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(54) **METHOD AND APPARATUS FOR MULTIPLE-INPUT-MULTIPLE-OUTPUT CONTROL OF A VALVE/ACTUATOR PLANT**

VERFAHREN UND VORRICHTUNG FÜR DIE MEHRFACHEINGABE/MEHRFACHAUSGABE EINER VENTIL-/STELLGLIEDANLAGE

PROCEDE ET DISPOSITIF POUR LA COMMANDE EN ENTREES/SORTIES MULTIPLES DANS UN GROUPE A VANNE ASSERVIE

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Description

Field of the Invention

[0001] The present invention relates generally to valve controllers and more particularly to a method and apparatus for controlling a valve/actuator plant with multiple independent controller outputs to the valve/actuator plant.

Background of the Invention

[0002] A variety of control algorithms may be used by valve controllers to control a valve/actuator plant. Typically, valve controllers use an error signal, which is the difference between the desired set point signal and the output feedback signal, to control the valve/actuator plant. The valve controller generates a correcting control output signal, specifically a pneumatic signal proportional to the error signal, through a control algorithm to drive the valve/actuator plant. The control output signal may be the result of either a linear or non-linear control algorithm. This output signal from the valve controller becomes an input signal to the valve/actuator plant and hereinafter will be referred to as a correcting control signal.

[0003] A correcting control signal is generated from a Proportional, a Proportional plus Derivative, or a Proportional plus Derivative plus Integral type linear control algorithm. The Proportional (P) type control algorithm generates a correcting control signal directly proportional to the error signal. The Proportional plus Derivative (PD) type control algorithm generates a correcting control signal that is the sum of a signal proportional to the error signal and a signal that is proportional to the rate of change of the error signal. The Proportional plus Derivative plus Integral (PID) type control algorithm generates a correcting control signal that is the sum of a signal proportional to the error signal, a signal that is proportional to the rate of change of the error signal, and a signal that is proportional to the integral of the error signal.

[0004] Non-linear control techniques may compensate for the non-linearities, such as friction, dead band, and hysterisis that are inherent in controlling a valve/actuator plant. One example of a non-linear control algorithm would be one that uses a pulse width modulation technique. This algorithm would provide an "on-off-on" correcting control signal which has a duty cycle that has some defined relationship to the error signal. With this "on-off-on" control algorithm there is a dead-band parameter that defines the values of the error signal for when the correcting control signal is "off" or zero, and when the correcting control signal is "on" or equal to one.

[0005] The correcting control signals from both the linear and non-linear control algorithms can be converted to pneumatic correcting control signals that would be used to drive a valve/actuator plant to the desired set point position. This pneumatic correcting control signal consists of, but not limited to, a pneumatic flow.

[0006] All electro-pneumatic valve controllers use either linear or non-linear control algorithms to provide pneumatic correcting control signals to the valve/actuator plant. Typically, a valve controller provides a single pneumatic correcting control signal to the valve/actuator plant. Accordingly, if the algorithm and/or mechanics used to generate the correcting control signal fails to operate, then the valve controller ceases to function and ceases to provide a pneumatic correcting control signal to the valve/actuator plant.

[0007] US 5,947,086, EP0 875 811 and EP0 604 149, each relates to the general field of control apparatuses and methods for valves and the like. In particular, these documents relate to systems for providing accurate control of the moveable member. These documents do not, however, consider the advantages of providing a plurality of independent correcting control signals which are themselves able to control the valve or actuator should one of these correcting signals fail.

Summary of the Invention

[0008] In accordance with the principles of the present invention, there is provided a method and apparatus for controlling a valve/actuator plant with multiple independent correcting control signals which may include correcting control signals derived from linear control signals, non-linear control signals or a combination of linear and non-linear control signals. The correcting control signals may be a pneumatic signal. The multiple correcting control signals operate independent of each other so if one correcting control signal fails to operate, the other correcting control signal or signals will continue to function independent of the failed correcting control signal and still be able to drive the valve/actuator plant.

