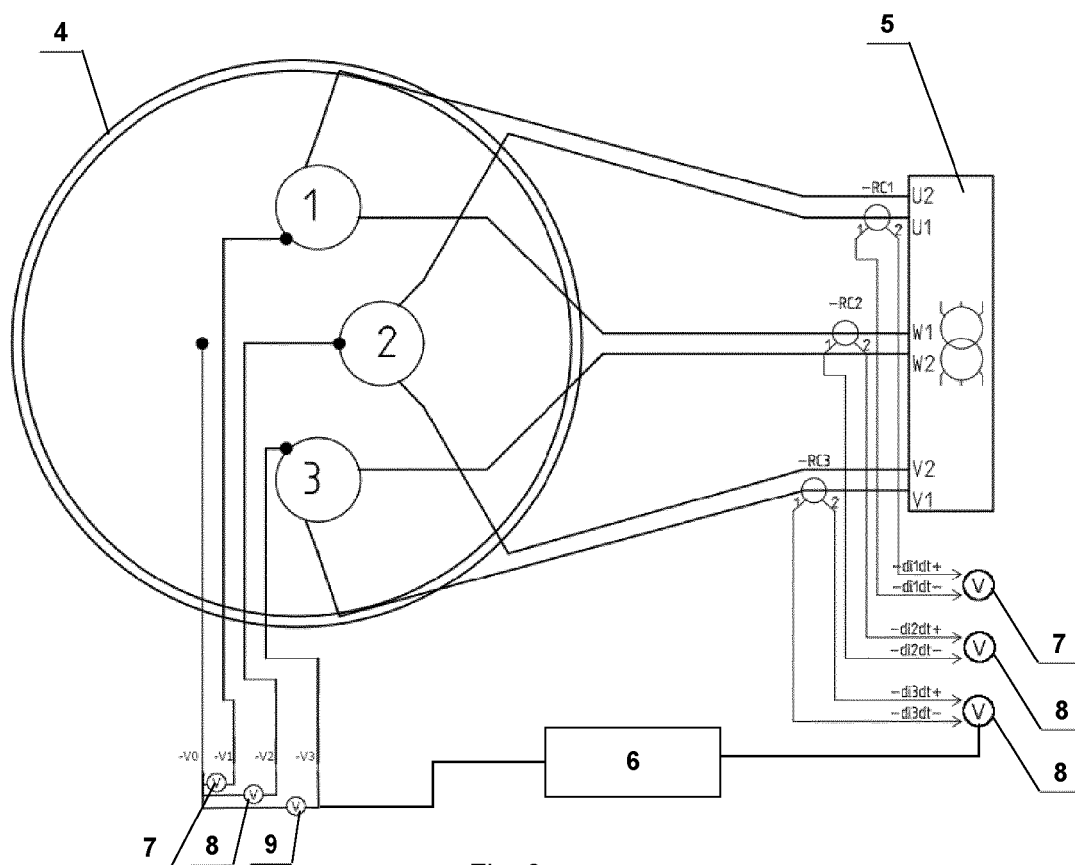


Fig. 3

Electrode currents i_{e1} [kA]	58.15
Electrode currents i_{e2} [kA]	61.12
Electrode currents i_{e3} [kA]	62,36
Arc voltage U_{luk1} [V]	78,30
Arc voltage U_{luk2} [V]	68,05
Arc voltage U_{luk3} [V]	77,53
Arc hysteresis power S_{luk1} [MVA]	1,224
Arc hysteresis power S_{luk2} [MVA]	1,316
Arc hysteresis power S_{luk3} [MVA]	1,459
Phase active power P_{e1} [MV]	4,977
Phase active power P_{e2} [MV]	4,788
Phase active power P_{e3} [MV]	5,401
Phase impedance Z_{e1} [mOhm]	1,599
Phase impedance Z_{e2} [mOhm]	1,432
Phase impedance Z_{e3} [mOhm]	1,510
Total active power P_e [MW]	15.165
Charge resistance minimum [mOhm]	1,153
Charge resistance minimum [mOhm]	0,962
Charge resistance minimum [mOhm]	1,063
Arc active power P_1 [MW]	2,019
Arc active power P_2 [MW]	1,571
Arc active power P_3 [MW]	2,133
Electrode length H_1 [m]	2,378
Electrode length H_2 [m]	2,525
Electrode length H_3 [m]	2,168

