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(54) **Improved circuit breaker**

(57) A circuit breaker comprising at least one moving contact and at least one fixed contact, an actuator for moving the moving contact, said circuit breaker com-

prising an active device which is operatively connected to the moving contact and is suitable to modulate the motion of the moving contact by applying an adjustable force.

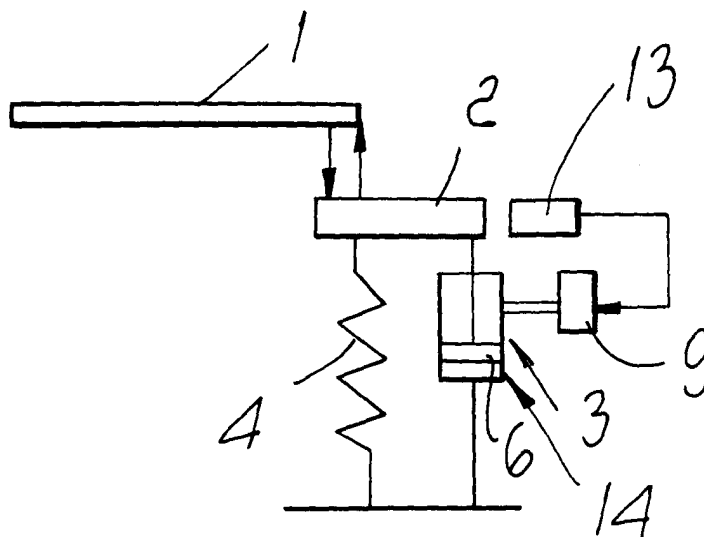


Fig. 1

Description

[0001] The present invention relates to a circuit breaker provided with an active device for modulating the motion of the contacts of the circuit breaker.

[0002] The present invention is particularly suitable for use in medium- and high-voltage applications (i.e. for a voltage range higher than 1 KV) and is now described with reference to these applications without intending to limit the scope of its application in any way.

[0003] Conventional circuit breakers, particularly for medium and high voltage applications, generally comprise at least a fixed contact and a moving contact that can be mutually coupled/separated for performing a closing/opening operation. Said moving contact is generally operated by actuators, that are provided according to different types.

[0004] In a first case, said actuators comprise mechanical devices, such as for example spring-operated controls, in which there is no dynamic control over the motion of the contact of the circuit breaker during transition. These actuators are applied both in circuit breakers being single- or three-phased and are provided, for example, with a spring-operated control for each pole of the circuit breaker.

[0005] A second type of actuators comprises electromechanical devices, wherein the stroke of the moving contact is controlled by modulating the active force that moves the contact. These electromechanical devices comprise, for example, two coils that are excited following an actuation command and supply, by means of the magnetic field that they produce, the traction force required to control the contacts of the circuit breaker both during closure and during opening.

[0006] The first type of actuators described falls in the category of the so-called "non-synchronized controls", whereas the second type within the category of the so-called "synchronized controls".

[0007] The above-described actuators entail considerable drawbacks, which can be summarized as follows.

[0008] For the non-synchronized controls, the main drawback is that it is not possible to synchronize the transition of the contacts with the phase of the electric line. This fact does not allow optimizing the management of electric power in the power distribution network. Also, the synchronized controls, even if they represent a step forward in the state of the art, have the drawback of entailing high power consumption and very high energy levels. So, it is necessary to use large capacitors and coils in order to ensure the electric power required to perform the corresponding mechanical movement. Moreover, complicated algorithms are used to control the stroke of the moving contact during opening/closing operations. Finally, for circuit breakers with three-phase control the cost of synchronized-type controls is remarkably high.

[0009] The aim of the present invention is to provide an improved circuit breaker, which can overcome the

mentioned drawbacks in a simple and reliable manner, both for single- or three-phased circuit breakers.

[0010] Within the scope of this aim, an object of the present invention is to provide a circuit breaker provided with an active device for the synchronous movement of the contacts with the electric phase of each pole.

