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(54) **CONTROL OF FLOW REGULATING DEVICE**

(57) A method to control a fluid flow regulating device being regulated through a control signal ranging from 0-100% during a normal operational load, defined as being within a given load threshold, where said control signal is 0% when said flow regulating device is to be closed

and 100% when it is to be open, but when said load gets outside said load threshold the control enters a modified control where said control signal either is never at 0% and/or is never at 100%. A controller including said control method.

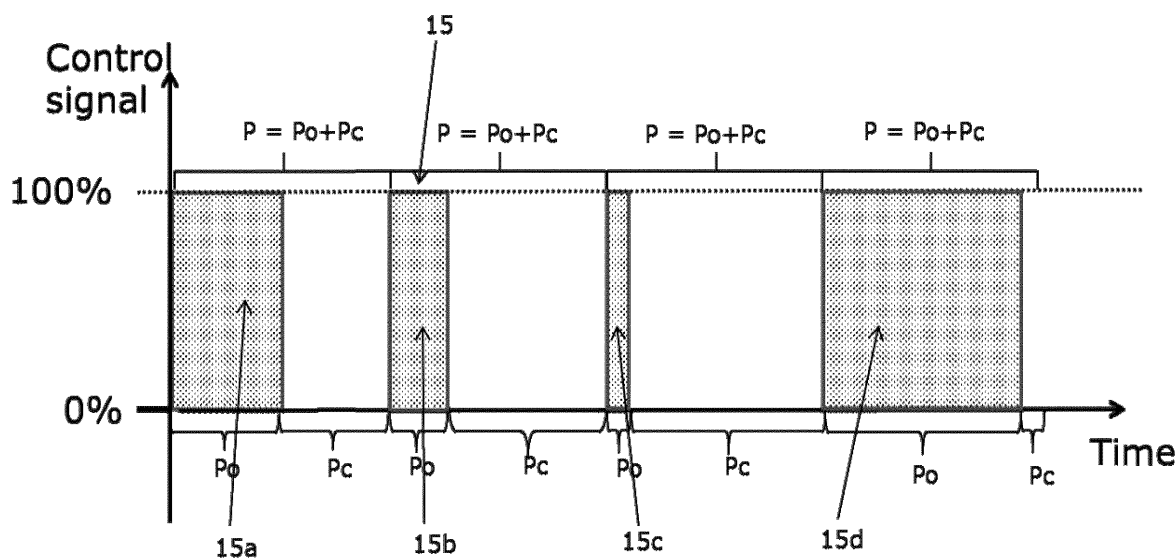


Fig. 4

Description

BACKGROUND

[0001] The present invention relates to a method to control a flow regulating device, such as for heating systems and such as a valve, when the load becomes low and/or high, and to a controller performing this method.

[0002] When such flow regulating devices are operated by actuating means having a significant delay this may lead to oscillations on the control, which predominantly is a problem when the load (e.g. a controlled flow rate depending on a return temperature of heating fluid) gets close to the limits of the flow regulating device, such as a valve opening getting near its closing position or getting near its full open position.

[0003] The object of the present invention thus is to introduce a method and controller to address these problems.

SUMMARY OF THE INVENTION

[0004] The present invention thus introduces a method to control a fluid flow regulating device being regulated through a control signal ranging from 0-100% during a normal operational load, defined as being within a given load threshold, where said control signal is 0% when said flow regulating device is to be closed and 100% when it is to be open, but when said load gets outside said load threshold the control enters a modified control where said control signal either is never at 0% and/or is never at 100%. Thereby possible connected actuating means at all times in this modified control will be stimulated, thus shortening the response time. In an embodiment where the actuating means is a thermal wax actuator this would mean it would never get fully cold or fully heated.

[0005] The control signal may be a pulse width modulated signal (PWM), where said modified control signal is formed of full cycle periods, P, each with open period Po of a 100% control signal and a closed period Pc of 0% signal and when the load gets below a low load threshold said control signal enters a low load control where the open period Po is higher than zero even when the flow regulating device are to be closed and/or when the load gets above a high load threshold said control signal enters a high load control where the open period Po is lower than 100% even when the flow regulating device are to be fully open.

[0006] In an embodiment the fluid flow regulating device is connected to actuating means setting fluid flow regulating device according to the communicated control signal from a connected controller.

[0007] In an embodiment the control signals includes a low load control where the control signal is below a point of reaction defined as the signal where the actuator (13) change flow regulating device between open and closed and/or where the control signal high load control is above said point of reaction. The high load threshold

and low load threshold defining when the control are to change to high load or low load control respectively would have to be at an significant distance to the average point of reaction as this is dependent on factors such as the ambient temperature. In one embodiment the high load threshold and/or low load threshold is non-constant, but is depending on factors such as ambient temperature.