[0009] In accordance with the invention, a plurality of independent correcting control signals are generated, each responsive to a plurality of input signals which include a set point signal. The correcting control signals to the valve/actuator plant are summed together by the pneumatic volume of the actuator providing a single controlled output from the valve/actuator in response to the plurality of independent correcting control signals. This single controlled output is the valve's mechanical travel.

[0010] The plurality of independent correcting control signals can be generated by only linear control signals, only non-linear control signals or a combination of linear control signals and non-linear control signals.

[0011] A significant advantage of the present invention is in being able to incorporate a plurality of independent linear and non-linear pneumatic correcting control signals to a valve/actuator plant and provide a single controlled output from the valve/actuator plant.

Brief Description of the Drawings

[0012] The features of this invention are set forth with

particularity in the appended claims. The invention may be best understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements in the several figures and in which:

Figure 1 is a block diagram illustrating a valve controller with multiple-input-single-output control.
Figure 2 is a block diagram illustrating the preferred embodiment of the present invention.
Figure 3 is a block diagram illustrating an alternate embodiment of the present invention.

Detailed Description of the Preferred Embodiments

[0013] Figure 1 illustrates a plurality of control inputs 10, which include, but are not limited to, electronic control inputs, coupled to a valve controller 13 with a plurality of independent correcting control signals 15 to control a valve/actuator plant 17. The plurality of independent correcting control signals 15, which may be a pneumatic signal, is derived from either all linear control algorithms, all non-linear control algorithms, or a combination of linear and non-linear control algorithms. For example, correcting control signals 15/1 through 15/n may be derived from either all linear control algorithms or all non-linear control algorithms. Moreover, correcting control signal 15/1 may be derived from a linear control algorithm and correcting control signals 15/2 through 15/n may be derived from non-linear control algorithms, or correcting control signals 15/1 through 15/n may be derived from any other combination of linear and non-linear control algorithms.

[0014] The plurality of control inputs 10 generate a plurality of correcting control signals 15 that are coupled to the valve/actuator plant 17. The plurality of correcting control signals 15 are independent of each other so if one correcting control signal fails to operate, the other correcting control signal or signals will continue to function independent of the failed correcting control signal. For example, if correcting control signal 15/1 failed to operate, correcting control signals 15/2 through 15/n should continue to function and control the valve/actuator plant 17. The valve controller 13 may be, but is not limited to, an electro-pneumatic controller.

[0015] As mentioned above, the output of the valve controller 13 may include multiple independent correcting control signals 15 derived from all linear control algorithms, all non-linear control algorithms or a combination of linear and non-linear control algorithms. In one embodiment, as shown in Figure 2, the valve controller 13 generates two independent correcting control signals including one derived from a linear control generator 20 and another from a non-linear control generator 23. The linear control generator 20, which is located in the valve controller 13, includes a PD type controller 26 coupled to a signal amplifier 29, such as a current to pressure (I/P) transducer, and a pneumatic amplifier 30, such as a pressure relay. As described above, a P, PD, or PDI type control generates a linear correcting control signal from the plurality of control inputs 10. The linear control generator 20 may be implemented by, but not limited to, the configuration used in a Type DVC5000 Digital Valve Controller, manufactured by Fisher Controls International, Inc.

[0016] The non-linear control generator 23 includes an "on-off-on" control 33 coupled to a signal amplifier 36 and solenoids 39. The non-linear control generator 23 is implemented by, but not limited to, pulsing two pneumatic solenoids in an "on-off-on" type control 33, which has a duty cycle proportional to an error signal. The signal amplifier 36 includes a current-to-pressure (I/P) transducer that provides a pressure output in response to a current input. The solenoids 39 provide a pneumatic flow in response to the pressure output of the signal amplifier 36. One solenoid provides a pneumatic supply flow and the second solenoid provides an exhaust flow capability.

