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(54) **Title**: AMPLITUDE STABILIZER FOR A STIRLING ENGINE SIGNAL GENERATOR

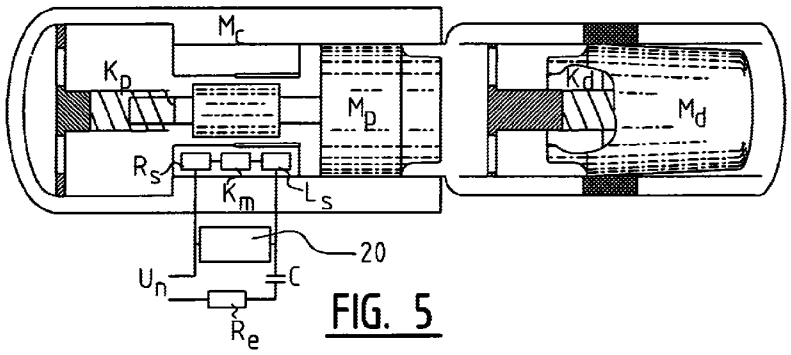

FIG. 5

(57) **Abstract**: A device for stabilizing the amplitude of a dynamic signal, in particular a current, generated by a generator, such as a Stirling engine, comprising: - an amplitude demodulator to be connected at least to the generator for demodulating the dynamic signal, at least in case of an unstable operation of the generator, into a signal component related to a stable operation of the generator and a signal component related to an unstable operation of the generator; and - a suppression circuit connected to the demodulator for suppressing the signal component related to the unstable operation of the generator.

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AMPLITUDE STABILIZER FOR A STIRLING ENGINE SIGNAL GENERATOR

The present invention relates to a device for stabilizing the amplitude of a dynamic signal, in particular a current, generated by a generator, such as a Stirling engine. The invention can also be implemented with a dynamic signal related to a different property or component of a generator (than the generated current). Thus, a signal representative of a piston movement is directly related to a current or voltage generated by the generator, and according to the invention said signal can as such be stabilized in the same manner as the generated current or voltage.

Generators are generally used for converting mechanical energy into electrical energy. This is for example based on movement of an electrical conductor in a magnetic field, variation of a magnetic field in the vicinity of a stationary electrical conductor, or another similar mechanism. When the generator is connected to the electricity grid, said energy is supplied to the electricity grid. A connecting circuit for connecting the generator to the electricity grid is for example described in International patent publication WO 02/07368. When the generator is connected to the electricity grid for supplying electrical energy thereto it is of major importance that the supplied current (and/or the generated voltage) has a predetermined frequency and an amplitude which is preferably as constant as possible. The frequency of the generated current or voltage must correspond to the grid frequency. Said grid frequency is for example 50 Hz in Europe and 60 Hz in the United States. A situation in which a constant amplitude of the current generated by the generator is realised is also referred to as stable grid operation, whilst a situation in which the amplitude varies the grid operation is referred to as unstable grid operation.

referred to as unstable grid operation. Unstable grid operation occurs, for example, when the power supplied to the electricity grid by the generator exceeds a specified limit, which limit depends on various interrelated system parameters.

Stable grid operation is in particular important if the generator is a (linear) generator that is driven by a Free Piston Stirling Engine (FPSE). An FPSE is described for example in US patent No. 3,552,120. The known FPSE comprises a displacer piston and a power piston in a cylinder, which displacer piston drives a working gas to and fro between a hot zone and a cold in a reciprocating movement, and which power piston is reciprocated within the cylinder as a result of expansion and compression of the working gas in the hot zone and the cold zone, respectively, and supplies power. When the known FPSE is connected to a linear generator, the power piston drives the electrical conductor through the magnetic field, or the electrical conductor is disposed in a magnetic field that varies with the power piston, in which case the generated current can subsequently be supplied to the electricity grid connected thereto. In an unstable grid operation situation, the varying amplitude of the current can also effect a variation in the amplitude of the reciprocating movement of the displacer piston and/or the power piston, so that there will be a risk of the displacer piston and/or the power piston striking against with stationary parts, such as the cylinder wall of the engine, for example, which may result in wear and or even rupture of said parts.

