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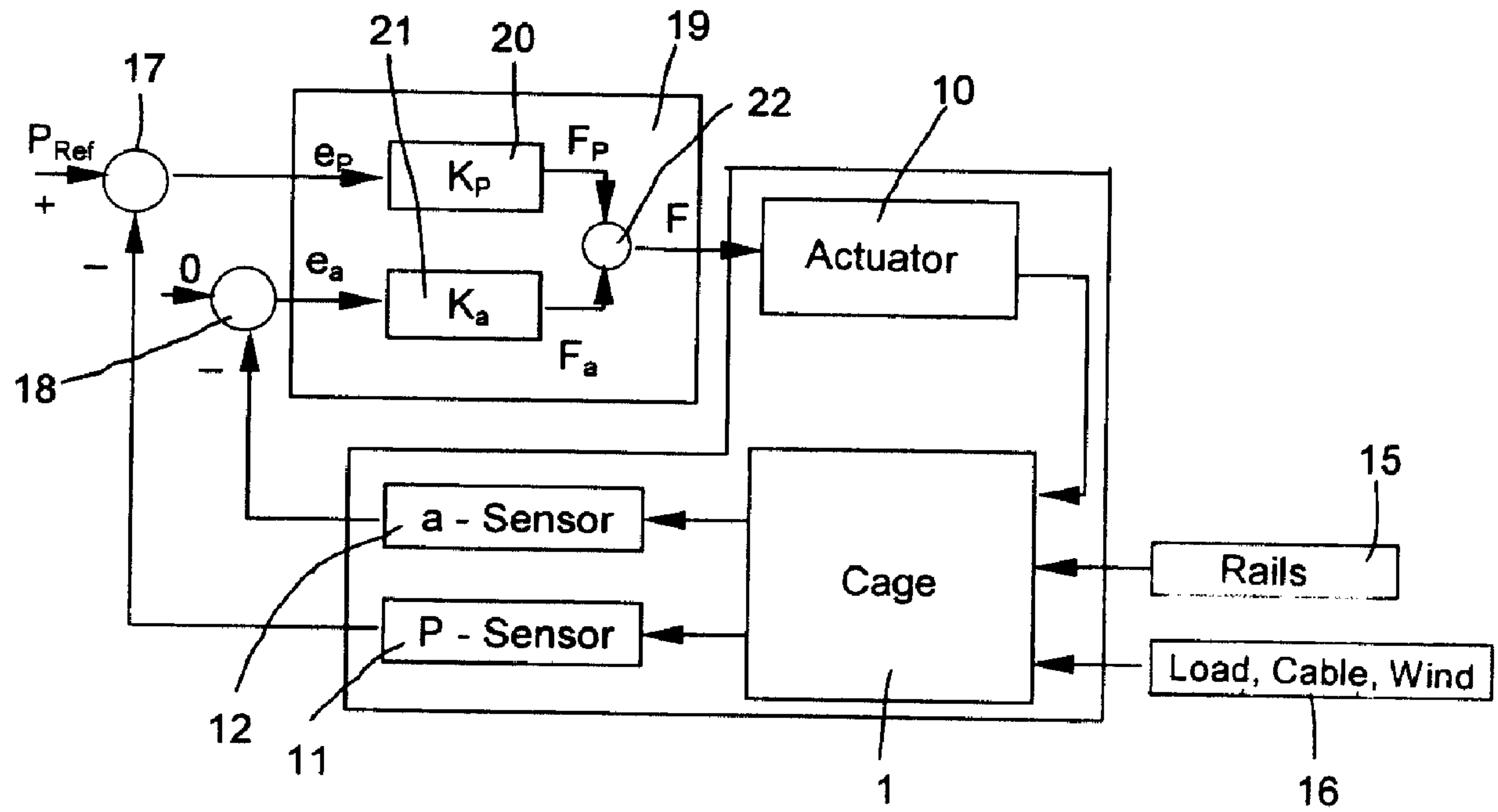
(54) Titre : EQUIPEMENT AMORTISSEUR DE VIBRATIONS D'UNE CABINE D'ASCENSEUR
(54) Title: EQUIPMENT FOR VIBRATION DAMPING OF A LIFT CAGE



(57) Abrégé/Abstract:
Equipment for reducing vibrations of a lift cage (1) guided at rails (15) comprises a plurality of guide elements (5, 6, 7) for guiding the lift cage (1) along the rails (15), a sensor (11, 12) for detecting positional changes of the lift cage (1) and/or of accelerations occurring at the lift cage (1), an actuator (1) arranged between the lift cage (1) and the guide elements (5, 6, 7) and a regulating device (19) which on the basis of the values transmitted by the sensor (11, 12) controls the actuator (10) for changing the position of the cage (1) relative to the rails (15). According to the invention the regulating device (19) has an amplification variable in dependence on the vertical speed (v) of the lift cage (1). In addition, the amplification of the regulating device (19) is continuously raised after activation of the regulating device (19) and continuously lowered after switching-off of the regulating device.

Abstract

Equipment for reducing vibrations of a lift cage (1) guided at rails (15) comprises a plurality of guide elements (5, 6, 7) for guiding the lift cage (1) along the rails (15), a sensor (11, 12) for detecting positional changes of the lift cage (1) and/or of accelerations occurring at the lift cage (1), an actuator (1) arranged between the lift cage (1) and the guide elements (5, 6, 7) and a regulating device (19) which on the basis of the values transmitted by the sensor (11, 12) controls the actuator (10) for changing the position of the cage (1) relative to the rails (15). According to the invention the regulating device (19) has an amplification variable in dependence on the vertical speed (v) of the lift cage (1). In addition, the amplification of the regulating device (19) is continuously raised after activation of the regulating device (19) and continuously lowered after switching-off of the regulating device.