[0017] During a transition from one set point to another, the non-linear control generator 23 attempts to control a pressure rate 42, which builds or decreases in an actuator 45 located in the valve/actuator plant 17. The pressure rate 42, used for the non-linear control generator 23, may be either fixed or user-defined. As mentioned above, the non-linear control technique compensates for non-linearities such as, but not limited to, friction, dead band, and hysterisis, that are inherent in control valve/actuator plants. The non-linear control generator 23 may be implemented by a modified version of the Type DVC5000 Digital Valve Controller referred to above.

[0018] The correcting control signals 15 from the linear control generator 20 and the non-linear control generator 23 are pneumatically summed and integrated to pressure by the load volume of the actuator 45. The pressure rate 42 from the actuator 45 is fed back to the non-linear control algorithm 23 on line 43. An error signal 57 is fed back on line 47 from the valve/actuator plant 17 that adjusts both the linear and non-linear control generators 20, 23, respectively.

[0019] In Figure 2, the two correcting control signals, which are generated by the linear control generator 20 and the non-linear control generator 23, are pneumatically summed and integrated to pressure which, in turn, provides the driving force for the valve/actuator plant 17. The valve/actuator plant 17 includes the actuator 45 coupled to a valve 51. A desired set point signal 54 enters the valve controller 13 to operate the control generators 20, 23. In the linear control generators 20, the PD controller 26 provides an electrical drive signal, which may be, but is not limited to, a current signal. The signal amplifier 29 includes a current-to-pressure (I/P) transducer that provides a pressure output in response to a current input from the PD controller 26. The pneumatic amplifier 30 includes a pressure relay that provides a pneumatic flow to the actuator 45 in response to the pressure output from the signal amplifier 29.

[0020] The non-linear control generator 23 is active

only when the feedback output signal, which may be the error signal 57 from the actuator 45, is outside a predetermined percent of a set point signal 54. If the output signal is within the predetermined percentage of the set point signal 54, then the non-linear control generator 23 shuts off and the linear control generator 20 continues to bring the output signal of the actuator 45 to within the desired set point signal 54.

[0021] Figure 3 illustrates an alternate embodiment of the present invention, which includes a plurality of independent correcting control signals that may be a combination of linear correcting control signals and non-linear correcting control signals. For example, the valve controller 13 includes, but is not limited to, a combination of linear control generators 20 with correcting control output signals 15/1 through 15/n and non-linear correcting control generators 23 with output signals 15/1' through 15/n'. The correcting control signals consist of, but are not limited to, pneumatic flows and are summed and integrated to pressure by the valve/actuator plant 17.

[0022] The foregoing detailed description has been given for clearance of understanding only, and no unnecessary limitations would be understood therefrom, as modifications will be obvious to those skilled in the art.

Claims

1. A method for controlling a valve/actuator plant (17) comprising the steps of:

   generating a plurality of independent correcting control signals (15), each responsive to a plurality of input signals (10) having a set point signal (54) and being adapted to control the valve/actuator plant (17) in case of failure of one of the plurality of independent correcting control signals (15); and
   combining the plurality of independent correcting control signals (15) into a single combined control output from the valve/actuator plant (17).

2. Method of claim 1, wherein the plurality of independent correcting control signals include a pneumatic control signal.

3. Method of claim 1 or 2, wherein the plurality of independent correcting control signals are each derived from respective linear control signals.

4. Method of claim 1 or 2, wherein the plurality of independent correcting control signals are each derived from respective non-linear control signals.

5. Method of claim 1 or 2, wherein the plurality of independent correcting control signals are derived from a combination of linear control signals and non-linear control signals.

6. Method of any of the claims 2, 3 or 5, wherein the linear correcting control signals are directly proportional to an error signal.

7. Method of any of the claims 2, 3 or 5, wherein the linear correcting control signals include a correcting control signal that is proportional to an error signal and a correcting control signal proportional to the rate of change of the error signal.

8. Method of any of the claims 2, 3 or 5, wherein the linear correcting control signals include a correcting control signal proportional to an error signal, a correcting control signal proportional to the rate of change of the error signal, and a correcting control signal proportional to the integral of the error signal.

