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(54) Title: SOLENOID VALVE CONTROLLING METHOD PROVIDED WITH MAGNETIC CURSOR

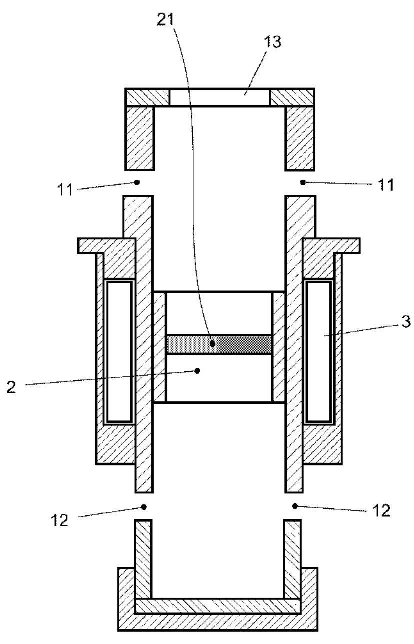

FIG. 1

(57) Abstract: Abstract: The present invention belongs to the technology field of electric or electronic methods and systems dedicated to the solenoid valves control. Problem to be solved: The current state of the art does not comprise controlling methods dedicated to bistable solenoid valves integrated by magnetic cursors whose movement does not cause the inductance change of inductive sensors and / or electric coils in general, such as the bistable solenoid valve described in the Brazilian patent document BR1020140072543. Problem Resolution: It is disclosed a solenoid valve controlling method provided with magnetic cursor, the positioning measuring of the scrollable sensor inside the valve body being performed by analysis of the voltage induced by said scrollable sensor in the electromagnetic field generating element.

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SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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"SOLENOID VALVE CONTROLLING METHOD PROVIDED WITH MAGNETIC CURSOR"

Field of the Invention

The subject invention relates to a solenoid valve controlling method provided with magnetic cursor and, more particularly, a controlling method that, applied in a bistable solenoid valve provided with a magnetic cursor able to be moved between two functional positions, provides the deceleration active control of said magnetic cursor from the measurement of the position thereof, without the need to use positioning measurement additional sensors.

Briefly, the controlling method disclosed herein provides for the dynamic change of the electric power of the component that induces the movement of the magnetic cursor (usually, an electric coil) and consequently the acceleration and / or deceleration of the magnetic cursor move, from the measurement, in real time, of the instantaneous positioning of said magnetic cursor, such positioning measurement being performed by means of the analysis of the voltage induced by the magnetic cursor itself in the component that induces the movement thereof.

Background of the Invention

As is known to those versed skilled in the subject matter, the current prior art comprises a plurality of solenoid valves models, which can be used in almost all fields and industrial segments.

Roughly speaking, a solenoid valve is basically composed of a valve body, a valve seat and an electric driving means responsible for causing mechanical move between said valve body and the valve seat, said mechanical move being usually performed by magnetic attraction and / or repulsion induced by the electric driving means on one of these two elements. Typically, the valve seat comprises a metallic and / or magnetic body and the electric driving means comprises an electric coil which, upon receiving electric power, generates a magnetic field able to attract or repulse the valve seat.

It is also worth mentioning that the components composing a solenoid valve are treated by different nomenclatures in specialized technical literature. The valve seat, for example, is also known as cursor, armor, piston, among others. In any case, and regardless of the denomination, the valve seat comprises the mobile element and excitable by means of electric drive. In order to avoid problems with technical names, the valve seat will be mentioned hereinafter only as cursor.

In particular embodiments and applications, and taking into consideration that the cursor comprises a mobile component (with respect to the valve body), it is often necessary to know the position thereof.

This interest and / or need may be related to different needs: avoid the shock of the cursor inside the valve body, dose the intensity of the magnetic field of the electric driving means, synchronize the cursor move frequency to the controlling system frequency, verify a static condition of the cursor during specific situations, among others. Thus, the current state of the art also provides different means, methods and solenoid valve controlling systems especially dedicated to the positioning measurement of the cursor thereof.

There are known more simplistic systems which provide the use of additional sensors solely responsible for the cursor positioning detection. Conventionally, such additional sensors may comprise secondary coils, inductive sensors in general, hall-type sensors, among others. Obviously, the use of additional sensors raises the final cost of solenoid valve itself and the controlling system.

In this sense, and in order to reduce the final cost of the solenoid valves, there are also known systems that, though more complex, are devoid of additional sensors.

Document US5053911 describes, for example, a solenoid valve cursor controlling system and method where it is described the indirect determination of the cursor position by measuring the electrical inductance variation of the electric driving means comprising an electric coil. That is, the cursor drive coil itself also functions as sensor. As the cursor moves along the valve body, there occur changes in the electrical inductance of the electric driving means and, consequently, the decay of the drive electric current of said cursor. Thus, it is described the possibility of measuring the “closure” of the solenoid valve when it is measured the largest electric inductance that the cursor can cause in the coil. It is worth emphasizing that although said document US5053911 provides for the measurement of the cursor positioning (in fact, only one possible positioning of the cursor) without the use of additional sensors, it is not provided any type of move active control of the cursor from the measurement of this positioning.

