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(54) Benævnelse: **Fremgangsmåde til drift af et system med drev, der er forbundet mekanisk med hinanden, og overordnet computer og system**

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DE-A1-102010 020 598
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Method for operating a system comprising drives, which are mechanically coupled to one another, and a higher-level computer

Description:

The invention relates to a method for operating a system comprising drives, which are mechanically coupled to one another, in particular in a slip-free manner, and a higher-level computer.

It is generally known that a multi-axle drive comprises a plurality of drives. Here, a drive will be understood to mean a converter-powered electric motor, the speed of which, that is to say the rpm, can be adjusted by means of the converter. To this end, the drive has an rpm detection in each case, that is to say a detection of the rpm of the shaft that is driven by the drive.

DE 10 2013 002 782 A1 discloses an axle drive having a device for reducing the mechanical play.

DE 10 2013 016 770 A1 discloses a motor control device for controlling a plurality of motors that drive one driven body.

DE 10 2014 115 881 A1 discloses a method for increasing a current sensing range in a system comprising a polyphase motor.

DE 10 2010 020 598 A1 discloses a method of clutch control for starting a machine with a hybrid transmission.

The problem addressed by the invention is therefore that of jointly operating drives of a multi-axle drive, the aim being in particular that of achieving simple communication.

With regard to the method, the problem is solved according to the invention by the features specified in claim 1.

Important features of the invention with regard to the method are that the method is provided for operating a system comprising drives which are mechanically coupled to one another, in particular without slip, and a higher-level computer which is connected to the drives by means of data bus connection,

wherein, in each drive, a respective parameter actual value, that is to say an actual value of a physical parameter of the respective drive, is determined and is transmitted to the higher-level computer, in particular by means of data bus connection,

wherein the higher-level computer determines for each drive a parameter setpoint value assigned to said respective drive, that is to say a setpoint value of a physical parameter of the respective drive,

wherein the higher-level computer has controllers, one of the controllers being assigned, in particular uniquely assigned, to each drive,

wherein the controller assigned to the respective drive adjusts the parameter actual value of the respective drive to the parameter setpoint value of the respective drive by determining as the control value a speed setpoint value assigned to the respective drive and transmitting this to the respective drive, in particular by means of data bus connection,

wherein the respective drive has a respective controller, to which the respective speed actual value of an electric motor of the drive, determined in the drive, is fed and which adjusts this respective speed actual value to the respective speed setpoint value, transmitted by the higher-level computer, by adjusting the motor voltage or the motor current of the electric motor of the respective drive.

The advantage here is that each drive has a shaft which is driven by the converter-powered electric motor of the drive, the speed of said shaft being adjusted according to the specification of the higher-level computer, this speed specification being determined by the higher-level computer such that the torque of the drive is adjusted to a desired setpoint value. This desired setpoint value is in turn determined as a function of the actual values of the torques of the drives.

Another advantage is that the drives are operated identically, in particular unlike in the case of master-slave control, in which the master is operated differently than the slaves. In addition, in the method according to the invention, the same data transfer rate is required for all drives. None of the drives requires a higher or lower data transfer rate than the other drives.

The drives of a multi-axle drive can thus be jointly operated, with simple communication being achievable.

According to the invention, instead of the parameter, a different parameter is used,

in particular the changeover being such that, instead of the actual value of the physical parameter of the respective drive, the actual value of a different physical parameter of the respective drive is used, and such that, instead of the setpoint value of the physical parameter of the respective drive, the setpoint value of the different physical parameter of the respective drive is used. The advantage here is that improved control can be achieved. Depending on the respective application, therefore, use can be made of a control method that has an improved quality of control.

In one advantageous embodiment, the respective parameter is the respective position or the respective torque of the respective drive. The advantage here is that it is possible to select the better of two different control methods, that is to say the control method that is better for the respective application, such as machine or system.

In one advantageous embodiment, the controllers of the drives and/or the controllers of the higher-level computer have are in each case linear controllers, in particular a PI controller. The advantage here is that of enabling easy implementation.