[Fig. 2]

Equipment for vibration damping of a lift cage

The present invention relates to equipment for reducing or damping vibrations of a lift cage guided at rails and to a corresponding method for vibration damping.

During travel of a lift cage in a lift shaft, different forces can act on the cage, which consists of the cage body and a cage frame holding the cage body, and excite the system to vibrate. The causes of vibrations in that case can be, in particular, unevennesses in the guide rails and forces produced by slipstream. Beyond that, lateral traction forces transmitted by the traction cables or sudden positional changes of the load during travel can produce transverse vibrations.

In order to increase travel comfort for persons using the lift, regulating systems are employed which are designed for the purpose of providing compensation for forces acting on the lift cage. For example, a system is known from EP 0 731 051 B1 of the applicant which comprises several guide elements connected with the lift cage and movable between two end settings. Vibrations or accelerations arising transversely to the direction of travel are measured by several sensors mounted at the cage and the signals thereof are used for control of a plurality of actuators arranged between the cage and the guide elements. The actuators are in that case controlled by a regulating device, which is connected with the sensors, in such a manner that they work in opposition to the arising vibrations and thereby suppress these as effectively as possible.

A typical characteristic of the method known from EP 0 731 051 B1 as well as other methods for reducing vibrations of lift cages in accordance with the state of the art is that these operate with regulators which are linear and invariable with respect to time. The reason for that is that, in the design of the regulator, non-linear processes can be taken into consideration only with difficulty and accordingly for simplification of the concept of the regulator the starting point is that the disturbances which occur are linear. However, the consequence of that is that undesired vibrations can arise when the regulator is switched on at the beginning and end of travel of the lift. The cause of that is that in this connection non-linear changes in the state of the system are concerned and cannot be controlled by the linear and time-invariable behaviour of the regulator.

The object of the present invention is accordingly to indicate the possibility of avoiding vibrations or even shocks of the lift cage during starting up and stopping of the lift and during loading and unloading of the cage.

The object is fulfilled by equipment for reducing vibrations of a rail-guided lift cage and by a method, according to, respectively, the independent claims.

The core of the present invention is to design the amplification of the regulating device, which is responsible for suppression of vibration, to be speed-variable and/or time-variable. In that case, according to a first aspect of the present invention it is provided to form the amplification of the regulating device to be dependent on the vertical speed of the lift cage, whereby better reaction to non-linear processes during starting up and during braking of the lift cage is possible. According to a second aspect of the present invention it is provided to continuously raise the amplification after switching-on of the regulating device and to continuously lower the amplification after switching-off of the regulating device.

The measures in accordance with the invention allow adaptation of the behaviour of the regulating device, which is fundamentally designed to be linear and time-variable to the above-mentioned non-linear processes. In particular, the vibrations arising during starting up and stopping of the lift, during loading and unloading of the cage and during switching-on and switching-off of the regulating device, and even shocks attributed to an inappropriate reaction of a linear regulator to non-linear system changes, can be suppressed by measures which are comparatively simple to undertake.

According to a preferred example of embodiment of the present invention the speed-variable or time-variable mode of behaviour of the regulating device is realised in that the error signals or regulating deviations fed to the regulator and/or the setting signals, which are produced by the regulator, for the actuators are weighted with time-dependent or speed-dependent parameters. For this purpose several amplification blocks, by the output signals of which the error signals or setting signals are weighted, can be provided within the regulating device. A part of these blocks is in that case responsible for realisation of the speed-dependent behaviour of the regulating device, whereagainst so-termed time delay blocks are responsible for the reaction to the switching-on and switching-off of the regulating device. This solution is distinguished by the fact that it is comparatively simple to realise. In particular, it is not necessary to influence the actual regulator converting the error signals supplied thereto into setting signals for the actuators. A linear and time-invariable regulator can thus be used as in the past.

According to a particularly preferred example of embodiment of the present invention the regulating device comprises two internal regulators, namely a position regulator and an acceleration regulator. The position regulator in that case is responsible for so regulating the setting of the guide elements with respect to the guide rails that a sufficiently high damping travel is available at all times. This means nothing other than that the lift cage or the frame holding the cage body shall follow the guide rails, particularly even the corresponding unevennesses of the rails. The task of the acceleration regulator, thereagainst, is to suppress the vibrations which arise at the cage frame and which can also be produced by the unevennesses. The target values of the forces which the two regulators of the actuators seek are then correspondingly summated and fed to the actuators as a common setting signal. This solution, which is already known from EP 0 731 051 B1, makes it possible to pursue the two above-mentioned objectives, which in fact are mutually opposed, in the most optimum manner possible.

In the case of use of the two separate regulators it is preferably provided to initially linearly raise the amplification of the position regulator after switching-on of the regulating device, whereagainst the acceleration regulator is activated only with a certain delay in time, similarly with a linear rise. After switching-off of the regulating device, thereagainst, initially the amplification of the acceleration regulator is linearly reduced to zero and the position regulator is also switched off only with a certain delay in time.