[0011] Another object of the present invention is to provide a circuit breaker provided with an active device for the synchronous movement of the moving contact in which the response times and the power levels used to move the contacts are modest with respect to circuit breakers provided with conventional actuators.

[0012] Another object of the present invention is to provide a circuit breaker provided with an active device for the synchronous movement of the moving contact which is compact and does not require capacitors for the transition of the contacts.

[0013] Another object of the present invention is to provide a circuit breaker provided with an active device for the synchronous movement of the moving contact in which the algorithms for controlling the stroke during the transition of the contacts are more simple than the control algorithms currently being used.

[0014] Another object of the present invention is to provide a circuit breaker provided with an active device for the synchronous movement of the moving contact, which is relatively easy to manufacture and at competitive costs.

[0015] Thus the present invention provides a circuit breaker comprising:

- at least a moving contact and a fixed contact that can be mutually coupled/separated;
- actuation means for operating said moving contact.

[0016] The present invention is characterized by the fact of comprising an active device which is operatively connected to said moving contact and modulates the motion of said moving contact by applying an adjustable force.

[0017] Further characteristics and advantages of the present invention will become apparent from the following detailed description of preferred but not exclusive embodiments of the circuit breaker according to the invention, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

- Figure 1 is a schematic view of a first embodiment of a circuit breaker with single-pole control according to the present invention, with the contacts in the open position;
- Figure 2 is a view of the same circuit breaker of Figure 1, with the contacts in the closed position;
- Figure 3 is a schematic view of a first embodiment of the active device used in the circuit breaker according to the present invention;
- Figure 4 is a view of a further embodiment of a circuit breaker, according to the present invention;

- Figure 5 is a view of a further embodiment of a circuit breaker with three-phase control, executed according to the present invention; and
- Figure 6 is a view of an active device used in the circuit breaker according to the present invention, shown in Figure 5.

[0018] With reference to the above figures, a circuit breaker according to the invention, of the type with single-pole control, is shown schematically by means of its fixed contact 1 and its corresponding moving contact 2 which can be operated by actuating means 4 in order to perform a closing/opening operation, according to requirements. In the embodiment presented in figures 1 and 2, the moving contact 2 is operatively connected to an active device 3.

[0019] Figure 1 illustrates the case in which the moving contact 2 is in the open position and Figure 2 illustrates the case in which said moving contact 2 moved into the closed position against the fixed contact 1.

[0020] The actuation means 4 can comprise, for example, elastic means, as shown in Figures 1 and 2, or an electromagnetic device or in any actuator that provides the energy for operating the moving contact 2.

[0021] The embodiment shown in Figures 1 and 2 therefore provides for the use of an active device 3, shown schematically also in Figure 3, which comprises a body 5, for example cylindrical, which contains a fluid with variable viscosity. Preferably, a magneto-rheological fluid can be used. Fluids of this type have the property of monotonically varying their viscosity according to the magnetic field applied to them.

[0022] Thanks to the characteristics of the magneto-rheological fluid, the active device 3 included in the circuit breaker, according to the present invention, allows to modulate the energy transmitted to the moving contact 2 by the actuation means 4.

[0023] In the body 5 of active device 3, shown in Figure 3, a stem 6 can move; said stem can be connected to the moving contact 2 of the circuit breaker 2. The active device 3 preferably comprises control magnetic circuits 7 for inducing a magnetic field and control circuits 9 for exciting said magnetic circuits 7.

[0024] The stem 6 preferably comprises gauged holes 8 for the flow of the magneto-rheological fluid 10 contained inside the body 5. The body 5 can be closed by a breech 14.

[0025] With reference to Figures 1 and 2, the actuation means 4 provide the energy for moving the moving contact 2 so that it opens and closes.