[0008] In an embodiment the flow regulating device is pressure independent, and may form part of a valve arrangement including a pressure controlling valve means.

[0009] In an embodiment the fluid flow regulating device adjusts the flow rate to maintain a set reference return temperature in a flow system, said low load related to a low flow rate and/or return temperature Tr being below a given threshold.

[0010] To make the controlling of the fluid regulating device such as to detect when the load gets outside the normal load thresholds (above the high load threshold or below the low load threshold), temperature sensors (9) are connected to the fluid flow system including the fluid flow regulating device and communicates the measurements to the controller as input parameter(s) to the control of the fluid flow regulating device.

[0011] In one embodiment the fluid flow system is a one pipe heating system and where at least one of said temperature sensors is connected to the return side of a heating line.

[0012] In one embodiment for the low load control, the open period Po is equal to or lower than or equal 10%, or 20%, of the total period P, and the closed period Pc is higher than or equal to 90%, or 80%, of the total period P and/or for the high load period open period Po is equal to or higher than or equal 90%, or 80%, of the total period P, and the closed period Pc is lower than or equal to 10%, or 20%, of the total period P

[0013] In an embodiment the control is even more improved the control of the return temperature, Tr, include a PID control.

[0014] The present invention further relate to a controller adapted to regulate a fluid flow regulating device by a control signal being 0% when said fluid flow regulating device is to be closed and 100% when it is to be fully open during a normal operational load, defined as being within a load threshold, and where the controller is in data communication with means to detect said load, characterized in that said controller includes a modified control signal where said control signal either is never at 0% and/or is never at 100%, and enters said modified control signal when the load is outside said load threshold.

[0015] In various embodiments, the controller is adapted to operate according to the method of any of previous embodiments.

FIGURES

[0016]

Fig. 1 A one-pipe heating flow circuit including a

- connection to a heat supply, such as a district heating system, and heat exchanging devices, such as radiators.
- Fig. 2 A pressure independent flow controller.
- Fig. 3 Illustration of the actuation of a wax actuator according to a controlling signal.
- Fig. 4 Illustrate controlling signals formed as pulse width modulated signals (PWM).
- Fig. 5 Flow chart illustrating the method of introducing a modified control signal when the load is outside a given threshold.
- Fig. 6A,B Illustrations of a system using respectively a PI and PID control method of a return temperature.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Fig. 1 is a schematic illustration of a heating flow circuit (1) such as a one-pipe system comprising a connection (2) to a heat supply (3), such as a district heating system. A heat transferring fluid is delivered through a supply line (4) to a plural of heating lines (5), or risers, positioned in parallel along the supply line (4) connecting it to a return line (6).

[0018] The heating lines (5) may connect to a plurality of individual heat exchanging circuits each comprising heat exchanging devices (8) (such as radiators etc.), where each of these could form the heating circuit for an individual flat, or just a domestic places in general. These circuits comprising the heat exchanging devices (8) are positioned in series along the heating lines, but by-pass lines ensure the distribution of fluid despite one would be closed. The heating lines (5) further includes flow controllers (7) positioned downstream of the heat exchanging devices (8).

[0019] Sensors, such as flow sensors and/or temperature sensors (9) may be connected to some or all of the heating lines (5), where the illustrated embodiment shows them positioned downstream of the heat exchanging devices (8) but upstream of the flow controllers (7).

[0020] Further, sensors, such as flow sensors and/or temperature sensors (10) may be connected to the supply line (4), return line (6), the connection (2) etc.

[0021] A controller (11) is in data communication (12) connection to actuating means (13) (or just actuator) of the flow controllers (7) to adjust the flow rates in response to the control signal from the controller (11).

[0022] The flow controllers (7) in an embodiment are valves including a valve element operating in connecting to a throttling element (or valve seat) together defining a valve opening given by the position of the valve element relative to the throttling element. The valve opening then defines the flow rate through the valve, and thus the flow

system where to it is connected. One such embodiment valve (7) is illustrated in fig. 2, the illustrated valve being a pressure independent valve including a pressure controlling part (14) formed of a membrane deflecting in response to a pressure difference over the flow controlling means as pressure control. Other embodiments of pressure independent valves (7) would also apply, just as non-pressure independent valves (7).

[0023] The flow controllers (7) in an embodiment is thermal controllers changing flow in response to a change in the temperature of the heat exchanging fluid, such as the actuating means (13) could be a wax thermal actuator, but the present inventions could also apply to other types of actuators, such as where there is a significant time delay in the response.