Document WO9824106 discloses, for example, a solenoid valve cursor controlling system and method very similar to the controlling method and system described in document US5053911, however being possible to measure at least two positioning of the cursor by means of the comparison between the electrical inductance of the cursor drive coil and pre-calibrated parameters correlated to specific positioning of the same. Therefore, the electric driving means (electric coil) is energized with a “first” electric current unable to move the cursor while a comparator circuit monitors the decay of this electric current, starting a time counter from the first indication of decay. Then, the same electric driving means (electrical coil) is energized with a “second” electric current able to move the cursor while another comparator circuit monitors the decay of this electric current, starting a time counter from the first indication of decay. Then, the decay times of the “first” and “second” electric current are compared to each other, the positioning of the cursor being measured from this comparison.

Document US5942892 also describes a cursor positioning checking system of a solenoid valve capable of checking, in real time, the positioning of said slider. Thus, there is provided the use of a circuit parallel to the circuit responsible for the electric drive (electric coil) and a frequency checking instrument (demodulator) connected to said circuit responsible for the electric supply of the electric driving means. An excitation frequency is introduced into the circuit responsible for the electric power of the electric driving means, and the positioning of the cursor is linked to the fluctuation of the frequency observed in the circuit responsible for the electric power of the electric driving means. However, the inclusion of a parallel circuit increases the cost and complexity of this system.

Document US6891710 describes a solenoid valve controlling method. According to this document, the cursor positioning is detected and, based on this information, it is performed a supply current control of the component responsible for triggering (electric coil) of said cursor. More particularly, the controlling method described herein is to identify the transition from the cursor between a blockade region and a controlling region, and immediately after this transition it is assigned a current value in the coil for maintaining the cursor in a defined position for a reliable pressure level. Note that the measurement of the transition time (in a way, the measurement of the positioning) of the cursor is based on the inductance variation especially generated in this situation. The cursor move from the blockade region to the controlling region occurs by reducing the electric current in the coil to a minimum value which is maintained by a current regulator which applies voltage in the coil by a pulse-width modulation, wherein such regulator is set to slowly respond to changes in current so that the current peak that occurs in the transition from the blockade region to the controlling region is detected.

However, the solutions proposed by documents US5053911, US5942892, WO9824106 and US6891710 are not applicable in bistable solenoid valves integrated by cursors which movement does not alter the inductance (considering significant values) of the electric coil.

An example of bistable solenoid valve of this type, where the change of the inductance caused by the cursor shift is too small (not allowing to extract information related to the positioning thereof) is fully described in the Brazilian patenting document BR1020140072543, now the applicant. This means that the current state of the art lacks controlling methods especially applicable in the solenoid valve described in said Brazilian patent document BR1020140072543, and it is based on this background that the present invention arises.

Objectives of the invention

It is therefore the main objective of the present invention to disclose a solenoid valve controlling method integrated by a cursor (moving inside a valve body from magnetic excitement generated by an electric coil) the movement of which is not particularly able to change the value of the electric inductance of the electric coil which stimulates the move of said cursor. Accordingly, it is one of the objectives of the subject invention to disclose a controlling method especially dedicated to the solenoid valve described in said Brazilian patent document BR1020140072543.

Summary of the Invention

Therefore, it is disclosed a new solenoid valve controlling method provided with magnetic cursor able to achieve all the objectives defined herein.

This method according to the present invention comprises at least one positioning controlling step of the cursor scrollable inside the valve body from at least one electric parameter of the valve electromagnetic field generating element, which is integrated by a valve body, a movable cursor arranged within the valve body, and an electromagnetic field generating element arranged outside the valve body, wherein said scrollable cursor is provided with at least one magnetic region excitable by at least one electromagnetic field generating element, which is able to stimulate the selective and targeted drive movement of the scrollable cursor inside the valve body by means of magnetic attraction or repulsion of the magnetic region of the scrollable cursor.

The subject invention differs from prior art by the fact that the measurement of the positioning of the scrollable cursor inside the valve body is performed by analysis of the voltage induced by said scrollable cursor in the electromagnetic field generating element. Based on this, the following steps are envisaged: (a) generate position reference signal by the reference generator block during pre-defined time interval related to the seal time of the input pathway of the valve body from which it is desired to start the selective move of the scrollable cursor, (b) after sealing time interval of the input pathway of the valve body from which the selective move began, generate position reference signal by means of the reference generator block during predefined time range referring to the sealing time of the input pathway lying in the opposite end of the valve body, and (c) maintain selective move through steps (a) and (b) until disconnection of the driving system.