[0026] The sensor means 13 report the position of the moving contact 2 to the control circuits 9, which modulate the excitation current of the magnetic circuits 7. The intensity of the magnetic field applied to the fluid 10, and therefore the viscosity of said fluid, are thus modulated according to the position of the moving contact 2. In this embodiment of the circuit breaker according to the present invention, the breech 14 is connected to a fixed

point of the circuit breaker, while the stem 6 is connected to the movable contact 2. In practice, the actuation means 4 are operatively connected to said moving contact 2 so as to transmit the motion to said moving contact in parallel to said active device 3.

[0027] The modulation of the viscosity of the fluid 10 allows modulating the stroke of the stem 6 of the active device 3, in contrast with the motion imparted to the moving contact by the actuation means 4.

[0028] In practice, the active device 3 applies an adjustable force to the movement of the moving contact which, in this embodiment, consists of an adjustable capacity of braking the motion of the moving contact.

[0029] The modulation of the braking force applied by the active device 3 to the force applied to the actuation means 4 of Figure 1 is useful for compensating all the phenomena that contribute to the deterioration of the behavior of circuit breakers over time, i.e., higher friction, aging of the components, etcetera, which alter their response times to an opening or closure command.

[0030] With reference to Figure 4, as represented in the block comprised by the dotted line 120, the active device 3 can comprise a breech 14, which is movable and is connected to motion transmission means 11 that are moved by the actuation means 4. The stem 6 is operatively connected to the moving contact 2 of the circuit breaker. The block 120 can be a pole of a single-phase circuit breaker or, as represented in figure 4, a pole of a three-phase circuit breaker.

[0031] In the last case, as represented in figure 4, there are provided three pairs of fixed contacts 1 and moving contacts 2, in which each the moving contacts 2 is actuated by a corresponding active device 3. All the active devices 3 are common-connected to motion transmission means 11, which are operatively connected to the actuation means 4. In this case there is a serial connection between the active devices 3 and the actuation means 4.

[0032] The actuation means 4 can be present for each individual pole of the circuit breaker or can constitute a single actuation device, as shown in Figure 4.

[0033] The actuation means 4 provide the energy for moving the moving contacts 2 of the circuit breaker by means of the motion transmission means 11, which are operatively connected to breeches 14 of each active device 3. The breeches 14 can move and are rigidly coupled to the motion transmission means 11.

[0034] The movement of each moving contact can be modulated independently by virtue of the modulation of the viscosity of the magneto-rheological fluid contained in each one of the active devices 3.

[0035] The control circuits 9 of each active device 3 modulate the excitation current of the magnetic circuits 7 contained in each active device 3. The modulation can be done on the basis of:

- the knowledge of the behavior of the electrical phase, which can be obtained by indicative signals

- generated by measuring means 12; and
- the knowledge of the position of the moving contact, which can be obtained by indicative signals generated by said sensor means 13.

[0036] The magnetic field applied to the fluid, and therefore the viscosity of said fluid, is modulated accordingly.

[0037] For each active device 3, the modulation of the viscosity of the magneto-rheological fluid implies, thanks to the above-described serial-type connection, a modulation of the capacity of the movable breech 14 to transmit rigidly to the stem 6, and accordingly to the moving contact 2, in a rigid manner.

[0038] If the viscosity of the magneto-rheological fluid is high, the breech 14 transmits the motion to the stem 6 and therefore to the moving contact 2 in a rigid manner.

[0039] If the viscosity of the magneto-rheological fluid is low, a relative motion occurs between the breech 14 and the stem 6 and therefore the moving contact is moved with less energy than imparted by the motion transmission means 11.

[0040] In other words, each active device 3 applies an adjustable force to the movement of the moving contact, which in this case consists of an adjustable capacity to transmit the motion to the moving contact. The actuation means 4 can preferably comprise a single actuator operatively connected with the active devices of each pole.

[0041] It is important to notice that, each active device 3 can act independently.

[0042] In this way, the movement of the three moving contacts 2 occurs in different times for each one of the moving contacts 2 and the time difference is correlated to the different viscosity of the fluid 10 that is present in the active devices 3, which therefore entails a different response of said active devices 3.