9. Method of claim 4 or 5, wherein the non-linear correcting control signal includes a correcting control signal having a duty cycle proportional to an error signal.

10. Apparatus for controlling a valve/actuator plant comprising:

    a plurality of control generators (20, 23) generating respective independent control signals (15), each control generator (20, 23) responsive to a respective set point to provide said respective control signals (15); and
    an actuator (45) having a plurality of inputs respectively coupled to each of the respective independent control signals (15) for providing a combined control output in response to one or more of the plurality of independent control signals (15), even in case of failure of one of the plurality of independent control signals (15).

11. Apparatus of claim 10, wherein the plurality of control generators include a plurality of linear control generators.

12. Apparatus of claim 10 or 11, wherein the plurality of control generators include a plurality of non-linear control generators.

13. Apparatus of claim 10, wherein the plurality of independent control generators include a combination of linear control generators and non-linear control generators.

Patentansprüche

1. Verfahren zum Steuern einer Ventil-/Stelleinheit-Anlage (17), das die folgenden Schritte aufweist:

   Erzeugen einer Vielzahl von unabhängigen Kor-

rektursteuersignalen (15), die jeweils auf eine Vielzahl von Eingangssignalen (10) ansprechen, die ein Sollwertsignal (54) haben und wirksam sind, um die Ventil-/Stelleinheit-Anlage (17) bei einem Ausfall eines der Vielzahl von unabhängigen Korrektursteuersignalen (15) zu steuern; und

Vereinigen der Vielzahl von unabhängigen Korrektursteuersignalen (15) zu einem einzigen vereinigten Steuerausgangssignal von der Ventil-/Stelleinheit-Anlage (17).

2. Verfahren nach Anspruch 1, wobei die Vielzahl von unabhängigen Korrektursteuersignalen ein pneumatisches Steuersignal aufweisen.

3. Verfahren nach Anspruch 1 oder 2, wobei die Vielzahl von unabhängigen Korrektursteuersignalen jeweils von entsprechenden linearen Steuersignalen abgeleitet werden.

4. Verfahren nach Anspruch 1 oder 2, wobei die Vielzahl von unabhängigen Korrektursteuersignalen jeweils von entsprechenden nichtlinearen Steuersignalen abgeleitet werden.

5. Verfahren nach Anspruch 1 oder 2, wobei die Vielzahl von unabhängigen Korrektursteuersignalen von einer Kombination aus linearen Steuersignalen und nichtlinearen Steuersignalen abgeleitet werden.

6. Verfahren nach einem der Ansprüche 2, 3 oder 5, wobei die linearen Korrektursteuersignale zu einem Fehlersignal direkt proportional sind.

7. Verfahren nach einem der Ansprüche 2, 3 oder 5, wobei die linearen Korrektursteuersignale aufweisen: ein Korrektursteuersignal, das zu einem Fehlersignal proportional ist, und ein Korrektursteuersignal, das zu einer Änderungsrate des Fehlersignals proportional ist.

8. Verfahren nach einem der Ansprüche 2, 3 oder 5, wobei die linearen Korrektursteuersignale aufweisen: ein Korrektursteuersignal, das zu einem Fehlersignal proportional ist, ein Korrektursteuersignal, das zu der Änderungsrate des Fehlersignals proportional ist, und ein Korrektursteuersignal, das zu dem Integral des Fehlersignals proportional ist.

9. Verfahren nach Anspruch 4 oder 5, wobei das nichtlineare Korrektursteuersignal ein Korrektursteuersignal aufweist, das ein zu einem Fehlersignal proportionales Tastverhältnis hat.