In one advantageous embodiment, the respective drive has an electric motor, which is powered by a respective converter of the drive,

wherein the respective converter adjusts the respective motor voltage. The advantage here is that the rpm of the electric motor can be adjusted by means of the converter of the drive. To this end, the converter adjusts the motor voltage, with the torque actual value of the drive being determined. This torque actual value is transmitted to the higher-level computer and is adjusted there to the associated torque setpoint value by suitably adjusting the speed setpoint value for the respective drive.

In one advantageous embodiment, the shafts driven by the drives are coupled to one another with a form fit, in particular by means of toothed wheels, or are coupled with a force fit, in particular by means of frictional engagement. This has the advantage that no tensioning forces build up since, if one of the drives “runs ahead”, the torque thereof increases and thus the speed setpoint value specification will accordingly be adjusted downward by the higher-level computer.

In one advantageous embodiment, no master-slave control is implemented in the system. This has the advantage that no cross-communication between the drives is necessary.

Important features with regard to the method for operating a system comprising drives and a higher-level computer are that each drive has a converter-powered electric motor, wherein the respective drive has a means for detecting a speed, in particular a respective speed of rotation of the rotor of the electric motor,

wherein the respective converter has a respective controller which adjusts the respective speed actual value to a respective speed setpoint value by suitably adjusting the motor voltage of the respective electric motor,

wherein the respective torque actual value is determined in the drive and is transmitted to the higher-level computer by means of data bus connection,

wherein the respective speed setpoint value is determined by a controller of the higher-level computer as a control value by adjusting the respective torque actual value to a respective torque setpoint value,

wherein the respective torque setpoint value is determined as a function of the torque actual values,

in particular,

- wherein the respective torque setpoint values correspond to the average of all the torque actual values, or
- wherein the respective torque setpoint values correspond to a respective proportion of the sum of all the torque actual values.

The advantage here is that the distribution of the data transfer rate between the higher-level computer and the respective drive is equal. In addition, no cross-communication between the drives is necessary. A particularly easy implementation can thus be achieved.

Important features with regard to the system for carrying out the aforementioned method are that no master-slave control is or can be operated. The advantage here is that all drives are equal, in particular including with regard to the data transfer rate, which is necessary for control purposes, and their respective share in the data stream as a whole.

Another advantage is that, according to the invention, unlike in the case of master-slave control, there is no cross-communication within the converters, but rather all the converters are actuated equally by the higher-level controller and thus the data transfer rate is equal, in particular is also evenly distributed.

In one advantageous embodiment, the higher-level computer has a changeover means, in particular for changing between the use of the first parameter and of the different parameter, in particular in the control method. The advantage here is that it is possible to change between the use of the two different parameters, such as torque and position, in particular during operation.

Further advantages will become apparent from the dependent claims.

The invention will now be explained in greater detail with reference to figures:

Fig. 1 schematically shows an exemplary embodiment according to the invention.

Here, two drives (2, 3) are provided, which are mechanically coupled to one another.

The first drive 2 has a converter-powered electric motor, which on the output side drives a first toothed wheel 4 directly or via a gearing, the toothing of said first toothed wheel meshing with the toothing of a sun gear 5, that is to say in particular a central gear.

The toothing of the sun gear 5 in turn meshes with the toothing of a second toothed wheel 6, which is driven by a converter-powered electric motor of a second drive 3 directly or via a gearing.

Each converter has a controller unit.

The controller unit of the first drive 2 adjusts the speed actual value V1_actual to a speed setpoint value V1_setpoint by suitably adjusting a control value, in particular the motor voltage for the electric motor of the first drive 2. In addition, the torque actual value M1_actual is determined by the controller unit of the first drive 2 and is transmitted via a data bus to a higher-level computer 1, that is to say a central controller. The speed actual value V1_actual is also transmitted to the central controller. The speed setpoint value V1_setpoint is transmitted by the central controller to the first drive via the data bus and is predefined.

In the same way, the controller unit of the second drive 3 adjusts the speed actual value V2_actual to a speed setpoint value V2_setpoint by suitably adjusting a control value, in particular the motor voltage for the electric motor of the second drive 3. In addition, the torque actual value M1_actual is determined by the controller unit of the first drive 2 and is transmitted via a data bus to a higher-level computer 1, that is to say a central controller. The speed actual value V1_actual is also transmitted to the central controller. The speed setpoint value V1_setpoint is transmitted by the central controller to the first drive via the data bus and is predefined.