[0043] In practice, the phase difference of the three transitions of the three moving contacts 2 on the three phases and their synchronization are achieved with different elongations along the directrix of movement of each moving contact 2.

[0044] In practice, by virtue of the single motion command imparted by the actuation means 4 it is possible to move all three moving contacts 2 of the circuit breaker while still providing independent synchronization of the three phases.

[0045] The transmission of the motion between said actuation means and said moving contact inside the circuit breaker can also be of the rotary type.

[0046] An embodiment of a circuit breaker with three-phase control according to the present invention, in which motion transmission is of the rotary type, is illustrated with reference to Figure 5. In this case, actuation means 20, constituted for example by elastic means, impart a translatory motion to a link 22. Motion transmission means 23, for each pole of the three-phase circuit breaker, convert the translatory motion of a link 22 into a rotary motion. The motion transmission means 23 are

constituted, in this case, for example by a rod-and-link system. The rotary motion is transmitted by means of the active devices 24 to the moving contact 30 that rotates toward the fixed contact 31. In a preferred embodiment (not illustrated) the rotational motion transmitted to the moving contact can be re-transformed in a linear motion by second motion transmission means, which are operatively connected between the active device 24 and the moving contact 30. For each pole of the three-phase circuit breaker, the active devices 24 can comprise sensor means 33 for sensing the position of the moving contact and measuring means 32 for detecting the electrical phase. The sensor means 33 and the measuring means 32 send signals to the control devices 29, which modulate the excitation current of the magnetic circuits of each active device 24 (not shown in Figure 5).

[0047] The structure of an active device 24 used in the embodiment shown in Figure 5 is illustrated schematically with reference to the figure.

[0048] The active device 3 can comprise a first disks 25 and a second disk 26 that are spaced by a gap 28 filled with magneto-rheological fluid. The disks 25 and 26 can be concentric as illustrated in figure 5 or positioned so as to face each other. This kinds of structures can be used also for other embodiments of the circuit breaker, according to the present invention, in which a rotary transmission of the motion is considered.

[0049] In a preferred embodiment, shown in figure 5, the first disk 25 is operatively connected to the motion transmission means 23, while the second disk 26 is operatively connected, for example through a shaft 35, to the moving contact 30 or to said second motion transmission means (not illustrated).

[0050] Bearings 34 can be provided between the disk 25 and the shaft 35.

[0051] Proximate to the gap 28 there are magnetic circuits 27 for inducing a magnetic field in the magneto-rheological fluid. The magnetic circuits 27 are connected to the power supply and control circuits 29.

[0052] The disk 25 is turned by the motion transmission means 23.

[0053] The power supply and control devices 29 of each active device 24, on the basis of the knowledge of the behavior of the electrical phase by means of the measurement means 32 and of the knowledge of the position of the moving contact thanks to the sensor means 33, modulate the excitation current of the magnetic circuits 27 contained in each active device 24.

[0054] The magnetic field applied to the fluid, and therefore the viscosity of said fluid, are modulated accordingly.

[0055] For each active device 24, the modulation of the viscosity of the magneto-rheological fluid entails, thanks to the above-described serial-type connection, a modulation of the capacity of the disk 25 to transmit motion to the disk 26 and accordingly to the moving contact 30. If the viscosity of the magneto-rheological fluid is

high, the disk 25 transmits the rotary motion to the disk 26 and therefore to the moving contact 30 in a rigid fashion.

[0056] If the viscosity of the magneto-rheological fluid is low, a relative motion occurs between the disk 25 and the disk 26 and therefore the moving contact is moved with less energy than applied by the motion transmission means 23.

[0057] In other words, each active device 24 applies an adjustable force to the movement of the moving contact which in this case consists of an adjustable capacity to transmit the rotary motion to the moving contact.

[0058] Each device 24 can act independently.

[0059] It is therefore possible to achieve movement of all three moving contacts 30 of the circuit breaker while still providing independent synchronization of the three phases.