A solution to this is given in, for example, International patent publication WO 2006/008540. In the known solution, a variation in the amplitude of the current is detected by means of Fourier Transform, whereupon the power of the burner that heats the hot zone is decreased, which leads to a decrease of the amplitude

of the displacer piston and/or the power piston. As a result, the power supplied to the electricity grid by the generator is reduced, resulting in stabilization of the amplitude of the current. A drawback of this manner of stabilizing the amplitude of the current is that it affects and/or decreases the power that is being supplied.

It is the object of the invention to obviate or at least alleviate the drawbacks of the prior art and in particular to provide a device for stabilizing the amplitude of a dynamic signal, in particular a current, generated by a generator, which device stabilizes said amplitude in an efficient and/or simple manner and/or without affecting, in particular reducing, the power being generated.

In order to accomplish that objective, the invention provides a device for stabilizing the amplitude of a dynamic signal, in particular a current, generated by a generator, such as a Stirling Engine, to which end the device is according to the invention different from the prior art in that it comprises:

- an amplitude demodulator to be connected at least to the generator for demodulating the dynamic signal, at least in case of an unstable operation of the generator, into a signal component related to a stable operation of the generator and a signal component related to an unstable operation of the generator; and
- a suppression circuit connected to the demodulator for suppressing the signal component related to the unstable operation of the generator. The generator is preferably connected to the electricity grid, in which case the generated power is supplied to the electricity grid.

By suppressing the signal component related to the unstable operation of the generator, only the signal component related to the stable operation of the generator is supplied to the electricity grid, so that there will be no contamination of the electricity grid. In a preferred embodiment, the generator is driven by a Free Piston Stirling Engine, so that suppression of the signal component related to the unstable operation of the generator has the advantage that variations in the amplitude of the reciprocating movement of the displacer piston and/or the power piston are suppressed, thereby reducing the risk of the displacer piston and/or the power piston striking against stationary parts, such as the cylinder wall of the engine, for example, and thus also the risk of damage to the generator and/or the FPSE.

In a preferred embodiment of the device according to the invention, the suppression circuit comprises at least one resistor connected to the generator and to the demodulator for dissipation of the energy in the signal component related to the unstable operation of the generator.

In another preferred embodiment of a device according to the invention, the demodulator comprises a rectifier and an RC circuit that determines a time constant, said RC circuit preferably comprising at least one capacitor and a second resistor connected in parallel thereto, and said rectifier preferably comprising a diode bridge. The values of the resistance component and the capacity component are preferably selected so that the time constant of the RC circuit corresponds to the frequency of the unstable signal component, whilst the frequency of the electricity grid is the same as the frequency of the signal component related to the stable operation of the generator. By having the time constant of the RC circuit

correspond to the frequency of the unstable signal component in the generated dynamic signal, the signal component related to the stable operation of the generator is blocked. The admitted signal component related to the unstable operation of the generator, which is thus isolated, can then be suppressed. Suppression of the signal component related to the unstable operation of the generator can then take place on the basis of dissipation of the energy in the signal component related to the unstable operation of the generator in the first and/or the second resistor.

The invention also relates to a system for supplying electric energy to an electricity grid.

The invention will now be explained in more detail with reference to figures illustrated in a drawing, in which:

- Figure 1 schematically shows a generator driven by a Free Piston Stirling Engine connected to the electricity grid;

- Figures 2A and 2B show an amplitude diagram and a frequency characteristic, respectively, of the current supplied to the electricity grid by the generator in a stable operating state;

- Figures 3A and 3B show an amplitude diagram and a frequency characteristic, respectively, of the current supplied to the electricity grid by the generator in an unstable operating state;

- Figures 4A and 4B show electric diagrams of embodiments of devices according to the invention for stabilizing the amplitude of the current supplied to the electricity grid by a generator;

- Figure 5 schematically shows an embodiment of a device according to the invention for stabilizing the amplitude of the current supplied to the electricity grid by a generator, which is connected to the electric connection points of the generator; and

- Figure 6 schematically shows an embodiment of a device according to the invention to be used as an alternative to or in addition to the embodiment shown in figure 5 for stabilizing the amplitude of the current supplied to the electricity grid by a generator connected to the electrical connection points of the electricity grid.