Fig. 4

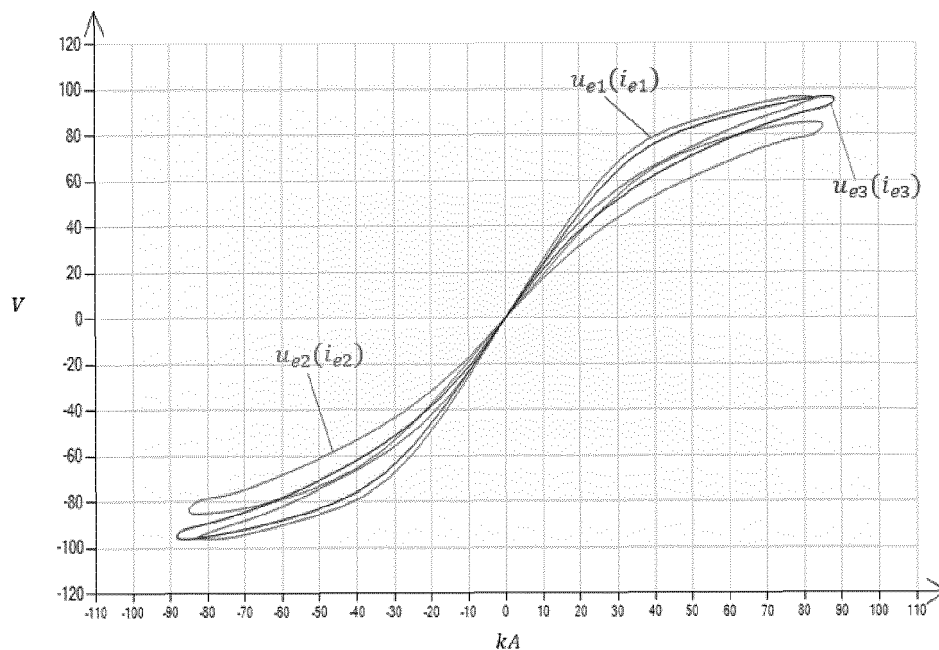


Fig. 5

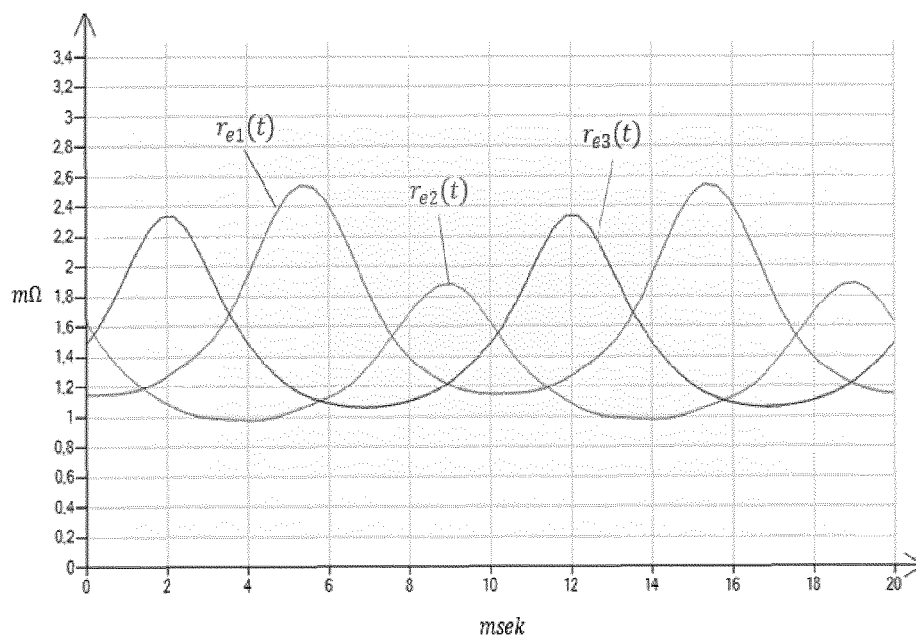


Fig. 6

Electrode voltage Ue1 [V]	61.76
Electrode voltage Ue2 [V]	26.74
Electrode voltage Ue3 [V]	53.84
Electrode currents Ie1 [kA]	46.66
Electrode currents Ie2 [kA]	47.97
Electrode currents Ie3 [kA]	29.78
Arc voltage Uluk1 [V]	50.21
Arc voltage Uluk2 [V]	8.64
Arc voltage Uluk3 [V]	46.09
Arc hysteresis power Sluk1 [MVA]	0.311
Arc hysteresis power Sluk2 [MVA]	0.005
Arc hysteresis power Sluk3 [MVA]	0.251
Phase active power Pe1 [MV]	2.697
Phase active power Pe2 [MV]	0.822
Phase active power Pe3 [MV]	1.529
Phase impedance Ze1 [mOhm]	1.324
Phase impedance Ze2 [mOhm]	0.557
Phase impedance Ze3 [mOhm]	1.808
Total active power Pe [MW]	5.048
Charge resistance minimum [mOhm]	1.014
Charge resistance minimum [mOhm]	0.171
Charge resistance minimum [mOhm]	1.371
Arc active power P1 [MW]	0.409
Arc active power P2 [MW]	0.029
Arc active power P3 [MW]	0.444
Electrode length H1 [m]	2.463
Electrode length H2 [m]	2.457
Electrode length H3 [m]	2.570