[0060] Also in the case of rotary transmission of the motion to the moving contact, the active device 3 can apply an adjustable force to the moving contact which can consist of an adjustable capacity of braking the rotary motion of said moving contact operated by said actuation means. In this case, not illustrated, said first disk can be connected to a fixed point of the circuit breaker while said second disk can be operatively connected to the moving contact. The active means can be operatively connected to the moving contact so as to transmit it the motion in parallel to said second disk.

[0061] In practice, it has been observed that the circuit breaker according to the present invention fully achieves the intended aim, since it allows, both in the single-phase case and in the three-phase case, to have control over the actuation force of said moving contact in a simple and reliable manner both for single- and three-phased circuit breakers.

[0062] The circuit breaker thus conceived is susceptible of numerous modifications and variations, all of which are within the scope of the inventive concept; all the details may also be replaced with other technically equivalent elements.

[0063] In practice, the materials employed, so long as they are compatible with the specific use, as well as the dimensions, may be any according to requirements and to the state of the art.

Claims

1. A circuit breaker comprising:

- at least one moving contact and one fixed contact that can be mutually coupled/separated; and
- actuation means for operating said moving contact;

characterized by the fact of comprising an active device which is operatively connected to said moving

contact and modulates the motion of said moving contact by applying an adjustable force.

2. The circuit breaker according to claim 1, characterized in that said active device comprises a body containing a fluid whose viscosity can be varied by applying a magnetic field.
3. The circuit breaker according to claim 2, characterized in that said fluid is a magneto-rheological fluid.
4. The circuit breaker according to one or more of the preceding claims, characterized in that said active device comprises magnetic circuits for generating a magnetic field, which is suitable to vary the viscosity of said fluid contained in the body of said active device and control circuits that are suitable to excite said magnetic circuits.
5. The circuit breaker according to claim 4, characterized in that said active device comprises sensor means for detecting the position of said moving contact and for sending to said control circuits signals indicative of the position of said moving contact.
6. The circuit breaker according to claim 4 or 5, characterized in that said active device comprises a breech, which is connected to a fixed point of said circuit breaker and a stem which is operatively connected to the moving contact of said circuit breaker, said stem being arranged inside the body of said active device and comprising gauged holes for the flow of said variable-viscosity fluid.
7. The circuit breaker according to claim 6, characterized in that said said actuation means are operatively connected to said moving contact, so as to transmit the motion to said moving contact in parallel with said active device.
8. The circuit breaker according to claim 4 or 5, characterized in that said active device comprises a breech which is movable and is operatively connected to motion transmission means, which are moved by said actuation means, and a stem which is operatively connected to the moving contact of said circuit breaker, said stem being arranged inside the body of said active device and comprising gauged holes for the flow of said variable-viscosity fluid.
9. The circuit breaker according to claim 8, characterized in that said active device is serially connected to said actuation means by virtue of said motion transmission means.
10. The circuit breaker according to claim 9, characterized by the fact that it is a three-phase circuit breaker.

er comprising three electric poles, each electric pole comprising an active device which comprises measuring means of the electrical phase that are suitable to send to the control circuits of said active device signals for synchronizing the modulation of the motion of the moving contact of said circuit breaker with the corresponding electrical phase.