Figure 1 shows a generator 1 which, in an operating state thereof, is driven by means of a Free Piston Stirling Engine (FPSE) 2. The FPSE 2 comprises a displacer piston 3, which is mounted in a cylinder 5 via a spring 4. The cylinder 5 is filled with a working gas, for example helium. On the side 6 of the cylinder 5, heat having a high temperature Q_H, for example as a result of heating by means of a burner, is supplied and on the other side 7 heat having a low temperature Q_L is dissipated, for example by cooling. As a result of the reciprocating movement of the displacer piston 3 in the cylinder 5, the working gas is alternately displaced to the hot side 6 and the cold side 7, with the working gas expanding and being compressed, respectively. As a result of expansion and compression of the working gas, a piston 8 present in a cylinder 11, which is mounted in the cylinder 11 by means of a spring 9, is reciprocated within the cylinder 11. The piston 8 drives an armature 10 of the generator 1, inducing a current that is supplied to the electricity grid connected thereto.

It is noted that the cylinders 5 and 11 are separate cylinders in the embodiment shown and described herein, but that it is also possible for the cylinders 5 and 11 to form one unit, although this is generally less common.

In figure 2A the amplitude of the current supplied to the electricity grid by the generator is shown in a stable grid operation situation. As is apparent from the figure, the amplitude of the current is stable in a stable grid operation situation, resulting in a single frequency peak, which corresponds to the frequency of the electricity grid, see figure 2B. In a stable grid operation situation, the amplitude and the frequency of the power piston and the displacer piston movement are controlled by the electricity grid.

Figure 3A shows that in a stable grid operation situation the amplitude of the current supplied to the electricity grid by the generator is not constant but rather varies. This variation of the amplitude of the current results in two frequency peaks besides the frequency of the electricity grid, see figure 3B. Said frequencies correspond to the signal component that is related to an unstable operation of the generator, with the frequency of the electricity grid corresponding to the signal component that is related to a stable operation of the generator. The amplitude variation is also reflected in the power piston and displacer piston movement, so that there is a risk of the power piston 8 and the displacer piston 3 striking against stationary parts of the generator 1 and/or the FPSE 2 and/or the cylinder 11, such as the cylinder wall of the cylinder 5 or the cylinder 11, for example. This is undesirable, since this may result in wear or even rupture of said parts, at any rate, there is a risk of damage resulting from unstable operation, which must be prevented. Unstable grid operation occurs, for example, when

the power supplied to the electricity grid by the generator exceeds a specified limit, which limit depends on various parameters of the system in combination with the power being supplied or to be supplied.

Figure 4A shows an electric diagram of a device, generally indicated at 20, according to a first embodiment of the invention, which device functions to stabilize the amplitude of the current supplied to the electricity grid by a generator. The device 20 comprises an electric circuit provided with diodes 21 arranged in a bridge configuration for rectifying the current. The device further comprises a capacitor 22 and a resistor 23 connected in parallel thereto, which circuit can also be referred to as a demodulator within the framework of the present invention. The circuit has a time constant T which is determined by the value C of the capacitor 22 and the value R of the resistor 23. The selection of time constant - and thus the dimensioning of the capacitor 22 and the resistor 23 - is so that the signal component which is related to a stable operation of the generator and which corresponds to the frequency of the electricity grid is largely blocked, whilst the signal component which relates to an unstable operation of the generator is admitted. The energy of the admitted unstable current component is subsequently dissipated in the damping resistor 24 and/or in the resistor 23. There are several possibilities for the placement of the damping resistor 24, in which regard it is important that all the admitted current passes through the damping resistor 24. As a result of the dissipation of the energy, the unstable component of the current, or the variation in the amplitude of the current, is suppressed. This results in suppression of the variation in the amplitudes of the power piston and the displacer piston movements, thus preventing the power piston 8 and the displacer piston 3 striking against stationary parts of the generator 1

and/or the FPSE. As a result, the stability limit of the generator is shifted to a higher electric power level, without this being realised at the expense of a great power loss. The fact is that "leakage" losses, which may occur when a small part of the signal component related to the stable operation situation is dissipated in the resistor 24 and/or the resistor 23, in spite of the separation of the signal components by means of the RC circuit (which thus performs a filter function), are left out of consideration in this regard.