[0024] A return temperature control, RTC, in a flow system (1) such as a one-pipe heating system is a control method where the flow rate in the individual heating lines (5) is adjusted such as to maintain a given set temperature downstream of the last of the heat exchanging devices (8), thus being the return temperature, at a given setpoint, which may be adjusted according to other conditions, such as external temperature etc. This method can be used to turn an otherwise traditionally constant flow one-pipe heating system into variable flow system and the one-pipe system can work at partial loads, resulting in increased energy efficiency.

[0025] Fig. 3 illustrate a situation of an embodiment where the actuating means (13) is, or includes, a thermal wax actuator. Such wax thermostatic elements transform heat energy into mechanical energy using the thermal expansion of waxes when they melt, but usually only have closed or open positions. In fig. 3 a transfer curve (30) between closed and open position is illustrated as being quite steep in relation to the control signal (15), thus roughly for all the control signals (15) below the point of reaction the actuator (13) will be closed and for all control signals (15) above the point of reaction it will be fully open. This point of reaction corresponds to certain minimum control signal (15) before the actuator (15) (or wax) reacts, and may fluctuate significantly such as in dependence on the ambient temperature. Seen in time it may have a significant delay, at least at low loads as will also be addressed later.

[0026] In the illustration fig. 3 the X-axis represent the control signal range (15) from 0 (no signal, or 0% signal) to 1 (full signal, or 100% signal), where the curve (30) illustrates the actuating setting in at a control signal (15) roughly around 3.5 (or 35%) (the point of reaction), but the exact value will depend on the nature / definition of the control signal (15), the ambient temperature (e.g. amplitude of the PWM impulses as will be described later), the exact actuator (13) embodiment etc.

[0027] It should in general be noted that fig. 3, just as the other figures, are just to illustrate the concept of embodiments of the present invention, the exact details, values, graphs etc. just being disclosed as example.

[0028] Fig. 4 illustrate embodiments of Pulse Width

Modulation (PWM) control of the flow controller(s) (7), optionally through the connected actuating means (13), where the controlling signal (15) changes for periods. In the figure four different control signals (15) are illustrated, each ranging over a cycle period P being the sum of the period P_o where the control signal (15) is on (in the illustrated embodiment meaning it is at full signal equal to 100%) and the period P_c where it is closed (in the illustrated embodiment meaning it is at no signal equal to 0%). In the actual systems the control signal (15) usually will be a voltage or current at some magnitude (amplitude of the pulses), but in the figures 3 and 4 this is normalized to a range from 0-100%, or as showing in fig. 3, a fraction from 0-1.

[0029] The four different control signals (15) schematically illustrated includes a 50% control signal (15a) being that the control signal (15) is on for 50% of the time of the cycle period P, thus $P_o = P_c = 50\%$, or 0.5 in the alternative scale. The second control signal (15b) illustrated is on for 30% of the time of the cycle period P, thus $P_o = 30\%$ and $P_c = 70\%$ of the cycle period P. The third control signal (15c) illustrated is on for 10% of the time of the cycle period P, thus $P_o = 10\%$ and $P_c = 90\%$ of the cycle period P. The fourth control signal (15d) illustrated is on for 90% of the time of the cycle period P, thus $P_o = 90\%$ and $P_c = 10\%$ of the cycle period P. Full signal thus would be the control signal (15) is on the full cycle period P, and no signal would be the control signal (15) off the full cycle period P. In more general terms, the control signal (15) in this PWM embodiment is related to the fraction of time, or period, the signal is fully on in relation to the full cycle period, and closed for the rest of the cycle period. The full cycle period P may be constant or change over time and may be adjustable, the open period P_o and closed period P_c being adjusted accordingly,

[0030] In the situation with a of low load on the flow system (1), where only a small amount of heat is extracted by the heat exchanging devices (8), the control performance becomes increasingly important.

[0031] For flow controllers (7) including or attached to actuating means (13), where the actuating means has some delay in its response, or at least a response time being such that problems may occur at low loads (or low flow rates), or at too high flow temperature (high flow rates), the slow response nature of the actuators (13) can compromise the control performance which may result is oscillation of the controlled return temperature. One example of such actuating means (13) is thermal wax actuators, where due to nature of heating wax element, it can take up to 3-4 minutes for actuator to start actuating, following by 3-4 minutes of opening time, and the end result can be 8 minutes response. The opposite happens in case of full load.