The higher-level computer 1 has controllers which are assigned to the respective drives (2, 3).

A first of said controllers adjusts the torque actual value M1_actual of the first drive M1_actual to a torque setpoint value M1_setpoint by adjusting the speed setpoint value V1_setpoint as the control value.

A second of said controllers adjusts the torque actual value M2_actual of the second drive M2_actual to a torque setpoint value M2_setpoint by adjusting the speed setpoint value V2_setpoint as the control value.

The central computer determines the torque setpoint values (M1_setpoint, M2_setpoint) as a function of the torque actual values (M1_actual, M2_actual), for example.

In the exemplary embodiment, the aim is to achieve an equal distribution, and therefore:

M1_setpoint = (M1_actual + M2_actual) / 2
M2_setpoint = (M1_actual + M2_actual) / 2

In other exemplary embodiments, the torque setpoint values of the drives will be determined using other functions, such as for example:

M1_setpoint = a * M1_actual + b * M2_actual
M2_setpoint = c * M1_actual + d * M2_actual

where a, b, c, d are proportional factors, in particular in each case a rational number between 0 and 1.

Alternatively, it is also possible to use a general function in each case, as follows:

M1_setpoint = f1(M1_actual, M2_actual)
M2_setpoint = f2(M1_actual, M2_actual)

where f1 and f2 are respective functions.

In another exemplary embodiment according to the invention, instead of the form-fitting coupling of the drives, a force-fitting or other type of mechanical coupling of the drives is provided.

In addition, it is also possible to use a larger number of drives, the control then being implemented in cascade. In this case, therefore, a torque setpoint value assigned to the respective drive will be determined in the higher-level computer 1 as follows:

M1_setpoint = f1(M1_actual, M2_actual, ... Mi_actual, ..., MN_actual)
M2_setpoint = f2(M1_actual, M2_actual, ... Mi_actual, ..., MN_actual)
...
Mi_setpoint = fi(M1_actual, M2_actual, ... Mi_actual, ..., MN_actual)
...
MN_setpoint = fN(M1_actual, M2_actual, ... Mi_actual, ..., MN_actual)

where the drives are numbered by the running variable i, which runs from 1 to N.

From the respective torque setpoint value specification and the respective torque actual value of the respective drive, a respective speed setpoint value is determined by a respective controller of the higher-level computer 1 and is transmitted to the respective drive, the controller of which adjusts the respective speed actual value thereof to the speed setpoint value transmitted by the higher-level computer 1.

In another exemplary embodiment according to the invention, instead of the parameter "torque" indicated in Fig. 1, a different physical parameter will be used, for example the "position" of the respective drive.

To this end, each drive has a position detection sensor. In the case of rotating electric motors, a conventional angle sensor is in each case installed or mounted in or on the electric motor of the drive. The detected angle values represent the actual values of the position.

As shown in Fig. 2, the currently detected position values X1_ACTUAL of the first drive 2 are transmitted by the latter to the higher-level computer 1 and are fed to a controller therein, which determines the speed setpoint value V1_setpoint for the first drive.

In the same way, the currently detected position values X2_ACTUAL of the second drive 3 are transmitted by the latter to the higher-level computer 1 and are fed to a further controller therein, which determines the speed setpoint value V2_setpoint for the second drive.

The setpoint value X1_SETPOINT for the first controller is determined as a function of the two position values X1_ACTUAL and X2_ACTUAL. In a corresponding manner, the setpoint value X2_SETPOINT for the second controller is determined as a function of the actual position values X1_ACTUAL and X2_ACTUAL of the two drives (2, 3). Suitable formulae can be used for this, such as those mentioned above for torque.

In addition, application to a plurality of drives can be achieved analogously.

In another exemplary embodiment, a means for changing over between the embodiment shown in Fig. 1 and the embodiment shown in Fig. 2 is provided in the higher-level controller.

A higher-level position control or a higher-level torque control can thus be selectively implemented in the higher-level computer 1. In other words, the changeover has the effect that, instead of the torque actual values delivered by the drives (2, 3) to the higher-level computer 1, position actual values are taken into consideration for the higher-level control, or vice versa. In any event, however, the higher-level control operations determine the speed setpoint value specifications for the drives (2, 3).