Figure 4B shows an electric diagram of a device 20 according to a second embodiment of the invention, likewise for stabilizing the amplitude of the current supplied to the electricity grid by a generator. This embodiment comprises additional resistors Rd for increasing the dissipate capacity of the device 20.

In figure 5 the device 20 is shown as connected to the generator. The device 20 may also be directly connected to the electricity grid, as is shown in figure 6.

It is noted that the present invention is not limited to a few of the embodiments as described above, but that it also extends to other variants, which fall within the spirit and scope of the appended claims.

CLAIMS

1. A device for stabilizing the amplitude of a dynamic signal, in particular a current, generated by a generator, such as a Stirling engine, comprising:

- an amplitude demodulator to be connected at least to the generator for demodulating the dynamic signal, at least in case of an unstable operation of the generator, into a signal component related to a stable operation of the generator and a signal component related to an unstable operation of the generator; and
- a suppression circuit connected to the demodulator for suppressing the signal component related to the unstable operation of the generator.

2. A device according to claim 1, wherein the suppression circuit comprises at least one resistor connected to the generator and to the demodulator for dissipation of the energy in the signal component related to the unstable operation of the generator.

3. A device according to claim 1, wherein the demodulator comprises a rectifier and an RC circuit that determines a time constant.

4. A device according to claim 3, wherein said RC circuit preferably comprises at least one capacitor and a second resistor connected in parallel thereto.

5. A device according to claim 3 or 4, wherein said rectifier comprises a diode bridge.

6. A device according to at least one of the preceding claims 1 - 5, wherein the frequency of the signal component related to the stable operation of the generator is the same as an electricity grid frequency.

7. A device according to claim 3 or 4 and claim 6, wherein the values of the resistance component and the capacity component of the RC circuit are selected so that the time constant of the RC circuit corresponds to the frequency of the signal component related to the unstable operation of the generator.

8. A system for supplying electrical energy to an electricity grid, comprising a generator connected to the electricity grid and a device for stabilizing the amplitude of a dynamic signal, in particular a current, generated by a generator, which device comprises an amplitude demodulator to be connected at least to the generator for demodulating the dynamic signal, at least in case of an unstable operation of the generator, into a signal component related to a stable operation of the generator and a signal component related to an unstable operation of the generator, and which further comprises a suppression circuit connected to the demodulator for suppressing the signal component related to the unstable operation of the generator.

9. A system according to claim 8, said generator is driven by a Free Piston Stirling Engine.

10. A system according to claim 9, wherein the device for stabilizing the amplitude of a dynamic signal generated by the generator is connected to the generator.

11. A system according to claim 9, wherein the device for stabilizing the amplitude of a dynamic signal generated by the generator is connected to the electricity grid.