[0032] In an embodiment, when the load gets low, meaning a low flow rate and/or return temperature is below a given threshold, the controller (11) will change the controlling signal (15) by a low load control (22a) (see

fig. 5) in a manner where it is newer at 0% the whole of the cycle period P. Thereby it is ensured that the response time of the actuating means (13) will be significantly faster. This could be such as by setting the control signal (15) at a level below the point of reaction, such as below 20%, or below 10% or below 5%.

[0033] Thus, at low load the closing signal, meaning the signal to keep the flow controller (7) closed will be above zero, but sufficiently below a range of point of reactions as they may be expected to fluctuate according to e.g. the expected changes in ambient temperature. The low load control (22a) helps to prevent the actuating means (13) to be too cold.

[0034] In an embodiment, if the flow rate and/or return temperature is outside the given threshold scope the method will return to the ordinary control method.

[0035] In an embodiment, as an additional or alternative feature, when the load is high, (or meaning a high flow rate and/or return temperature is above a given threshold) the controller (11) will change the controlling signal (15) by a high load control (22b) (see fig. 5A) in a manner where it is newer at 100% the whole of the cycle period P. Thereby it is ensured that the response time of the actuating means (13) will be significantly faster. This could be such as by setting the control signal (15) at a level above the point of reaction, such as above 80%, or above 90% or above 95%.

[0036] Thus, at high load the closing signal, meaning the signal to keep the flow controller (7) open be below zero, but sufficiently above a range of point of reactions as they may be expected to fluctuate according to e.g. the expected changes in ambient temperature. The high load control (22b) helps to prevent the actuating means (13) to be overheated.

[0037] In fig. 5 a basic flow chart is shown illustrates the control method as run by the controller (11) according to an embodiment. The system normally will operate in a normal load situation where the system the control signals (15) is run under a normal control method (20) when the load is within a given load threshold, this is when the load is above a low load threshold and/or below a high load threshold.

[0038] When the load becomes low (21), meaning if a low flow rate and/or return temperature is below the given low load threshold, it will start the a low load control (22a) where the control signal (15) includes a non-zero opening period P_o , where the signal P_o is lower than the critical point of reaction, Alternatively, when the load becomes high (21), meaning if a high flow rate and/or return temperature is above the given low load threshold, it will start the a high load control (22b) where the control signal (15) includes an opening period $P_o < 100\%$, where the signal P_o is higher than the critical point of reaction

[0039] In an embodiment, if the flow rate and/or return temperature is outside the given threshold scope (23) the method will return to the ordinary control method (20), being how the control is performed during normal load, otherwise it will repeat from the step (22a, 22b).

[0040] In an embodiment the controller (11) regulates according to a PID control. Figs. 6A and 6B schematically illustrate the control of the return temperature T_r according to a return temperature setpoint (40) where Fig. 6A schematically illustrates the control according to a PI control method and 6B according to a PID control method.

[0041] The PID control includes three parts, where the part 'P' accounts for present values of the error (where a large and positive error gives a large and positive control output etc.). The part 'I' is an integration and accounts for past values of the error, where with an insufficient current output the error will accumulate over time, and the controller will respond by applying a stronger action. This is what is illustrated in fig. 6A, where it has been experienced event when controlling according to the above described low load control (22a) method and/or high load control (22b), the problem of oscillations may still not be fully solved, though still significantly improved, the system may react too quickly.

[0042] Therefore in an embodiment the 'D' (the differential part), is included (the full PID control), where this part accounts for possible future values of the error, based on its current rate of change.