The invention is explained in more detail in the following on the basis of the accompanying drawings, in which:

Figure 1 shows a schematic illustration of a lift cage guided at rails;

Figure 2 shows the signal flow diagram of a system for active vibration damping; and

Figure 3 shows the signal flow diagram of the regulating equipment designed in accordance with the invention.

Before the regulating equipment according to the invention is explained in more detail, the realisation of an overall system for active damping of vibrations or oscillations of a lift cage will initially be discussed by reference to Figure 1.

The cage illustrated in Figure 1 and provided generally with the reference numeral 1 is in that case divided into a cage body 2 and a cage frame 3. The cage body 2 is mounted in the frame 3 with the help of several rubber springs 4 which are provided for insulation of solid-borne sound. These rubber springs 4 are designed to be comparatively stiff in order to suppress the occurrence of low-frequency vibrations.

The cage 1 is guided, with the help of four roller guides 5 at the two guide rails 15 which are arranged in a lift shaft (not shown). The four roller guides 5 are usually of identical construction and mounted laterally at the bottom and the top at the cage frame 3. They each have a respective post on which there are mounted in each instance three guide rollers 6, i.e. two lateral rollers and one centre roller. The guide rollers 6 are in that case each movably mounted with the help of a respective lever 7 and are pressed by way of a spring 8 against the guide rails 15. The levers 7 of the two lateral guide rollers 6 are, in addition, connected together by way of a tie rod 9 so that they move synchronously with one another.

Two electrical actuators 10, which exert on the respective levers 7 a force acting parallel to the associated springs 8, are provided per roller guide 5. A first actuator 10 in that instance moves the centre lever 7 together with the associated centre guide roller 6, where against the second actuator 10 moves the two lateral levers 7 together with the associated lateral guide rollers 6. The setting of the levers 7 or of the rollers 6 and thereby the position of the lift cage 1 with respect to the guide rails 15 is thus influenced by way of the actuators 10.

The cage oscillations or vibrations to be damped by the equipment according to the present invention arise in the following five degrees of freedom:

- displacements in X direction
- displacements in Y direction
- rotations about the X axis
- rotations about the Y axis
- rotations about the Z axis

The different displacements or rotations in the five degrees of freedom are in that case respectively attributable to a different mounting of the lift cage 1 at the four roller guides 5 in X and/or Y direction.

In order to be able to detect vibrations of the cage 1 in all five above-mentioned degrees of freedom, there are provided at the outset two position sensors 11 per roller guide 5, i.e. a first sensor for detecting the position of the centre lever 7 together with the associated guide roller 6 and a second sensor for detecting the position of the two lateral levers 7 together with the associated lateral guide rollers 6. Beyond that, each roller guide 5 is equipped with two horizontally oriented acceleration sensors 12, of which one detects accelerations in displacement direction of the centre guide roller 6 and the second detects accelerations perpendicularly thereto in displacement direction of the two lateral guide rollers 6. The measurement signals of the sensors 11 and 12 give information about the current position of the lift cage 1 in relation to the two guide rails 15 and additionally inform whether the cage body 1 is currently subject to accelerations which can lead to vibrations.

A control apparatus 14 fastened to the roof of the cage body 2 processes the signals transmitted by the sensors 11 and 12 and controls, after evaluation of the sensor signals, the electrical actuators 10 of the four roller guides 5 with the help of a power supply unit in order to counteract the accelerations and vibrations in appropriate manner.

Before the design of the control apparatus 14, in particular the regulating device arranged therein, is explained in more detail it is still to be pointed out that in the case of the lift cage illustrated in Figure 1 a special feature consists in that a rotational movement sensor 13, which measures the rotational angle of a guide roller 6 associated therewith, is provided at a roller guide 5 (here at the righthand upper roller guide). The measurement values obtained by way of this rotational movement sensor 13 give information about the travel path of the cage and about the current travel speed thereof in vertical direction, thus in Z direction. The speed-variable regulation according to the present invention as described in the following is thereby made possible.

Figures 2 and 3 show the signal flow diagram of the system according to the invention for active vibration damping. The basic build-up according to Figure 2 in that case substantially corresponds with the method as also used in EP 0 731 051 B1. The illustrated signals are then to be understood as vector signals comprising several signals of like kind. The regulating equipment is designed as a so-termed MIMO (Multi-Input Multi-Output) regulator which on the basis of a plurality of input signals determines a plurality of setting signals for the actuators disposed at the roller guides.

In the system illustrated in Figure 1, external disturbances act on the cage 1, which are composed of indirect disturbing forces from the rails 15 as well as disturbing forces 16 which engage directly at the cage 1, in the form of cage load, cable forces and wind forces. The current state of the cage is ascertained with the assistance of the position sensors 11 and acceleration sensors 12, wherein initially the positions measured by the position sensors 11 are compared in a summation block 17 with reference values which reproduce a reference setting of the cage 1 with respect to the rails 15. The result of the summation is the error signal or regulating deviation e_p, which describes the deviations of the positions of the roller guides with respect to the reference setting. In the summation block 18, thereagainst, the acceleration values of the acceleration sensors 12 are negated, i.e. subtracted from the ideal or reference value 0 (no accelerations), whereby the second error signal e_a is produced.