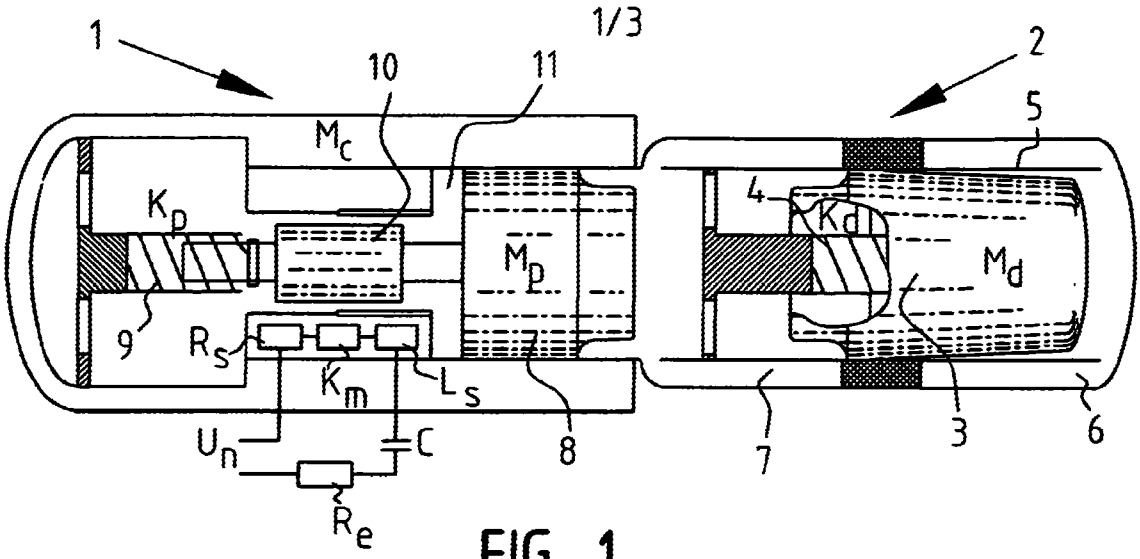

FIG. 1

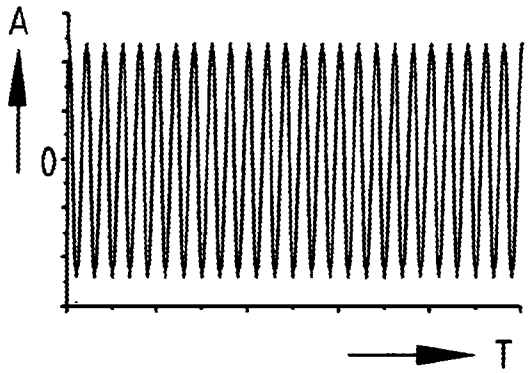

FIG. 2A

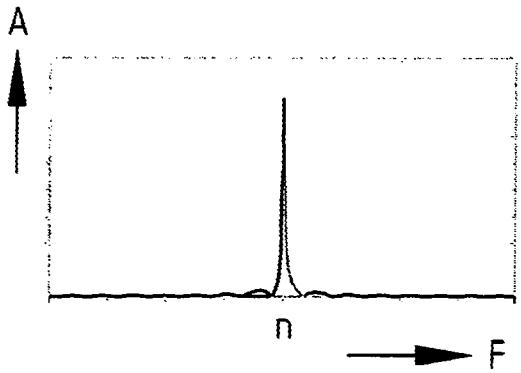

FIG. 2B

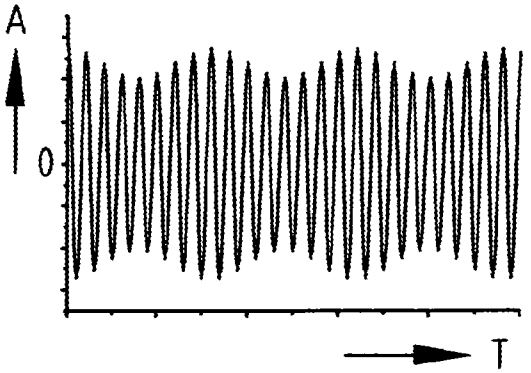

FIG. 3A

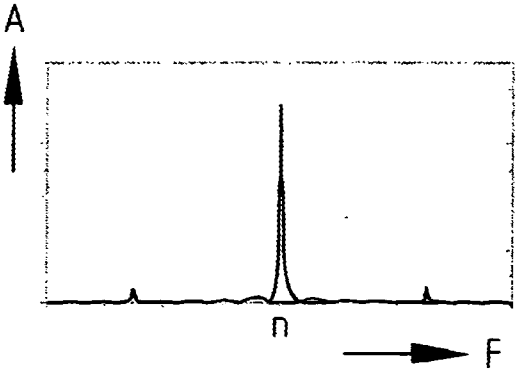

FIG. 3B

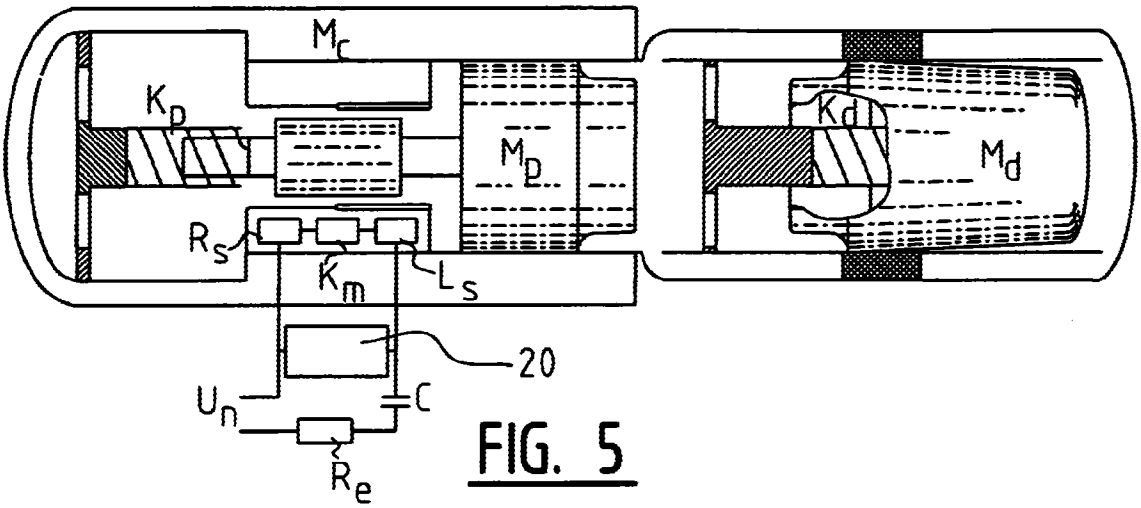

FIG. 5

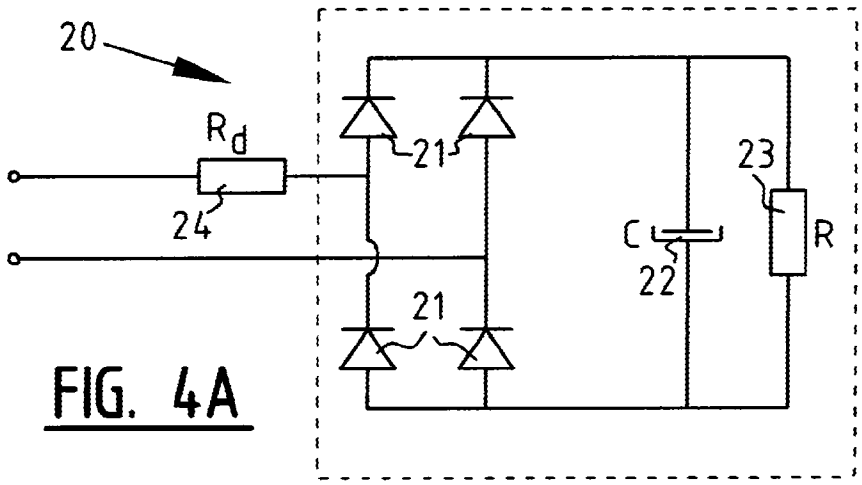

FIG. 4A

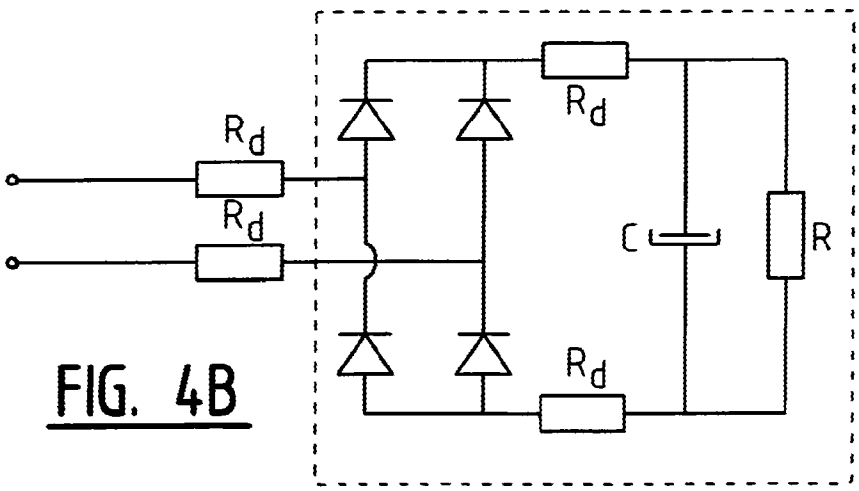

FIG. 4B

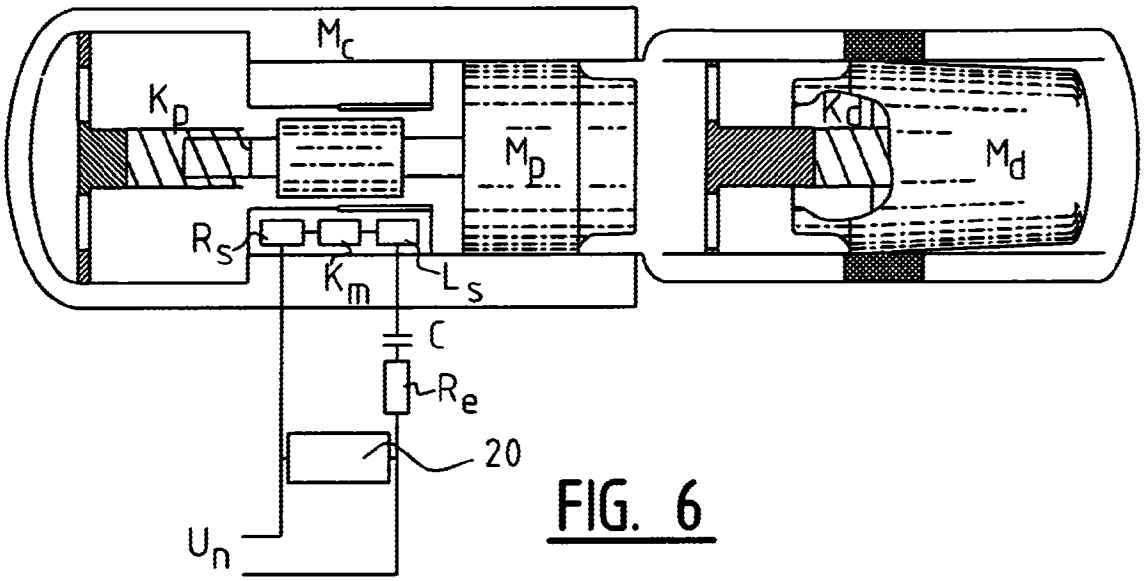

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2010/050366

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02P25/02 H03L5/00
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)
H02P H03L

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 practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 00/12866 A1 (STIRLING TECHNOLOGY CO [US]; GENSTLER CURTIS [US]; WILLIFORD IAN [US];) 9 March 2000 (2000-03-09) page 5, line 24 - page 11, line 18; figures 1-3	1-11
A	US 2004/221576 A1 (LYNCH THOMAS H [US] ET AL) 11 November 2004 (2004-11-11) page 3, paragraph 27 - page 4, paragraph 36; figures 1,2	1-11

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

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Date of the actual completion of the international search	Date of mailing of the international search report
16 August 2010	20/08/2010

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	Aouichi, Mohamed

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2010/050366

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0012866 A1	09-03-2000	AU 5783299 A	21-03-2000
		US 6050092 A	18-04-2000
US 2004221576 A1	11-11-2004	NONE	