10. Vorrichtung zum Steuern einer Ventil-/Stelleinheit-Anlage, wobei die Vorrichtung Folgendes aufweist:

eine Vielzahl von Steuerungsgeneratoren (20, 23), die jeweilige unabhängige Steuersignale (15) erzeugen, wobei jeder Steuerungsgenerator (20, 23) auf einen jeweiligen Sollwert anspricht, um die jeweiligen Steuersignale (15) zu erzeugen; und

eine Stelleinheit (45), die eine Vielzahl von Eingängen hat, die jeweils mit jedem der entsprechenden unabhängigen Steuersignale (15) gekoppelt sind, um auch bei einem Ausfall eines der Vielzahl von unabhängigen Korrektursteuersignalen (15) ein vereinigtes Steuerausgangssignal in Abhängigkeit von einem oder mehreren der Vielzahl von unabhängigen Steuersignalen (15) zu erzeugen.

11. Vorrichtung nach Anspruch 10, wobei die Vielzahl von Steuerungsgeneratoren eine Vielzahl von linearen Steuerungsgeneratoren aufweisen.

12. Vorrichtung nach Anspruch 10 oder 11, wobei die Vielzahl von Steuerungsgeneratoren eine Vielzahl von nichtlinearen Steuerungsgeneratoren aufweisen.

13. Vorrichtung nach Anspruch 10, wobei die Vielzahl von unabhängigen Steuerungsgeneratoren eine Kombination aus linearen Steuerungsgeneratoren und nichtlinearen Steuerungsgeneratoren aufweisen.

Revendications

1. Procédé pour commander une unité vanne/actionneur (17), comportant les étapes consistant à :

générer une pluralité de signaux de commande de correction indépendants (15), sensibles chacun à une pluralité de signaux d'entrée (10) ayant un signal de point de consigne (54), et adaptés pour commander l'unité vanne/actionneur (17) en cas de défaillance d'un de la pluralité de signaux de commande de correction indépendants (1), et

combiner la pluralité de signaux de commande de correction indépendants (15) en une sortie de commande combinée unique à partir de l'unité vanne/actionneur (17).

2. Procédé selon la revendication 1, dans lequel la pluralité de signaux de commande de correction indépendants comprennent un signal de commande pneumatique.

3. Procédé selon la revendication 1 ou 2, dans lequel la pluralité de signaux de commande de correction indépendants sont chacun déduits de signaux de

commande linéaires respectifs.

4. Procédé selon la revendication 1 ou 2, dans lequel la pluralité de signaux de commande de correction indépendants sont chacun déduits de signaux de commande non linéaires respectifs.

5. Procédé selon la revendication 1 ou 2, dans lequel la pluralité de signaux de commande de correction indépendants sont déduits d'une combinaison de signaux de commande linéaires et de signaux de commande non linéaires.

6. Procédé selon l'une quelconque des revendications 2, 3 ou 5, dans lequel les signaux de commande de correction linéaires sont directement proportionnels à un signal d'erreur.

7. Procédé selon l'une quelconque des revendications 2, 3 ou 5, dans lequel les signaux de commande de correction linéaires comprennent un signal de commande de correction qui est proportionnel à un signal d'erreur, et un signal de commande de correction proportionnel à la vitesse de changement du signal d'erreur.

8. Procédé selon l'une quelconque des revendications 2, 3 ou 5, dans lequel les signaux de commande de correction linéaires comprennent un signal de commande de correction proportionnel à un signal d'erreur, un signal de commande de correction proportionnel à la vitesse de changement du signal d'erreur, et un signal de commande de correction proportionnel à l'intégrale du signal d'erreur.

9. Procédé selon la revendication 4 ou 5, dans lequel le signal de commande de correction non linéaire comprend un signal de commande de correction ayant un cycle de service proportionnel à un signal d'erreur.

10. Appareil pour contrôler une unité vanne/actionneur, comportant :

une pluralité de générateurs de commande (20, 23) générant des signaux de commande indépendants respectifs (15), chaque générateur de commande (20, 23) étant sensible à un point de consigne respectif pour fournir lesdits signaux de commande respectifs (15), et
un actionneur (45) ayant une pluralité d'entrées couplées respectivement à chacun des signaux de commande indépendants respectifs (15) pour fournir une sortie de commande combinée en réponse à un ou plusieurs de la pluralité de signaux de commande indépendants (15), même en cas de défaillance d'un ou de la pluralité de signaux de commande de correction indépendants (15).