The regulating equipment 19 is composed, as already mentioned, of two regulators, i.e. a position regulator (K_p) 20 as well as an acceleration regulator (K_a) 21. The reason for use of two separate regulators is that an objective of the regulating equipment 19 consists of suppressing cage vibrations in the high-frequency range (between 0.9 and 15 Hz, and preferably between 0.9 and 5 Hz) without the regulated lift having a worse behaviour outside this frequency range than the unregulated lift. On the other hand, the regulating equipment 19 has to ensure that the setting of the cage frame 3 with respect to the guide rails 15 is so regulated that a sufficient damping travel at the rails is available at any time. This is particularly important when the cage 1 is asymmetrically loaded.

For the first regulating purpose an acceleration or speed feedback with inertia sensors is sufficient, whereagainst for the second regulating objective a position feedback is required. The two feedbacks have two opposing objectives, which are pursued by the use of the two separate regulators 20 and 21. As illustrated in Figure 2, the position regulator 20 takes into consideration exclusively the measurement values of the position sensors 11 and is correspondingly responsible for maintenance of the guidance play of the cage 1. The acceleration regulator 21, thereagainst, processes the measurement values of the acceleration sensors 12 and is required for suppression of vibrations. The target or setting values of the two regulators 20 and 21 are summated in the summation block and fed as a common setting signal to the actuators 10.

The solution for avoidance of the above-mentioned conflict between the two regulators 20 and 21 is based on the circumstance that the forces responsible for a skewed position of the cage 1 (a non-symmetrical loading of the cage, a large lateral cable force and the like) change substantially more slowly than the other sources of disturbance causing the cage vibrations. These are principally rail unevennesses or air disturbance forces. The amplification changes in the frequency range are always continuous, i.e. there are no fixed limits. At a defined frequency, the two regulators 20 and 21 have much the same influence. Above that the acceleration regulator 21 acts more strongly and below that the position regulator 20 acts more strongly.

The two above-mentioned regulating objectives can be pursued through division of the regulating equipment 19 into a position regulating circuit and an acceleration regulating circuit. A further advantage of the division consists in that the regulators 20 and 21 do not contain non-linearities. An analysis of stability and thus a corresponding configuring of the two regulators would otherwise be possible only with difficulty.

The design of the position regulator 20 and acceleration regulator 21 as linear regulators has, however, the consequence that these cannot react in suitable manner to non-linear processes which arise, for example, during starting up and during braking of the lift cage or during switching-on and switching-off of the regulating device. In order to be able to take these processes into consideration, the behaviour of the two regulators 20 and 21 is now designed in accordance with the present invention to be time-variable and speed-variable, which will be explained in the following by reference to Figure 3.

Figure 3 in that case shows the extended signal flow diagram of the method according to the invention, wherein only the extended regulator device 19 is shown, since the other parts of the system - cage, actuators and sensors - remain unchanged.

The time-variable and speed-variable design of the regulating device in accordance with the invention is achieved in that the error signals e_p, which are delivered by the summation point 17, for the position regulator 20 are initially weighted or multiplied by specific factors before they are fed to the position regulator 20. The variable behaviour of the acceleration regulating loop, thereagainst, is realised in that the setting signals determined by the acceleration regulator 21 on the basis of the error signals e_a fed thereto are weighted by several amplification factors. In both cases the amplification of the regulator 20 or 21 is ultimately varied, wherein this takes place with respect to the instant in time and the vertical speed of the cage.

The time-variable behaviour of the two regulators 20 and 21 is produced by two so-termed time delay blocks 23 and 24, which are controlled by a common 'on' or 'off' signal with the value 1 or 0. After switching-on of the regulating device initially the amplification factor k_{Pt} for the position regulator 20 is continuously moved up and, in particular, with a linear rise from 0 to 1. The amplification factor k_{at} for the acceleration regulator 21 thereagainst follows, with a certain delay in time, similarly with a linear rise from 0 to 1. After switching-off of the regulating device, initially the amplification k_{at} for the acceleration regulator 21 is linearly reduced from 1 to 0, whereagainst the amplification factor k_{Pt} for the position regulator 20 is lowered in time-delayed manner. The staggered placing in operation and deactivation of the two regulators 20, 21 achieved in this manner permits a particularly good reaction to the processes during switching-on and switching-off of the regulating device.

The amplification factors k_{Pt} and k_{av} delivered by the time delay blocks 23 and 24 are, in addition, also respectively multiplied in the blocks 27 and 28 by a speed-dependent factor k_{Pv} and k_{av} so that the amplification factors k_{Pvt} for the position regulator 20 and k_{avt} for the acceleration regulator 21 result. The speed factors k_{Pv} and k_{av} are produced by two blocks 25 and 26 which ascertain the two weighting factors in dependence on the speed value v is determined by the rotational speed sensor 13, wherein the speed-dependent amplification values are filed in tables and linearly intabulated. It is important that the two amplification factors k_{Pv} and k_{av} dependent on the absolute amount of the speed v are themselves never zero, whereby it is ensured that regulation still takes place even when the cage is at standstill.

The amplification factor k_{avt}, which is formed in the just-described manner, for the acceleration regulator 21 is then multiplied in block 29 by the output signal or setting signal of the acceleration sensor 21. The amplification factor k_{Pvt} for the position regulator 21 is, thereagainst, multiplied in the multiplication block 28 by a modified error signal e_{PIq} and fed to the position regulator 20.