Claims

1. A method to control a fluid flow regulating device (7) being regulated through a control signal (15) ranging from 0-100% during a normal operational load, defined as being within a given load threshold, where said control signal (15) is 0% when said fluid flow regulating device (7) is to be closed and 100% when it is to be open, **characterized in that** when said load gets outside said load threshold the control enters a modified control (22a, 22b) where said control signal (15) either is never at 0% and/or is never at 100%.
2. A method to control a fluid flow regulating device (7) according to claim 1, wherein said modified control signal (22) is formed of full cycle periods, P, each with open period P_o of a 100% control signal (15) and a closed period P_c of 0% signal and when the load gets below a low load threshold said control signal (15) enters a low load control (22a) where the open period P_o is higher than zero even when the flow regulating device (7) are to be closed and/or when the load gets above a high load threshold said control signal (15) enters a high load control (22b) where the open period P_o is lower than 100% even when the flow regulating device (7) are to be fully open.
3. The method according to claim 2, wherein the fluid flow regulating device (7) is connected to actuating means (13) setting fluid flow regulating device (7) according to the communicated control signal (15) from a connected controller (11).
4. The method according to claim 3, where the control signals (15) in the low load control (22a) is below a point of reaction defined as the control signal (15) where the actuator (13) change flow regulating device (7) between open and closed and/or where the control signal (15) high load control (22b) is above said point of reaction.
5. The method according to claim 4, wherein the high load threshold and/or low load threshold depending on the ambient temperature.
6. The method according to claim 5, wherein in the low load control (22a) the open period P_o is equal to or lower than 10% of the total period P, and the closed period P_c is higher than or equal to 90% of the total period P, and/or in the high load control (22b) the open period P_o is equal to or higher than 90% of the total period P, and the closed period P_c is lower than or equal to 10% of the total period P.
7. The method according to claim 6, wherein in the low load control (22a) the open period P_o is equal to or lower than 20% of the total period P, and the closed period P_c is higher than or equal to 80% of the total period P, and/or in the high load control (22b) the open period P_o is equal to or higher than 80% of the total period P, and the closed period P_c is lower than or equal to 20% of the total period P.
8. The method according to any of the previous claims, wherein the method includes the control of a return temperature T_r by a PID control.
9. A controller (11) adapted to regulate a fluid flow regulating device (7) by a control signal (15) being 0% when said fluid flow regulating device (7) is to be closed and 100% when it is to be fully open during a normal operational load, defined as being within a load threshold, and where the controller (11) is in data communication with means to detect said load, **characterized in that** said controller (11) includes a modified control signal (22) where said control signal (15) either is never at 0% and/or is never at 100%, and enters said modified control signal when the load is outside said load threshold.
10. The controller (11) according to claim 9, wherein the fluid flow regulating device (7) forms part of a valve arrangement including a pressure controlling valve means (14).
11. The controller (11) according to claim 10, wherein the fluid flow regulating device (7) adjusts the flow rate to maintain a set reference return temperature (40) in a flow system (1), said low load related to a

low flow rate and/or return temperature, T_r , being below a given threshold.

12. The controller (11) according to claim 11, wherein temperature sensors (9) connected to the fluid flow system (1) including the fluid flow regulating device (7) and communicates the measurements to the controller (11) as input parameter(s) to the control of the fluid flow regulating device (7). 5
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13. The controller (11) according to claim 12, wherein the fluid flow system (1) is a one pipe heating system and where at least one of said temperature sensors (9) is connected to the return side of a heating line (5). 15
14. A controller (11) according to claim 13 adapted to operate according to the method of any of the claims 2-7.
15. A controller (11) according to claim 14 and claim 4, wherein the actuating means (13) is a thermal wax actuator. 20
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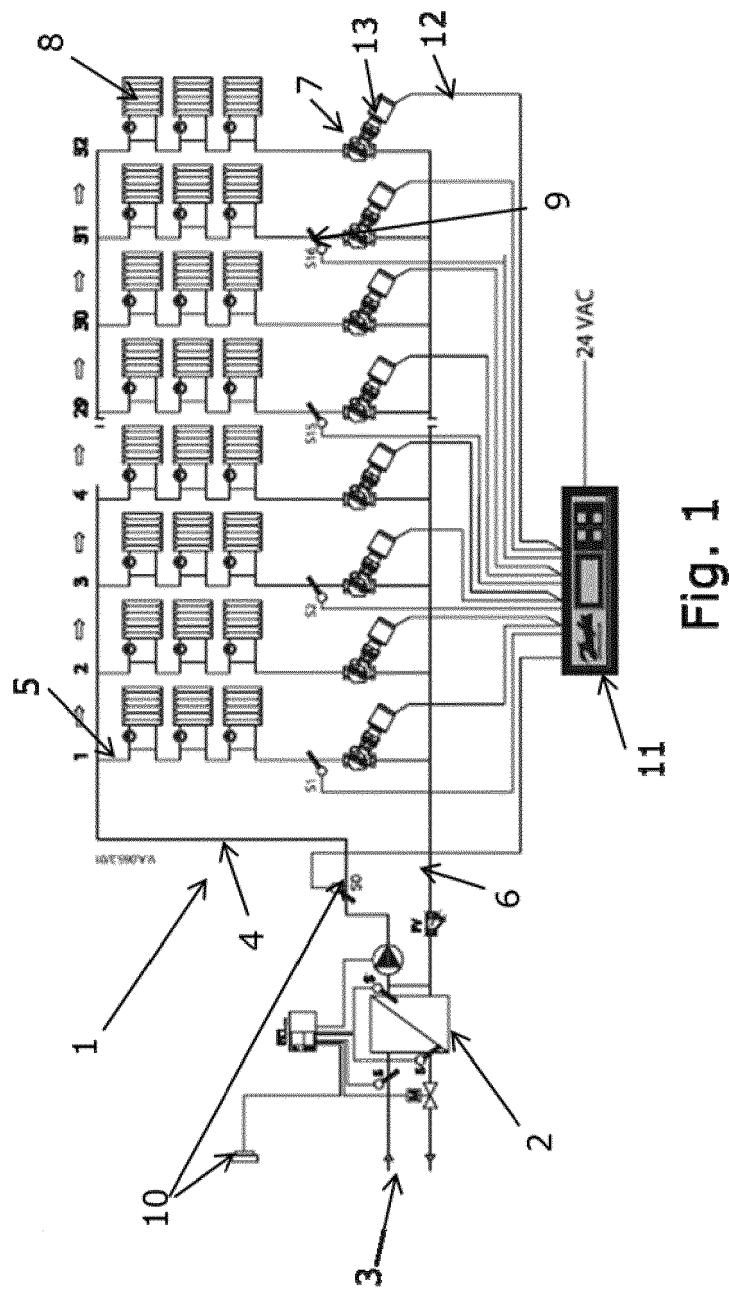