Preferably, the variation of the cyclic ratio of the pulses that control the switches of the CC-AC converter feeding the electromagnetic field generator of the valve is performed by a proportional, integral and derivative controller.

Brief Description of the Drawings

The present invention will be described in details based on the figures listed below, which:

Figure 1 illustrates schematically the solenoid-type valve able to be actuated by the method described in the present invention;

Figure 2 illustrates a graph related to the inductance value (L) of the electromagnetic field generating element and the flow (K) of the magnetic region of the scrollable actuator of the solenoid-type valve able to be actuated by the method described herein;

Figure 3 illustrates schematically a block diagram relating to the magnetic actuator driving system of solenoid type valve;

Figure 4 illustrates schematically an electric representation of the CC-AC converter (H bridge) which feeds the electromagnetic field generator of the solenoid type valve;

Figure 5 illustrates a graph of the voltage waveforms and electric current of the electromagnetic field generator of the solenoid type valve; and

Figures 6A, 6B, 6C, 6D and 6E illustrate graphs of the electric signals of reference position, actual position, voltage, current and FCEM respectively.

Detailed Description of the Invention

In accordance with the objectives of the instant invention, it is shown the solenoid valve controlling method provided with magnetic cursor and, particularly, a solenoid valve as shown in Figure 1.

Thus, the aforesaid solenoid valve comprises a valve body 1, a scrollable cursor 2 and an electromagnetic field generating element 3.

Said valve body 1 comprises a tubular body provided with at least two input pathways 11 and 12, and an output pathway 13.

Said scrollable cursor 2 comprises a tubular body provided with at least one magnetic region 21 of cooperative interaction with the electromagnetic field generating element 3.

Said electromagnetic field generating element 3 is able to stimulate the selective and targeted move of the scrollable cursor 2 inside the valve body 1 by means of magnetic attraction or repulsion of the magnetic region 21 of the scrollable cursor 2.

In this context, it is also worth noting that the magnetic region 21 of the scrollable cursor 2 preferably comprises a magnet of fixed magnetic field, and the electromagnetic field generating element 3 comprises an electric coil. Therefore, and in accordance with the polarity of the electric supply of the electromagnetic field generating element 3, it generates an attractive or repulsive field able to move the scrollable slider 2 according to the operating needs of the solenoid valve.

Accordingly, the selective and targeted move of the scrollable cursor 2 inside the valve body 1 is apt to control the fluid communication or the sealing between the input pathways 11 and 12 and the output pathways 13 of said body valve 1. Note that, as already anticipated by the Brazilian patent document BR1020140072543, the movement of the scrollable cursor 2, inside the valve body 1 (or regarding the valve body 1) can comprise a linear move or a rotary move.

To perform the selective move of the scrollable cursor 2, two voltage pulses are applied alternating the voltage polarity so that the magnetic cursor 2 moves from one pathway to another at predefined time intervals according the sealing times of each input pathway. These voltage pulses are applied in the electromagnetic field generating element 3 through a voltage source characterized by an electronic system that, during application of the driving pulses, varies the amplitude of the supply voltage of the electromagnetic field generating element, depending on the position of the scrollable actuator 2. This type of power supply is called position-controlled voltage source.

The instant position of the scrollable cursor 2 is calculated by the voltage induced in the electromagnetic field generating element 3 by the displacement of the magnetic cursor 2.

To calculate the induced voltage, it is assumed that the inductance values (L) of the electromagnetic field generating element 3 and the flow (K) of the magnetic region 21 of said scrollable cursor 2 are quite constant between the valve body ends delimiting the travel of said magnetic slider 2, as illustrated in Figure 2. Also worth noting that the graph of Figure 2 applies both to a scrollable cursor 2 of linear move and to a scrollable cursor 2 of rotary move.

From this finding, it is demonstrated how the position of the magnetic region 21, and hence the scrollable cursor 2 can be estimated only by the voltage induced in the electromagnetic field generating element 3.

In this sense, the voltage existing on the electric terminals of the electromagnetic field generating element 3 (electrical coil) can be represented mathematically by the following basic equation:

$$v = Ri + L\frac{di}{dt} + K\frac{dx}{dt} \quad (1)$$

In the fundamental equation presented above, the terms on the right of the equation are, respectively, the voltage drop due to the electric resistance, the voltage drop due to inductance and the voltage induced by the displacement of the magnetic cursor, also named counter-electromotive force (FCEM). When writing the counter-electromotive force (FCEM) on the basis of other electric variables of the electromagnetic field generating element 3 (electric coil), it is obtained the following expression:

$$FCEM = v - Ri - L\frac{di}{dt} \quad (2)$$

By approaching the variable "L" by a constant value in this equation, it is determined the FCEM of the electromagnetic field generating element 3 (electric coil), after all, the value of electric current "I" is obtained through a sensor, the variation of the electric resistance "R" with temperature can be neglected and the terminal voltage of the coil "v" is imposed by the driving circuit. From equation (1), it is noted that the FCEM is the product between the flow "K" of the cursor and the scroll rate "x" of it. As the flow "K" is constant throughout the travel of the cursor, as found from Figure 2, and the FCEM had been previously determined by equation (2), it is so determined the cursor position by the following expression:

$$x = \int \frac{FCEM}{K} \quad (3)$$

From the position of the magnetic cursor 2, it is embodied the feedback of the power source of electromagnetic field generator 3, as can be seen in the block diagram of Figure 3, so that it can vary the amplitude of the feeding voltage of the electromagnetic field generating element during the application of the driving pulses and cause the selective move of the cursor between the input pathways of the valve avoiding the shock of the magnetic cursor 2 at the ends of valve body 1.

The blocks of Figure 3 are the proportional, integral and derivative controller 41, the pulse generating block 42, the continuous voltage bus (Vcc) 43, the CC-AC converter 44, the reference generator 45, the position estimator of magnetic cursor 46, in which there are implemented equations 1, 2 and 3, and the electromagnetic field generating element 3. Blocks 43 and 44 represent the circuitry of the electronic system feeding the electromagnetic field generator 3 and blocks 41, 42, 45 and 46 are software modules implemented in the microcontroller of the electronic system. The CC-AC converter (H bridge) operates in half-bridge mode where the cyclic ratio RC defined by pulse generator 42 and the complementary value thereof 1-RC are applied as shown in Figure 4. For an RC value higher than 0.5 as illustrated in Figure 5, the average value of the electric current and hence the voltage is positive. For an RC value lower than 0.5, the mean value of the electrical current and hence the voltage is negative.

The proportional, integral and derivative controller 41 serves to correct the error between the current position 4 of the cursor and the reference position 4' by varying the cyclic ratio of the pulses generated by block 42 that control the converter keys 44, which has the function of transforming the continuous voltage supplied by bus 43 into alternate voltage.

Thus, the voltage applied to the electromagnetic field generating element 3 (electric coil) is appropriately varied so that it is reached the reference position 4 determined by reference generator block 45. The selective move of the magnetic cursor starts only after determination of the initial position made by block 45, so that sealing times T5 and T6 are applied to the respective input pathways.

The selective move starts with magnetic cursor 2 positioned in a predefined input pathway to ensure that the sealing times are applied to the respective input pathways thereof. For example, to start the selective move of the magnetic cursor 2 on pathway 11 located in position X1, as shown in Figure 6B, it is applied from block 45 the reference value X1' at the reference position input 4' of the position controller 41 during a predetermined time interval T1, as illustrated in Figure 6A. In the input of current position 4 of position controller 41 it is applied to the position value calculated by the position estimating block 46. As the cursor is already positioned as the example shown in Figure 6B, there is no variation of the cyclic ratio RC applied by position controller 41 in pulse generating block 42, because the magnetic cursor 2 does not move.

After time interval T2 with respect to the sealing time of the input pathway 11, it is applied from block 45 the reference value X2' in reference position input 4' of position controller 41 for a period of time T3, as illustrated in Figure 6A. As the magnetic cursor moves from the input pathway 11 to the input pathway 12, the value of cyclic ratio RC applied to the pulse generator block 42 varies, as shown in Figure 6C, decreasing the average value of the electric current applied in the electromagnetic field generator 3. Thus, the electric force exerted on the electromagnetic field generator 3 decreases, preventing the shock of magnetic cursor 2 with the end of valve body 1. At the end of time interval T3, the cursor is positioned at the input pathway 12, as illustrated in Figure 6B, keeping this input pathway sealed until the end of time interval T4. Past time interval T4 related to the sealing time of input pathway 12, it is applied the reference value X1' again by block 45 restarting the selective move.

REIVINDICAÇÕES

1. Solenoid valve controlling method provided with magnetic cursor, comprising at least one positioning controlling step of scrollable cursor (2) inside valve body (1), from at least one electric parameter of the electromagnetic field generating element (3) of the valve;

said method being especially applicable in a solenoid valve comprised of a valve body (1), a scrollable cursor (2) and an electromagnetic field generating element (3); said scrollable cursor (2) being provided with at least one magnetic region (21) excitable by at least one electromagnetic field generating element (3), which is able to stimulate the selective and guided movement of scrollable cursor (2) relative to valve body (1) through magnetic attraction or repulsion of magnetic region (21) of scrollable cursor (2);

said method being particularly characterized by the fact that the measurement of the position of scrollable cursor (2) inside valve body (1) is performed by analyzing the voltage induced by the said scrollable cursor (2) in electromagnetic field generating element (3).