The error signal e_p delivered by the summation block 17 is itself still subject to a modification which takes into account that in the case of relatively large deviations in position, as can happen at standstill of the cage (for example during loading), a quick correction has to be available. In order to take this circumstance into account, the square of the position error e_p with the same sign is formed in block 30 so that on the one hand a position error e_p is present in linear form and on the other hand in squared form. In the case of relatively large deviations, the squared error signal is to be used in order to achieve a sufficiently rapid correction of position. During travel of the cage, however, the large amplification would lead to vibrations and even to instabilities, for which reason it is necessary to switch over from the squared position error to the linear position error in dependence on travel speed.

The switching over itself should not, however, be carried out abruptly, so as not to produce any further instabilities. The consequently desired continuous transition is achieved with the help of an error signal modification device formed by the blocks 30 to 37, wherein block 31 initially switches an output signal from 0 to 1 when the (directionally independent) travel speed v exceeds a threshold value v_{sw}. Block 32 is a low-pass filter and causes a time-delayed continuous change in the output signal in the case of abrupt change of the input signal received by block 31. The output of the low-pass filter is multiplied in block 35 by the linear position error, whereagainst a difference between the reference value 1 and the output value delivered by the low-pass filter 32 is produced in the summation block 34. The sum of the amplification values fed to the multiplication block 35 for the linear error on the one hand and to the multiplication block 36 for the squared error on the other hand is thus always 1, i.e. the component of the squared error continuously reduces after exceeding of the limit speed v_{sw}, whereagainst the component of the linear error increases. The linear and squared position errors weighted in this manner are superimposed in the summation block 37 and finally multiplied in the block 38 by the time-dependent and speed-dependent amplification factor k_{Pvt}. The values weighted in this manner are ultimately fed to the position regulator 20 as input signals.

The weighting and amplification, which is realised in this manner, of the position and acceleration regulating loops enable adaptation of the behaviour of the regulating device to non-linear processes which arise during switching-on and switching-off of the regulator and during starting-up and braking of the lift cage. A decisive advantage of the solution according to the invention consists in that the position and acceleration regulators can be designed, as before, to be linear and time-invariable and thus the cost for configuring the regulating device is increased overall only slightly. Taking into account of the time-dependent and speed-dependent factors can be carried out in that case without greater cost, so that the entire regulating behaviour of the equipment according to the invention can be significantly improved in simple manner. The switching over between the linear and the square error signal for the position of the guide elements additionally makes it possible to achieve, at standstill of the lift cage, a quickest possible regulation with respect to changes in position.

Claims

1. Equipment for reducing vibrations of a lift cage guided at rails, comprising:

- a plurality of guide elements for guiding the lift cage along the rails,
- a sensor for detecting positional changes of the lift cage and/or accelerations occurring at the lift cage,
- an actuator arranged between the lift cage and the guide elements and
- a regulating device which on the basis of values transmitted from the sensor controls the actuator for changing the position of the cage relative to the rails,

characterised in that the regulating device has an amplification variable in dependence on the vertical speed (v) of the lift cage.

2. Equipment according to claim 1, characterised in that the regulating device comprises a time delay device which continuously raises the amplification of the regulating device after activation of the regulating device and continuously lowers the amplification after switching-off of the regulating device.

3. Equipment according to claim 1 or 2, characterised in that a signal representing the vertical speed is detected at a lift drive and transferred to the regulating device by way of a suspension cable.

4. Equipment according to claim 1 or 2, characterised in that the lift cage comprises a speed sensor which detects the vertical speed and the measurement value of which is converted by the regulating device into a speed-dependent amplification factor (k_{Pv}, k_{av}), which is multiplied by an input signal for a regulator and/or a setting signal, which is detected by the regulator, for controlling the actuator.

5. Equipment according to any one of the preceding claims, characterised in that the regulating device comprises an error signal modification device, by way of which the error signal (e_p) ascertained by position sensors arranged at the lift cage is fed as modified error signal to a position regulator

- in squared form below a predetermined limit speed (v_{sw}) of the cage and
- in linear form above the limit speed (v_{sw}) of the cage.

6. Equipment according to claim 5, characterised in that the change from the squared to the linear error signal and conversely is carried out continuously in the case of exceeding or falling below the limit speed (v_{sw}).

7. Equipment according to any one of the preceding claims, characterised in that the regulating device comprises a time delay device which continuously raises the amplification of the regulating device after activation of the regulating device and continuously lowers the amplification after switching-off of the regulating device.

8. Equipment according to any one of the preceding claims, characterised in that the regulating equipment comprises:

- a position regulator which controls the actuator in dependence on signals from position sensors, which are arranged at the lift cage, in such a manner that the guide elements adopt a predetermined position and
- an acceleration regulator which controls the actuator in dependence on signals from acceleration sensors, which are arranged at the lift cage, in such a manner that vibrations arising at the lift cage are suppressed,

wherein the setting signals of the position regulator and of the acceleration regulator are summated and fed to the actuator as a summation signal.

9. Equipment according to claim 7 and claim 8, characterised in that an amplification factor (k_{pt}), which is formed by a first time delay block, for the position regulator linearly rises after activation of the regulating device and linearly drops to 0 after switching-off of the regulating device.

10. Equipment according to claim 9, characterised in that the drop of the amplification factor (k_{pt}) for the position regulator is carried out delayed in time after switching-off of the regulating device.

11. Equipment according to claim 9 or 10, characterised in that an amplification factor (k_{at}), which is formed by a second time delay block, for the acceleration regulator linearly rises in time-delayed manner after activation of the regulating device and linearly drops to 0 after switching-off of the regulating device.