11. The circuit breaker according to claim 10, characterized in that said actuation means comprise a single actuator which is serially connected to the active devices of each pole of said three-phase circuit breaker by virtue of said motion transmission means.
12. The circuit breaker according to claim 4 or 5, characterized in that said active device comprises a first disk which is operatively connected to said actuation means by virtue of motion transmission means, a second disk which is operatively connected to the moving contact of said circuit breaker, a gap filled with said variable-viscosity fluid being arranged between said first disk and said second disk.
13. The circuit breaker according to claim 12, characterized in that said first and second disks are positioned so as to be concentric each other.
14. The circuit breaker according to claim 12, characterized in that said first and second disks are positioned so as to face each other.
15. The circuit breaker according to one or more of the claims from 12 to 14, characterized in that said motion transmission means are constituted by a link which is connected to said actuation means and by a crank which is connected to said first disk of said active device.
16. The circuit breaker according to one or more of the claims from 12 to 15, characterized in that said second disk is operatively connected to said moving contact through second motion transmission means for transforming the rotary motion of said second disk in a linear motion of said moving contact.
17. The circuit breaker according to one or more of claims from 12 to 16, characterized in that it is a three-phase circuit breaker comprising three electric poles, each pole comprising an active device which comprises measuring means of the electrical phase, said measuring means being suitable to send to the control circuits of said active device signals for synchronizing the modulation of the motion of said moving contact with the corresponding electrical phase.
18. The circuit breaker according to claim 17, charac-

terized in that said actuation means comprise a single actuator which is serially connected to the active devices of each pole of said three-phase circuit breaker by virtue of said motion transmission means.

19. The circuit breaker according to claim 4 or 5, characterized by the fact that said active device comprises a first disk, which is connected to a fixed point of said circuit breaker, and a second disk which is operatively connected to said moving contact.
20. A circuit breaker according to claim 19, characterized by the fact that said actuation means are operatively connected to said moving contact, so as to transmit the motion to said moving contact in parallel with said second disk.