2. Solenoid valve controlling method provided with magnetic cursor, according to claim 1, characterized in that it comprises at least the following steps:

(a) generate position reference signal by means of reference generator block (45) during predefined time range related to the sealing time of the input pathway of valve body (1) from which it is desired to start the selective drive of scrollable cursor (2);

(b) after sealing time range of the input pathway of valve body (1) from which it was started the selective movement, generate position reference signal by means of reference generator block (45) during predefined time range referring to the sealing time of the input pathway lying at the opposite end of the valve body (1);

(c) maintain selective movement through steps (a) and (b) until shutdown of the driving system.

3. Solenoid valve controlling method provided with magnetic cursor, according to claim 1, characterized by the fact that the variation of the cyclic ratio of the pulses commanding the switches of CC-AC converter (44) that feeds the electromagnetic field generator element (3) of valve (1) is performed via a proportional, integral and derivative controller (41).

4. Solenoid valve controlling method provided with magnetic cursor according to claim 1, characterized by the fact that the selective and guided movement of scrollable cursor (2) relative to valve body (1) comprises a linear move.

5. Solenoid valve controlling method provided with magnetic cursor according to claim 1, characterized by the fact that the selective and guided movement of scrollable cursor (2) relative to valve body (1) comprises a rotary move.

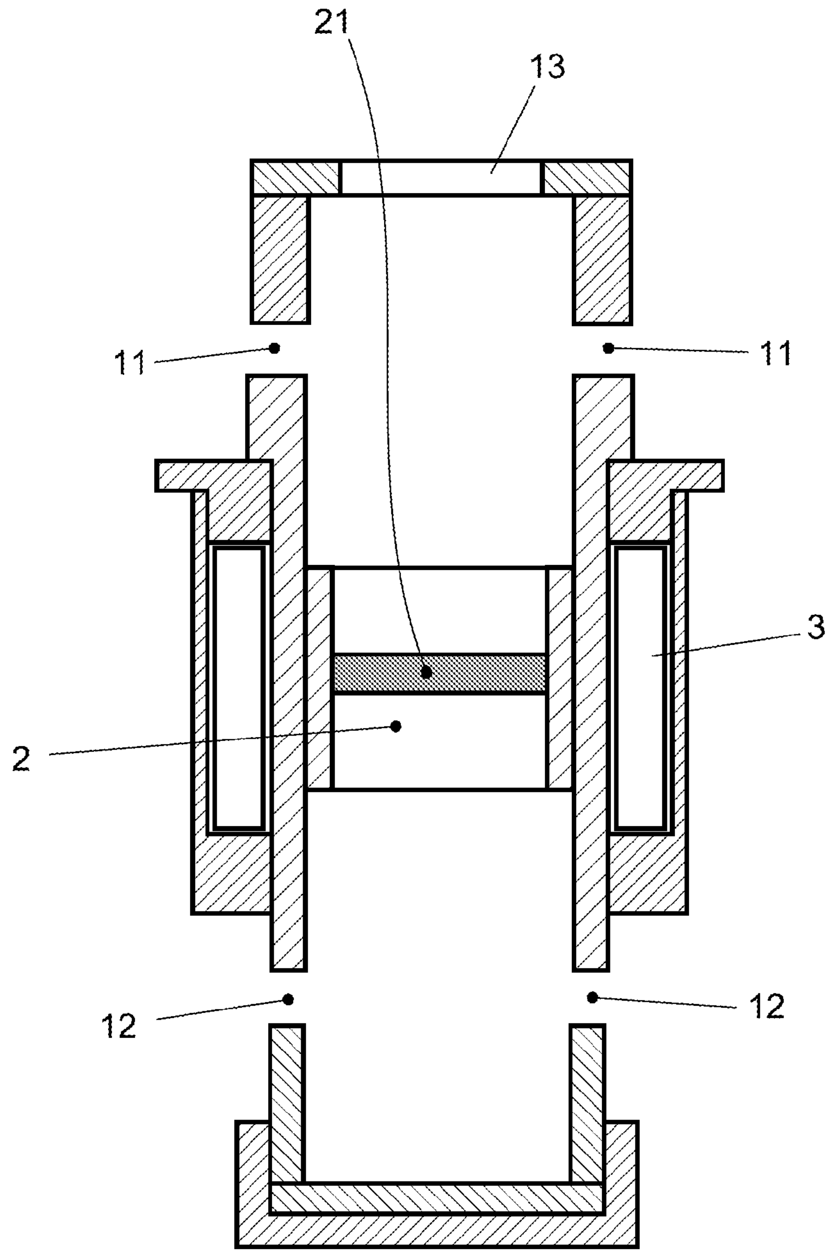


FIG. 1

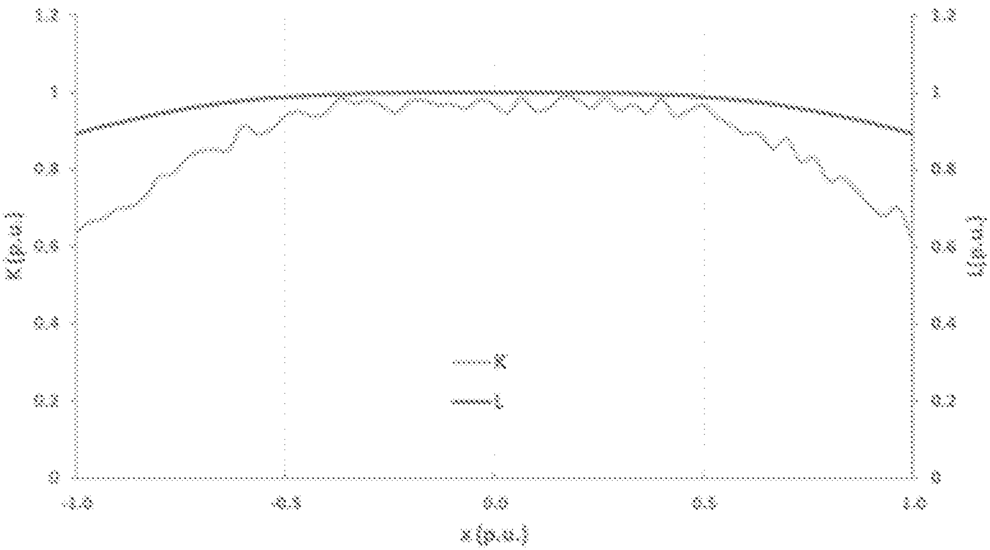
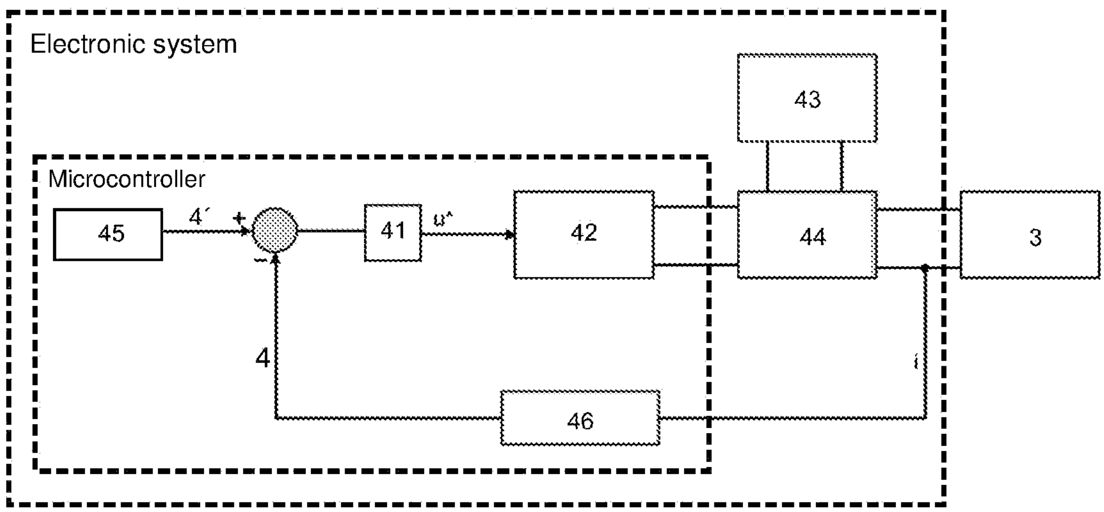

1
0.8
0.6
0.4
0.2
0
x (p.u.)

FIG. 2


Electronic system
Microcontroller
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+
41
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42
43
44
3
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i
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FIG. 3