12. Equipment according to claim 11, characterised in that the amplification factor (k_{at}) for the acceleration regulator rises, after activation of the regulating device, in time-delayed manner by comparison with the amplification factor (k_{pt}) for the position regulator and that the lowering of the amplification factor (k_{at}) for the acceleration regulator begins directly after switching-off of the regulating device, whereas lowering of the amplification factor (k_{pt}) for the position regulator takes place in time-delayed manner.

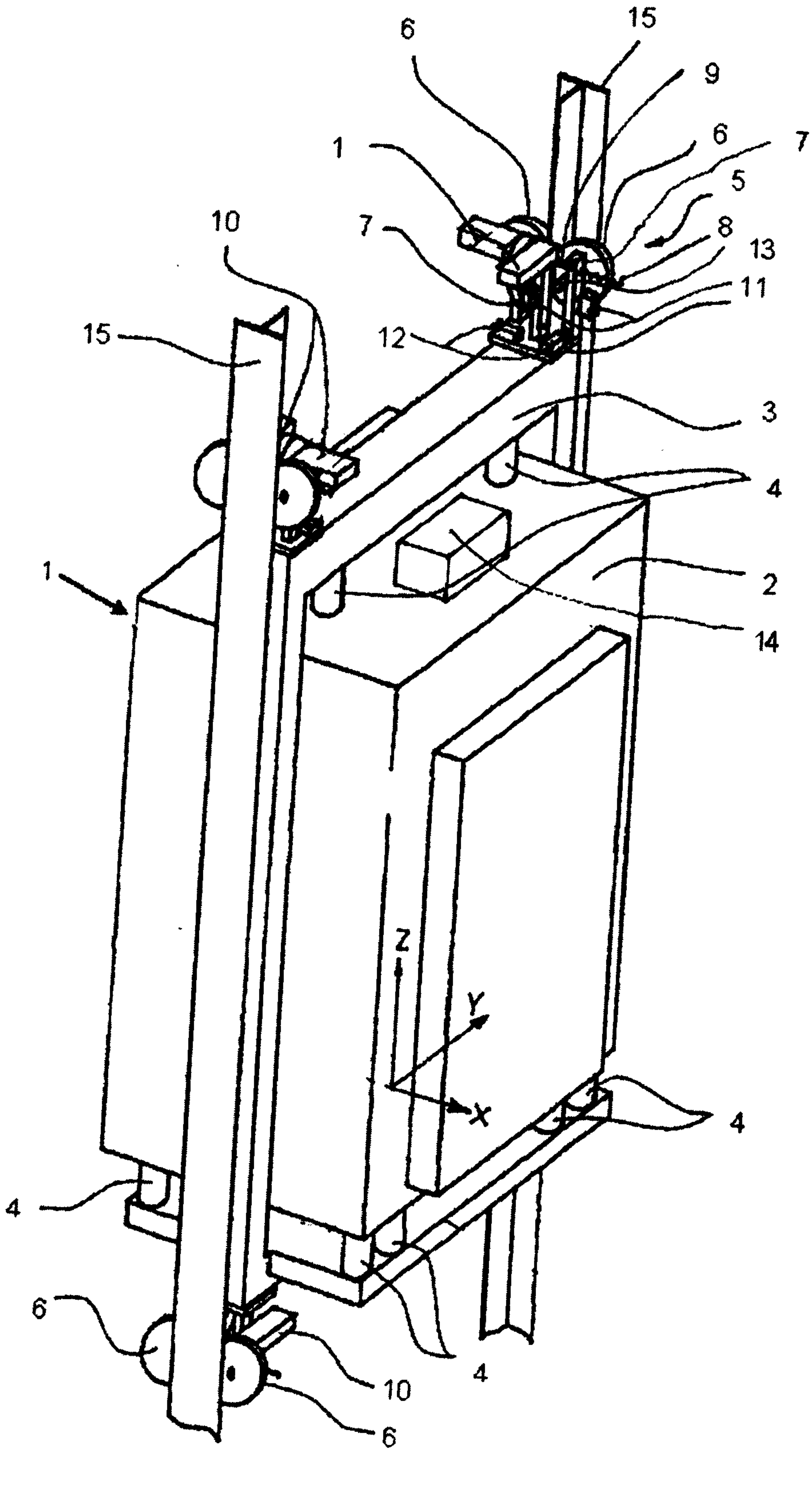


Fig. 1