11. Dispositif selon la revendication 10, dans lequel la pluralité de générateurs de commande comprennent une pluralité de générateurs de commande linéaires.

12. Dispositif selon la revendication 10 ou 11, dans lequel la pluralité de générateurs de commande comprennent une pluralité de générateurs de commande non linéaires.

13. Dispositif selon la revendication 10, dans lequel la pluralité de générateurs de commande indépendants comprennent une combinaison de générateurs de commande linéaires et de générateurs de commande non linéaires.

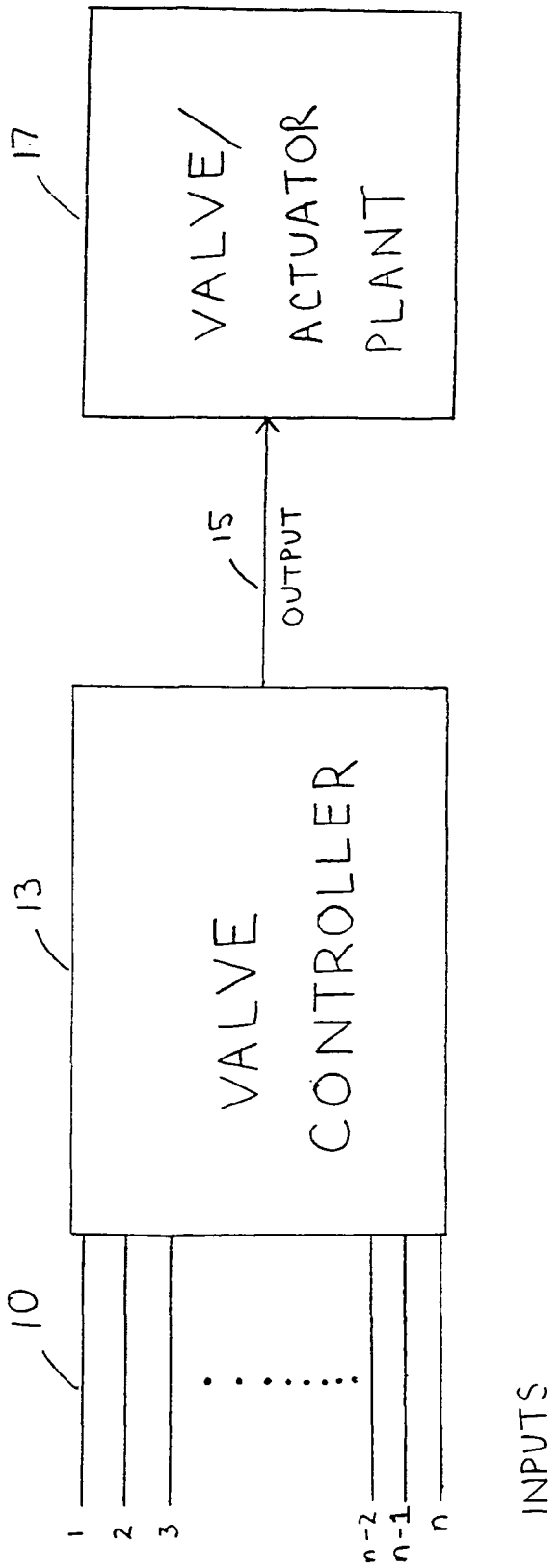
17
VALVE/
ACTUATOR
PLANT
15
OUTPUT
13
VALVE
CONTROLLER
10
1
2
3
n-2
n-1
n
INPUTS