Fig. 1

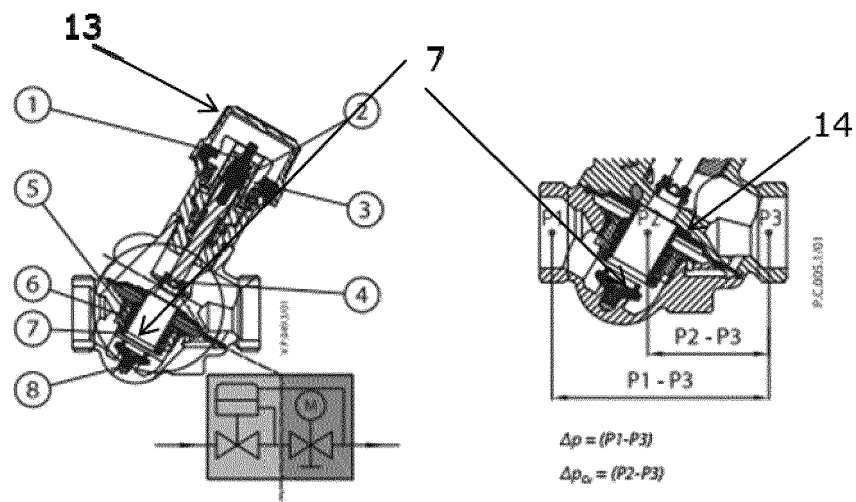


Fig. 2

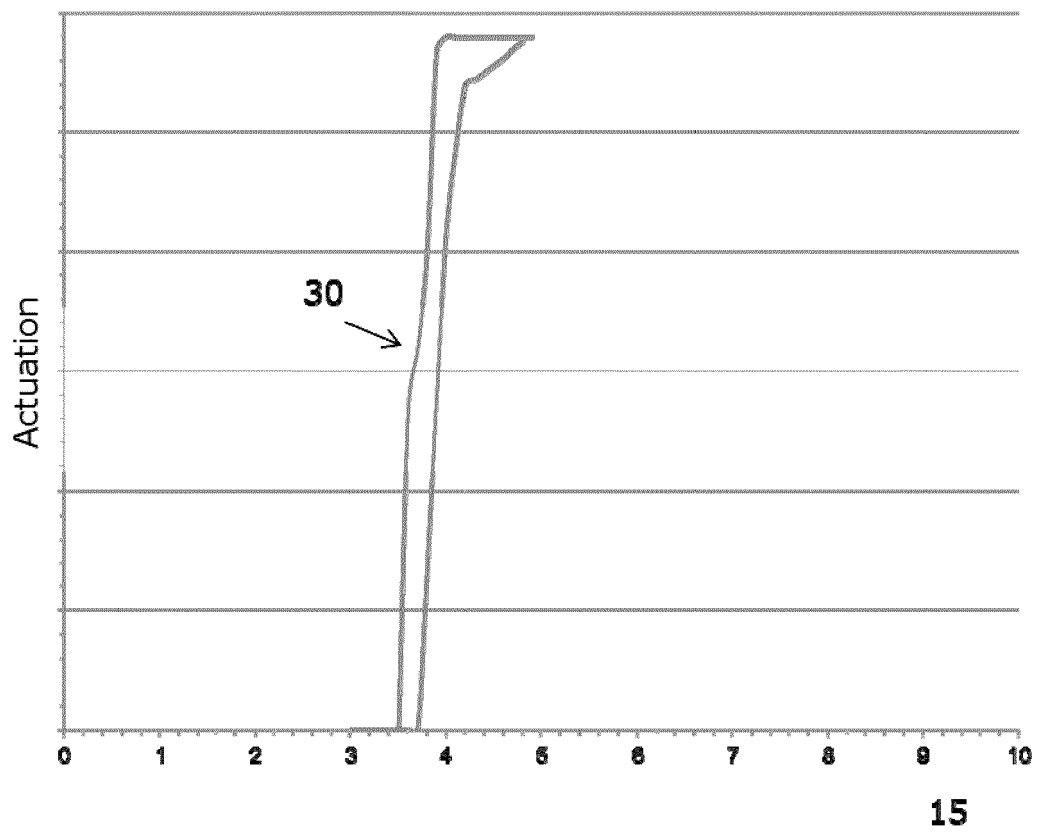


Fig. 3

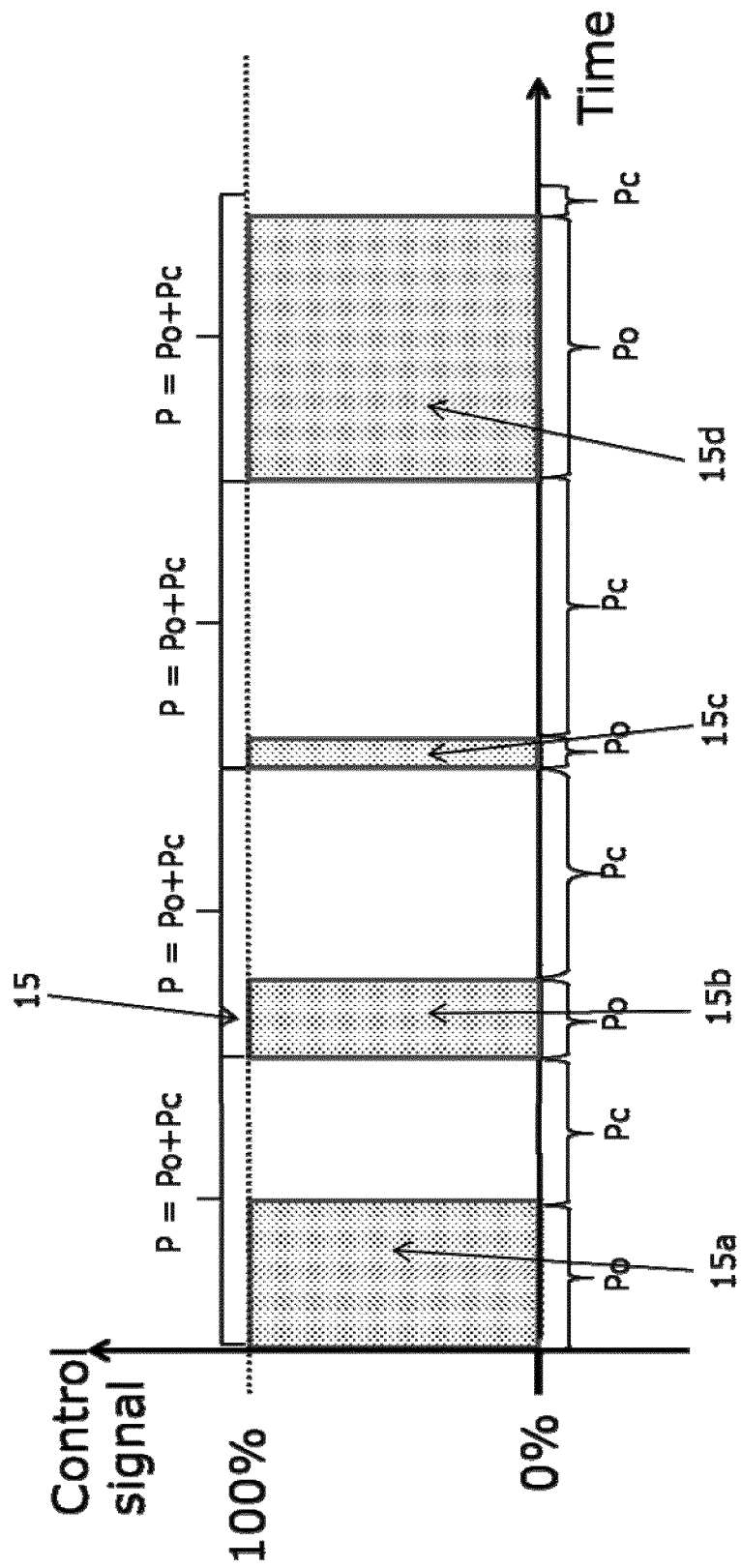


Fig. 4