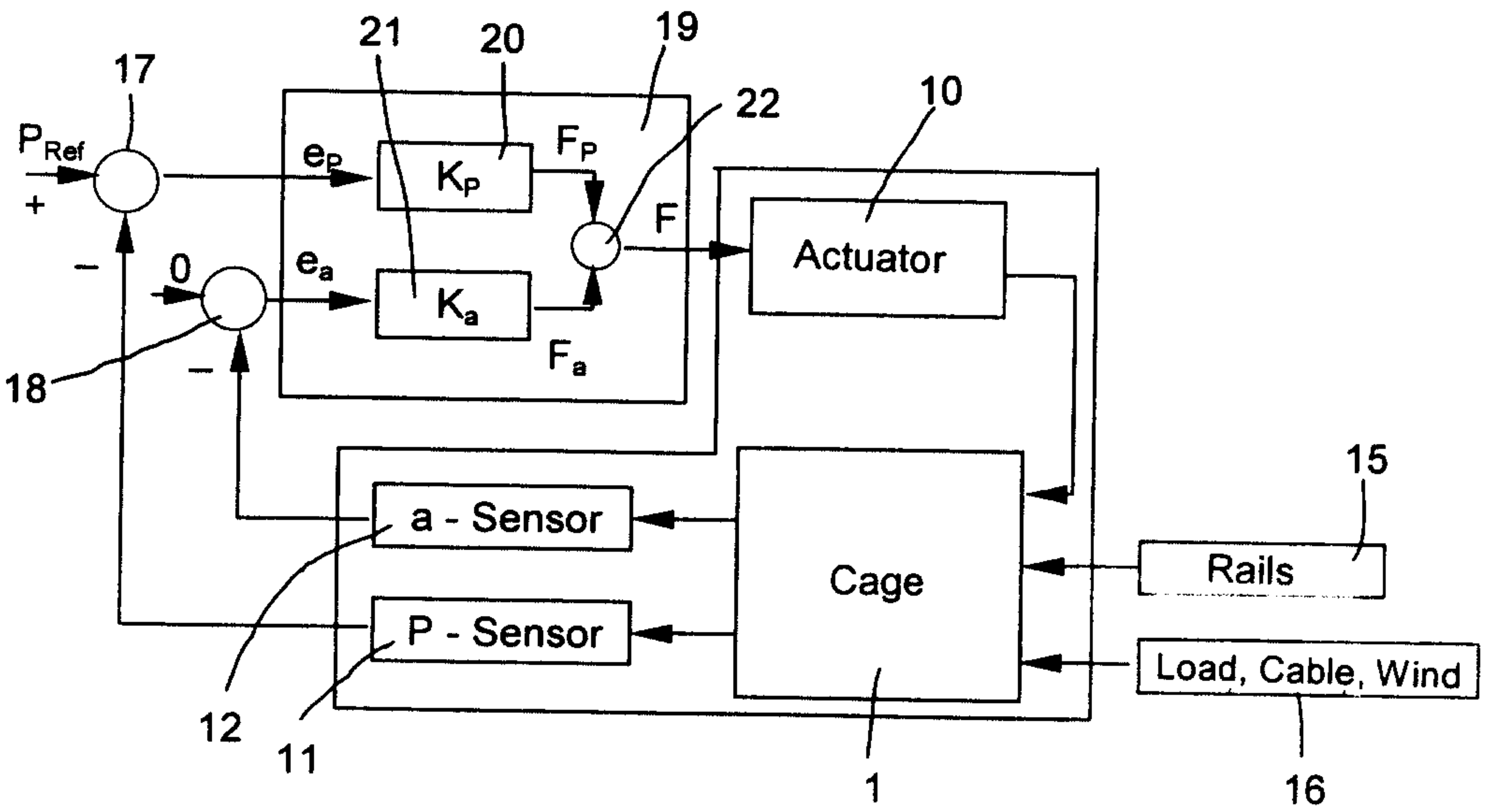

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Fig. 2

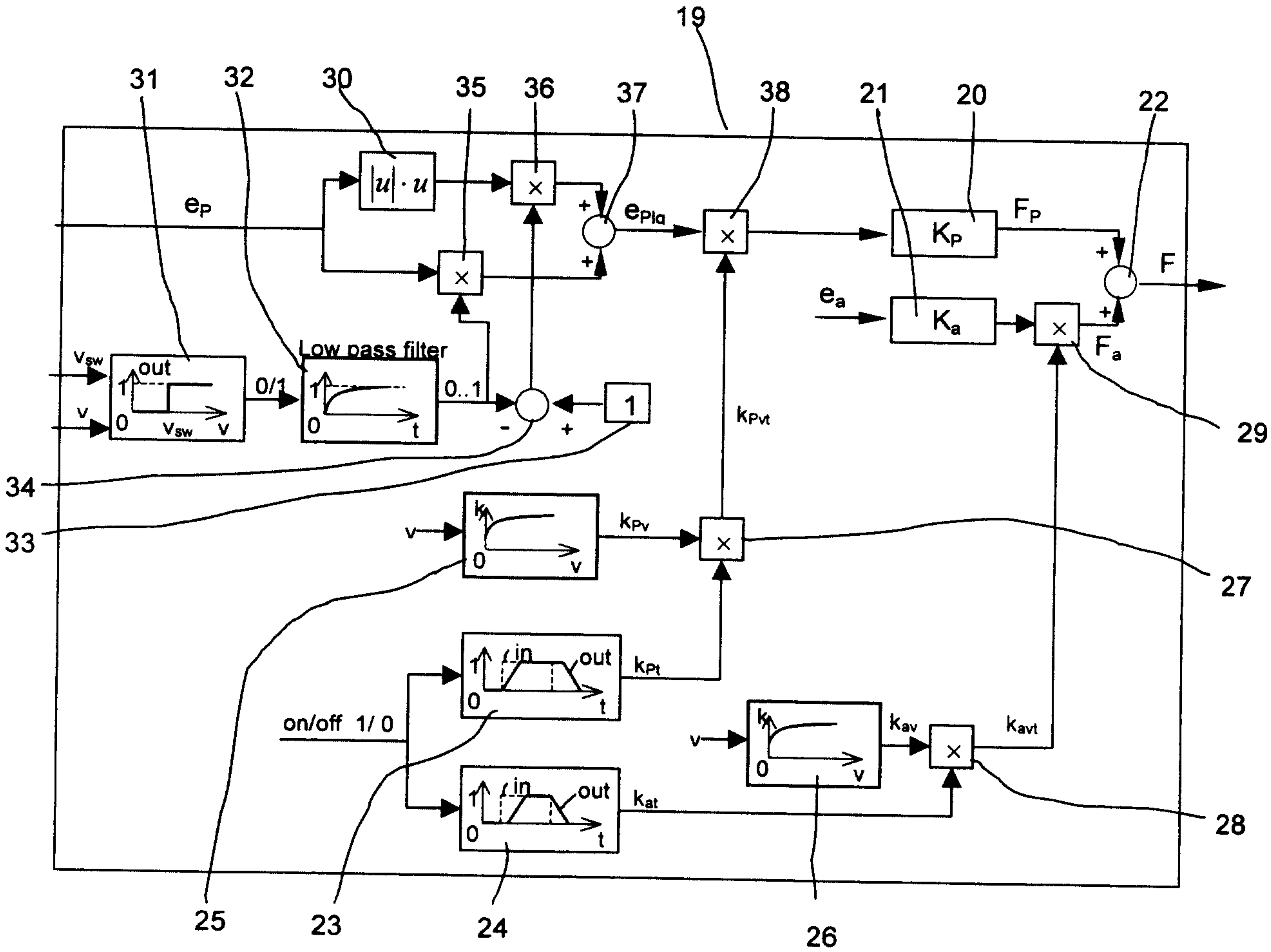
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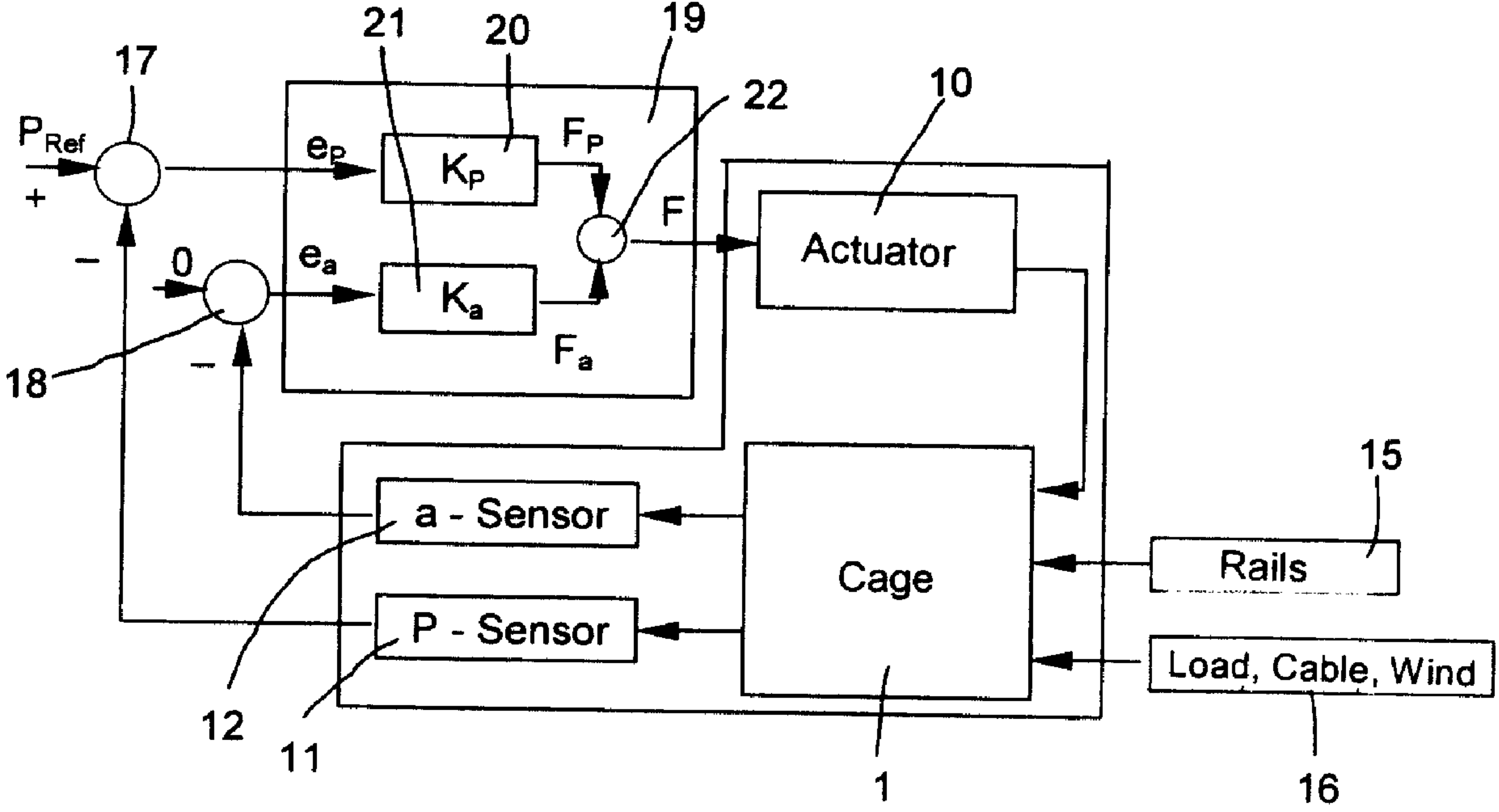
Fig. 3



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