FIG. 1

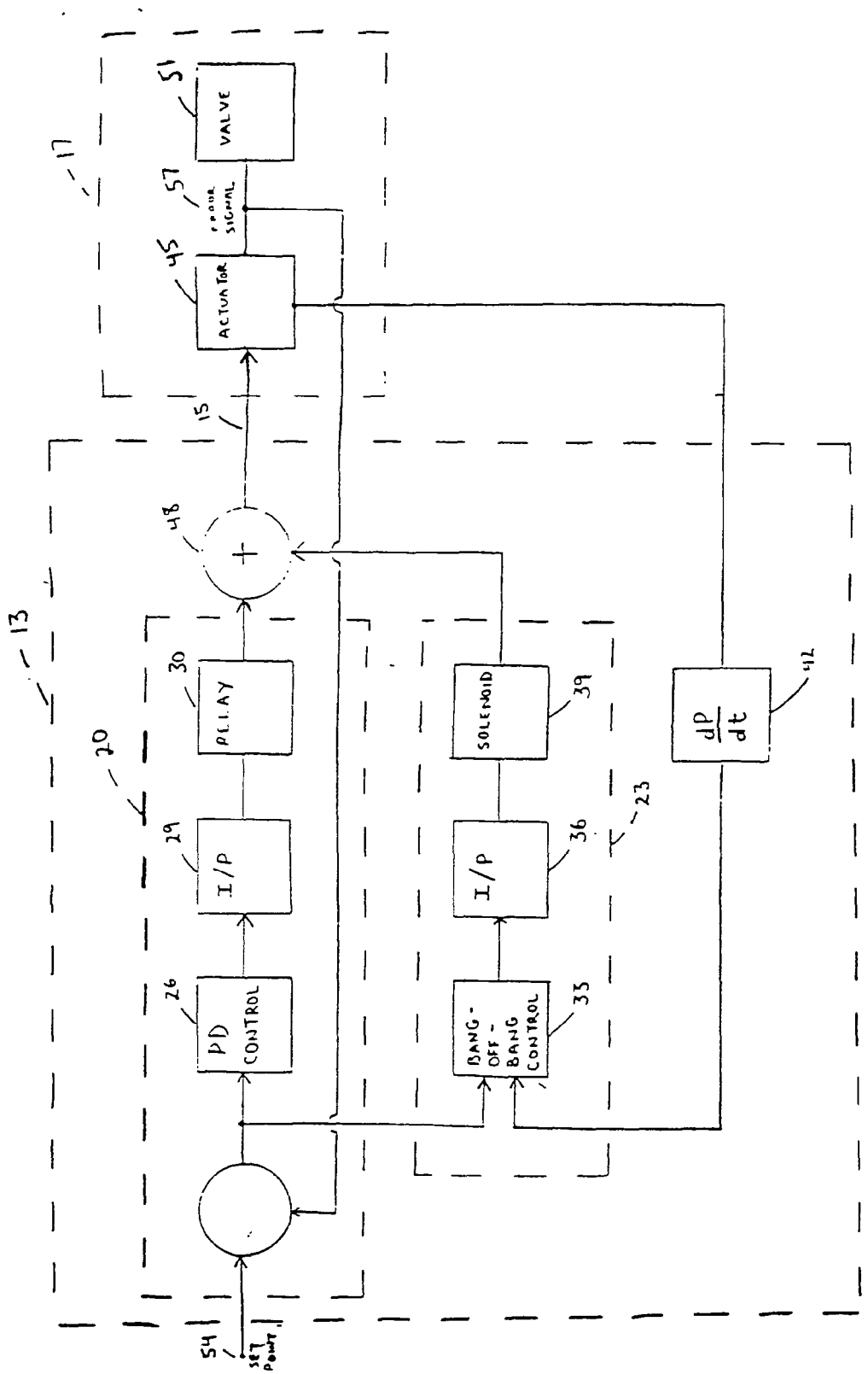
17
51
VALVE
57
FEEDBACK SIGNAL
45
ACTUATOR
15
48
+
13
20
30
RELAY
29
I/P
26
PID CONTROL
39
SOLENOID
36
I/P
33
BANG-OFF-BANG CONTROL
23
42
dP/dt
54
SET POINT