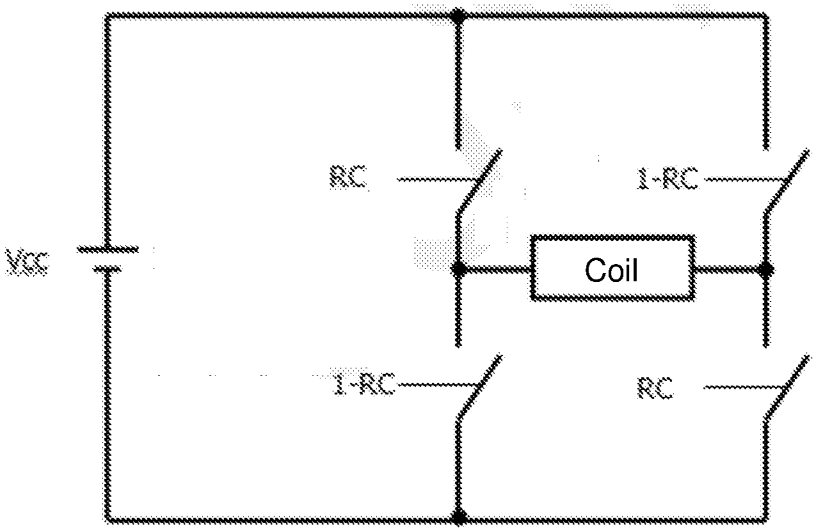

FIG. 4

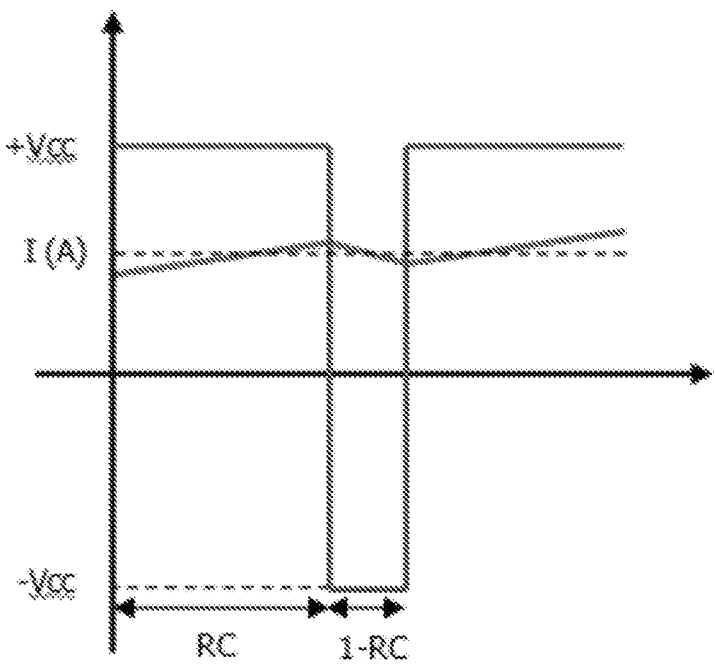

FIG. 5

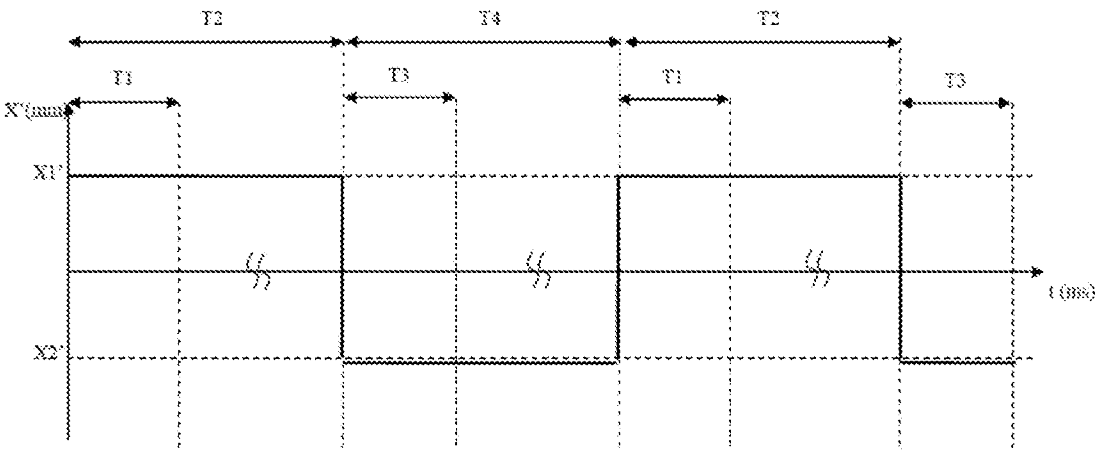

FIG. 6A

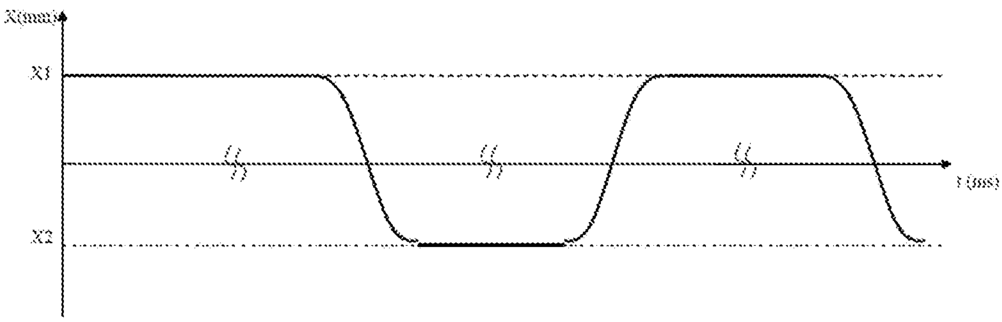

FIG. 6B

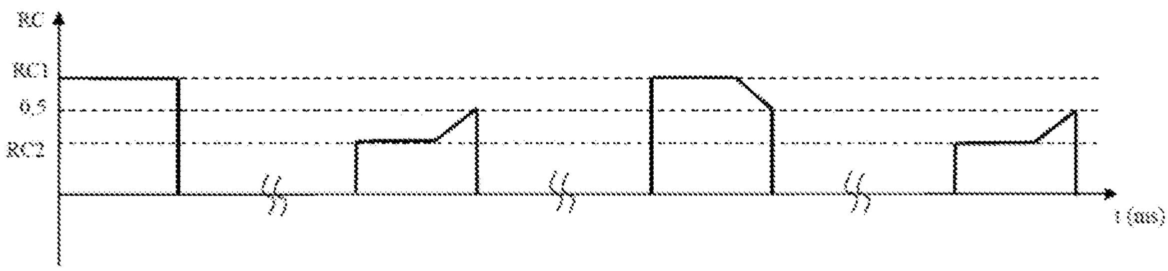

FIG. 6C

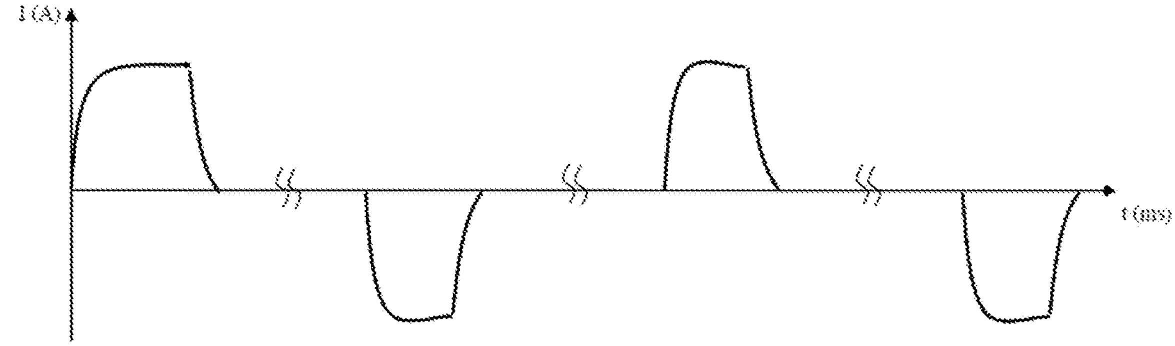

FIG. 6D

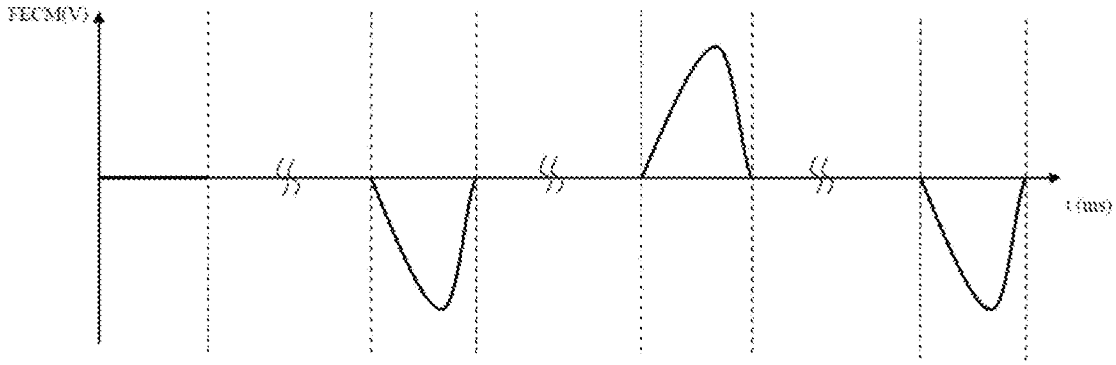

FIG. 6E

INTERNATIONAL SEARCH REPORT

International application No
PCT/BR2015/050114

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01F7/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16H H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, COMPENDEX, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 424 637 A (OUDYN ET AL) 13 June 1995 (1995-06-13) column 2, line 39 - column 3, line 49 column 6, line 29 - column 7, line 3 figures 1, 9 -----	1-5
X	WO 93/11369 A1 (CATERPILLAR) 10 June 1993 (1993-06-10) figures 3, 7 page 9, line 3 - page 10, line 33 -----	1-5
X	EP 2 553 694 A1 (SCHNEIDER) 6 February 2013 (2013-02-06) claim 1 figure 2 -----	1-5
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 November 2015	20/11/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Subke, Kai-Olaf

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 069 284 A2 (SIEMENS) 17 January 2001 (2001-01-17) paragraphs [0009], [0013] figure 12 -----	1-5
X	EP 0 400 389 A2 (MOTOROLA) 5 December 1990 (1990-12-05) cited in the application column 2, lines 26-42 -----	1-5
X	US 5 942 892 A (LI) 24 August 1999 (1999-08-24) cited in the application figure 6 -----	1-5

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/BR2015/050114

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5424637	A	13-06-1995	NONE			
WO 9311369	A1	10-06-1993	US	5481187	A	02-01-1996
			US	5578904	A	26-11-1996
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