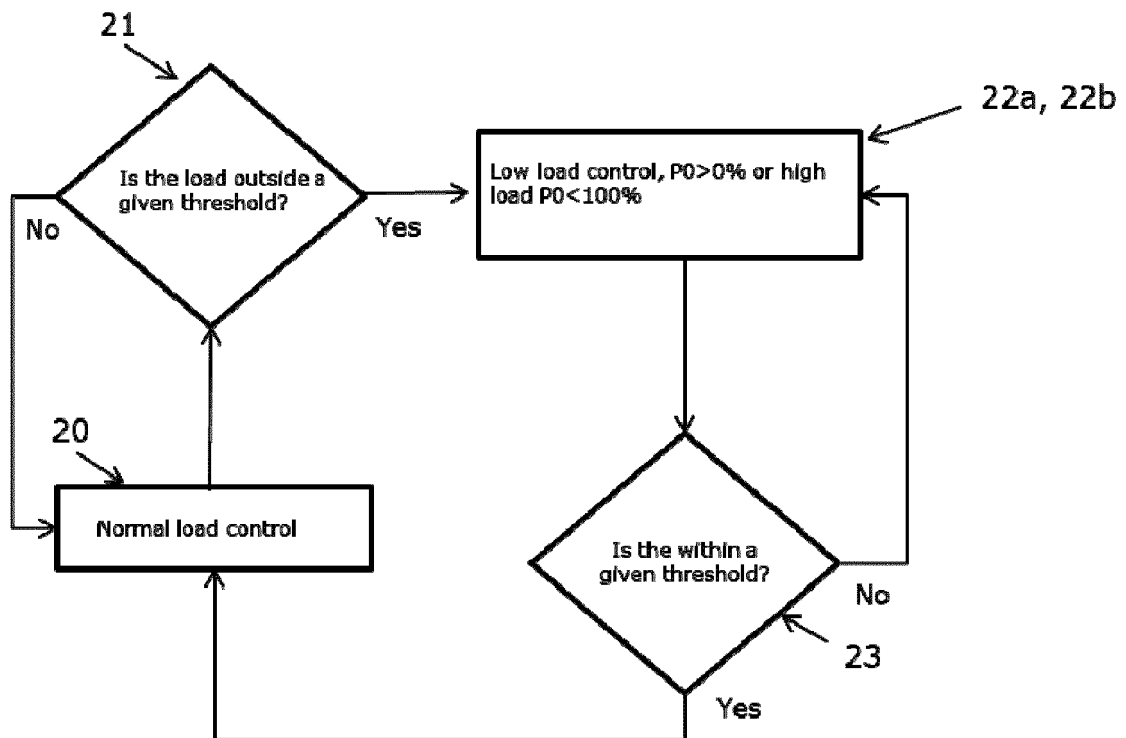


Fig. 5

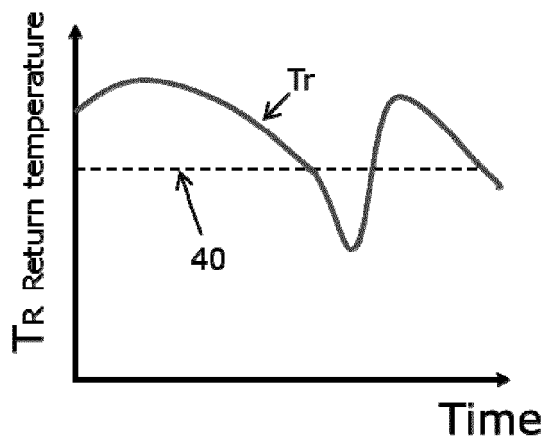


Fig. 6A

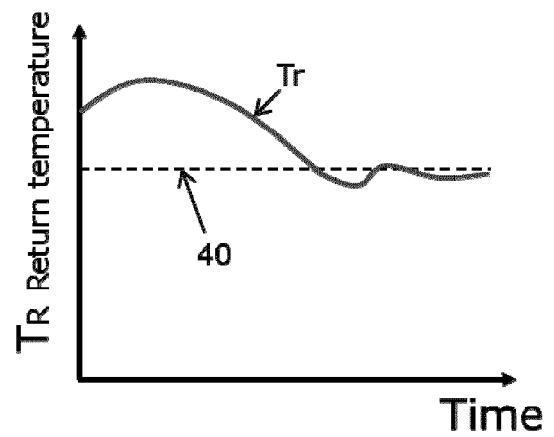


Fig. 6B



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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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