FIG. 2

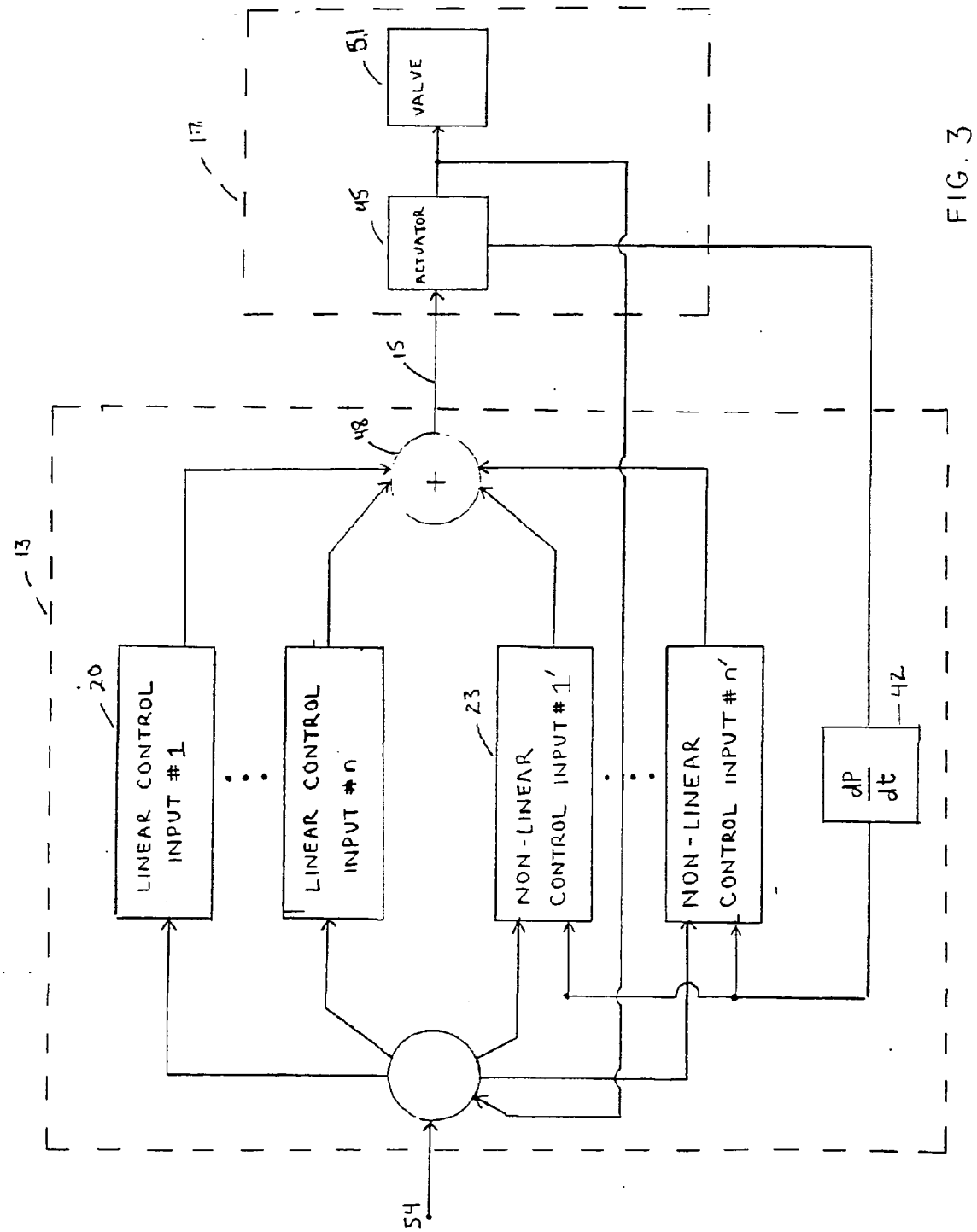
17
51
VALVE
45
ACTUATOR
15
48
+
13
20
LINEAR CONTROL INPUT #1
LINEAR CONTROL INPUT #n
23
NON-LINEAR CONTROL INPUT #1'
NON-LINEAR CONTROL INPUT #n'
42
dP/dt
54

FIG. 3

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

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