Fig. 7

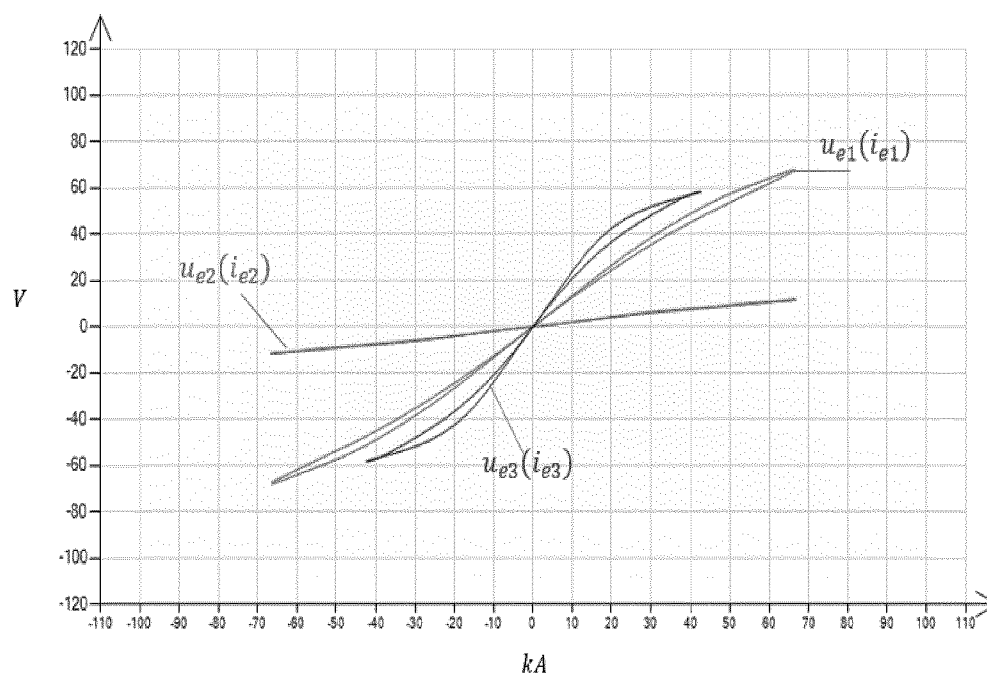


Fig. 8

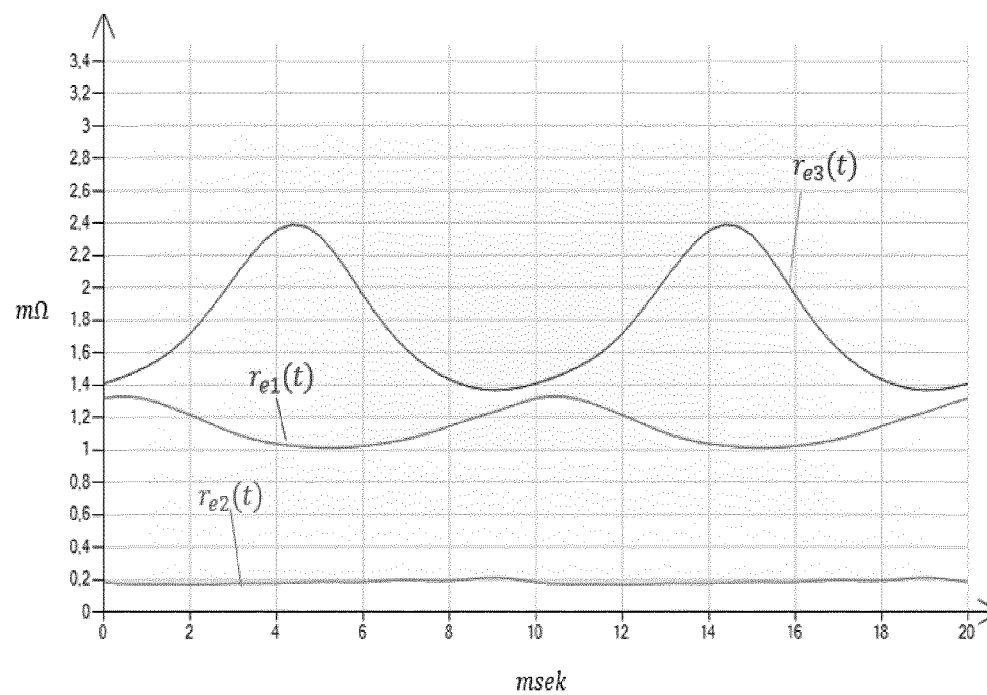


Fig. 9

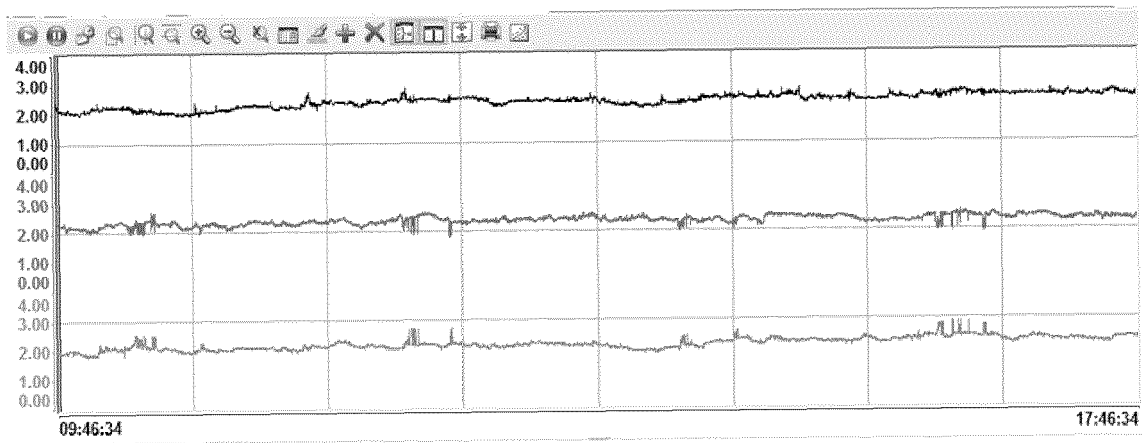