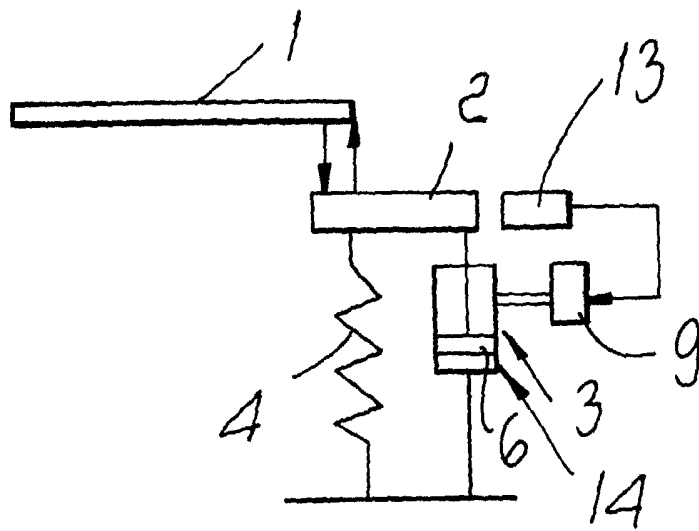


Fig. 1

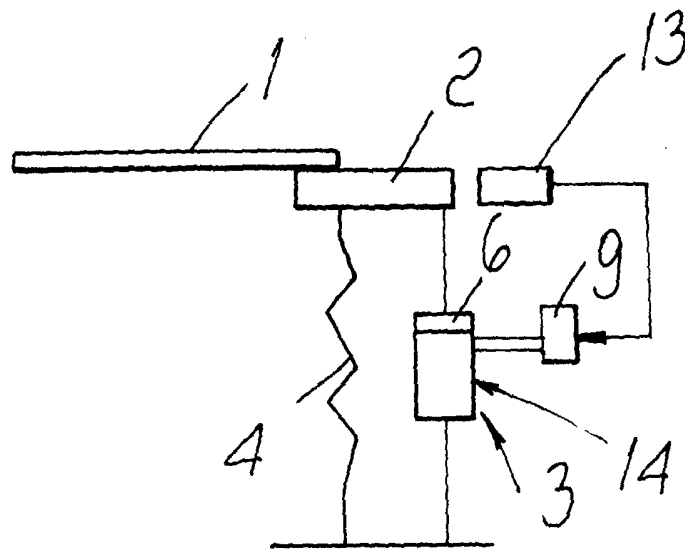


Fig. 2

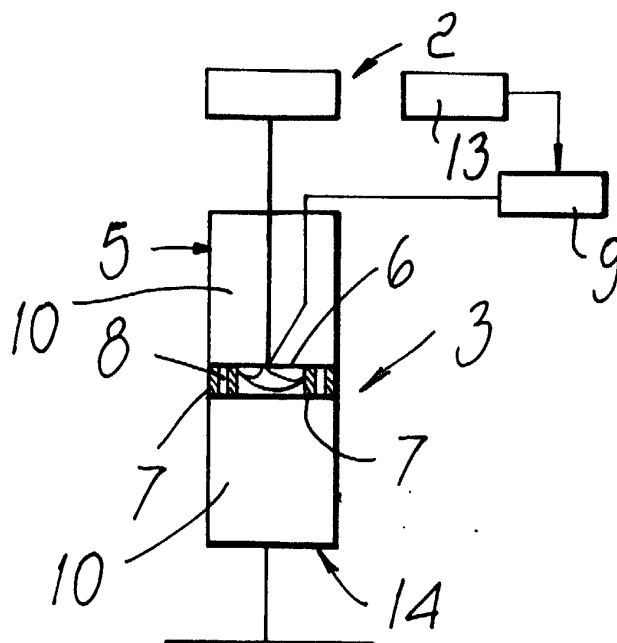


Fig. 3

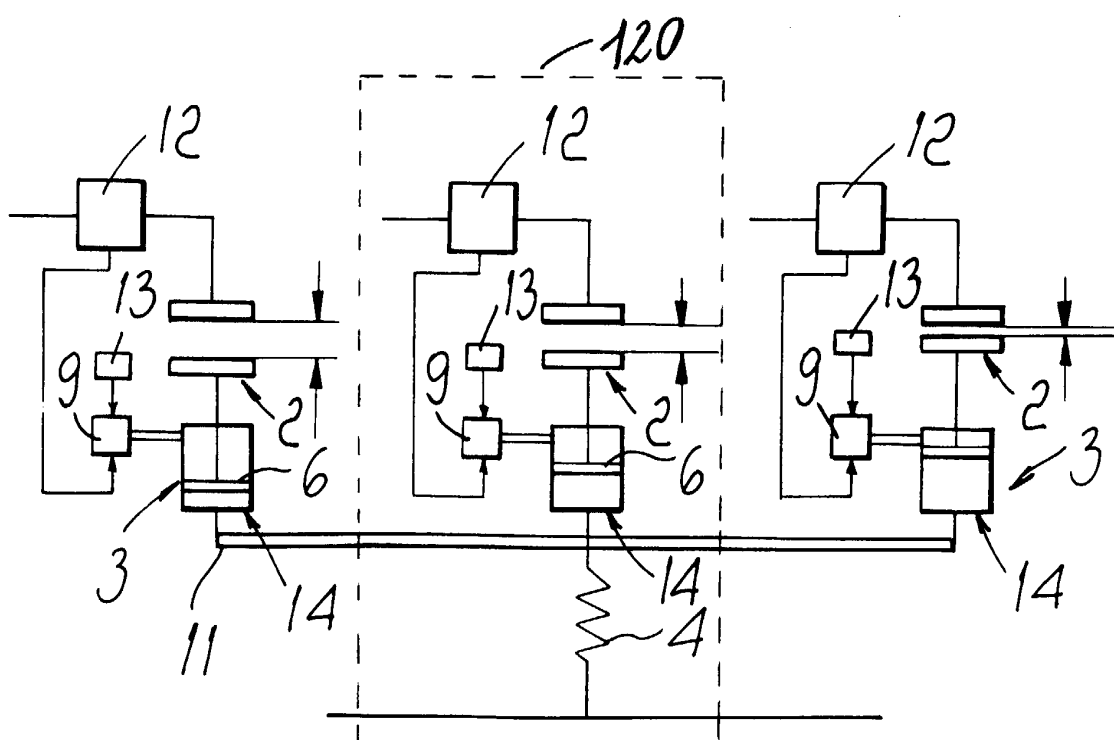


Fig. 4