Fig. 10

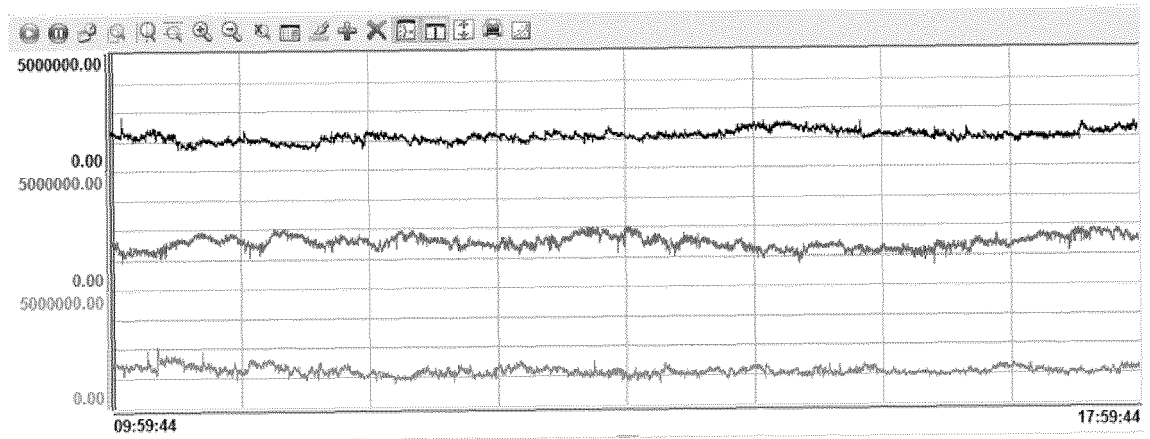


Fig. 11

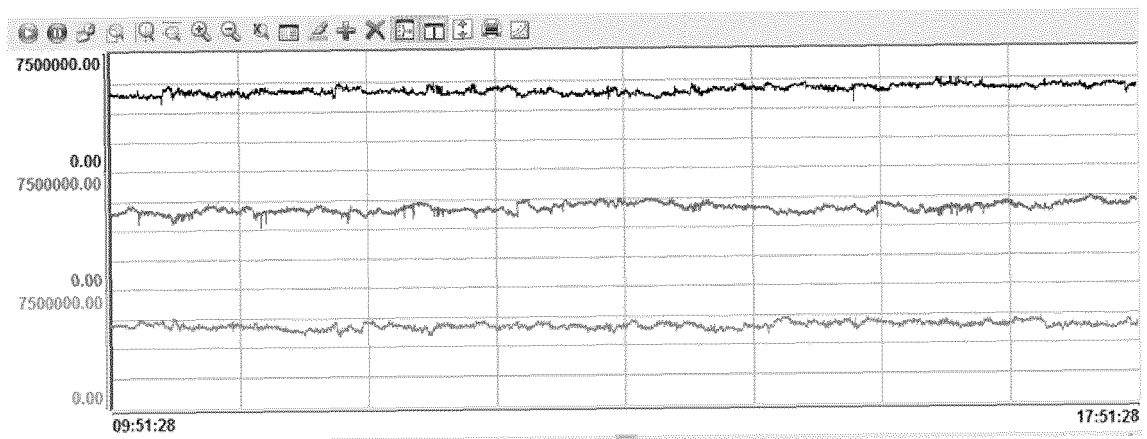


Fig. 12

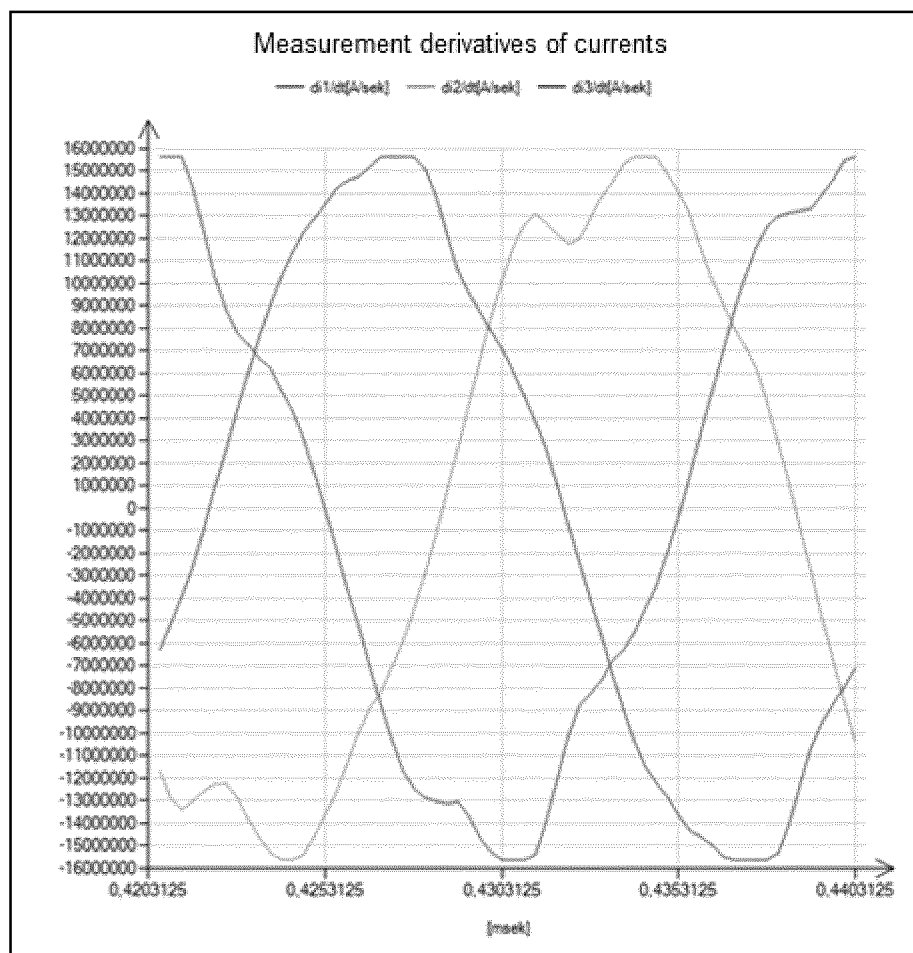


Fig. 13



EUROPEAN SEARCH REPORT

Application Number

EP 23 46 1680

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