It is particularly advantageous for the changeover between the two control methods to take place during operation.

List of reference signs

1	higher-level computer
2	first drive
3	second drive
4	first toothed wheel
5	sun gear
6	second toothed wheel
M1_setpoint	torque setpoint value for first drive
M2_setpoint	torque setpoint value for second drive
V1_setpoint	speed setpoint value for first drive
V2_setpoint	speed setpoint value for second drive
M1_actual	torque actual value for first drive
M2_actual	torque actual value for second drive
V1_actual	speed actual value for first drive
V2_actual	speed actual value for second drive

Patentkrav

1. Fremgangsmåde til drift af et system med drev (2; 3), der er forbundet mekanisk med hinanden, især uden slip, og overordnet computer (1), som er forbundet med drevene (2;3) ved hjælp af en databusforbindelse,
hvor der i hvert drev bestemmes en pågældende aktuel størrelsesværdi, dvs. aktuel værdi med en fysisk størrelse af det pågældende drev, især ved hjælp af databusforbindelse, og transmitteres til den overordnede computer,
hvor den overordnede computer for hvert drev bestemmer en størrelsesindstillingsværdi, der er tilknyttet dette pågældende drev, dvs. en indstillingsværdi med en fysisk størrelse af det pågældende drev,
hvor den overordnede computer (1) har reguleringsindretninger, hvor en af reguleringsindretningerne er knyttet, især entydigt, til hvert drev,
hvor reguleringsindretningen, der er knyttet til det pågældende drev, regulerer den aktuelle størrelsesværdi for det pågældende drev i retning mod indstillingsstørrelsesværdien for det pågældende drev, idet den som indstillingsværdi bestemmer en hastighedsindstillingsværdi, der er tilknyttet det pågældende drev, og især ved hjælp af databusforbindelse, transmitterer den til det pågældende drev,
hvor det pågældende drev har en pågældende reguleringsindretning, til hvilken den pågældende aktuelle hastighedsværdi, der bestemmes i drevet, for en elektromotor af drevet, tilføres, og som regulerer denne pågældende aktuelle hastighedsværdi i retning mod den pågældende indstillingshastighedsværdi, der er transmitteret af den overordnede computer, idet den stiller motorspændingen eller motorstrømmen af det pågældende drevs elektromotor,
kendetegnet ved et trin med omskiftning under den igangværende drift, som bevirker, at der i stedet for den fysiske størrelse af drevet anvendes en anden fysisk størrelse af drevet til reguleringen, hvor omskiftningen foregår valgfrit, at der altså omskiftes på en sådan måde, at den aktuelle værdi af en anden fysisk størrelse af det pågældende drev anvendes i stedet for den aktuelle værdi af den fysiske størrelse af det pågældende drev, og at indstillingsværdien af den anden fysiske størrelse af det pågældende drev anvendes i stedet for indstillingsværdien af den fysiske størrelse af det pågældende drev.

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** den pågældende størrelse er den pågældende position eller det pågældende drejningsmoment af det pågældende drev.

3. Fremgangsmåde ifølge mindst et af de foregående krav, **kendetegnet ved** tilvejebringelsen af lineære reguleringsindretninger, især PI-reguleringsindretninger, som reguleringsindretningerne for drevene og/eller reguleringsindretningerne for den overordnede computer.

4. Fremgangsmåde ifølge mindst et af de foregående krav, **kendetegnet ved** tilvejebringelsen af en elektromotor for det pågældende drev, som fødes af en pågældende konverter af drevet, hvor den pågældende konverter stiller den pågældende motorspænding.

5. Fremgangsmåde ifølge mindst et af de foregående krav, **kendetegnet ved, at** akslerne, der drives af drevene, forbindes formsluttende med hinanden, især ved hjælp af tandhjul, eller forbindes kraftsluttende, især ved hjælp af en friktionsforbindelse.

6. Fremgangsmåde ifølge mindst et af de foregående krav, **kendetegnet ved, at** der ved systemet ikke udføres nogen master-slave-regulering.

7. Fremgangsmåde ifølge mindst et af de foregående krav, **kendetegnet ved** tilvejebringelsen af mere end to drev.

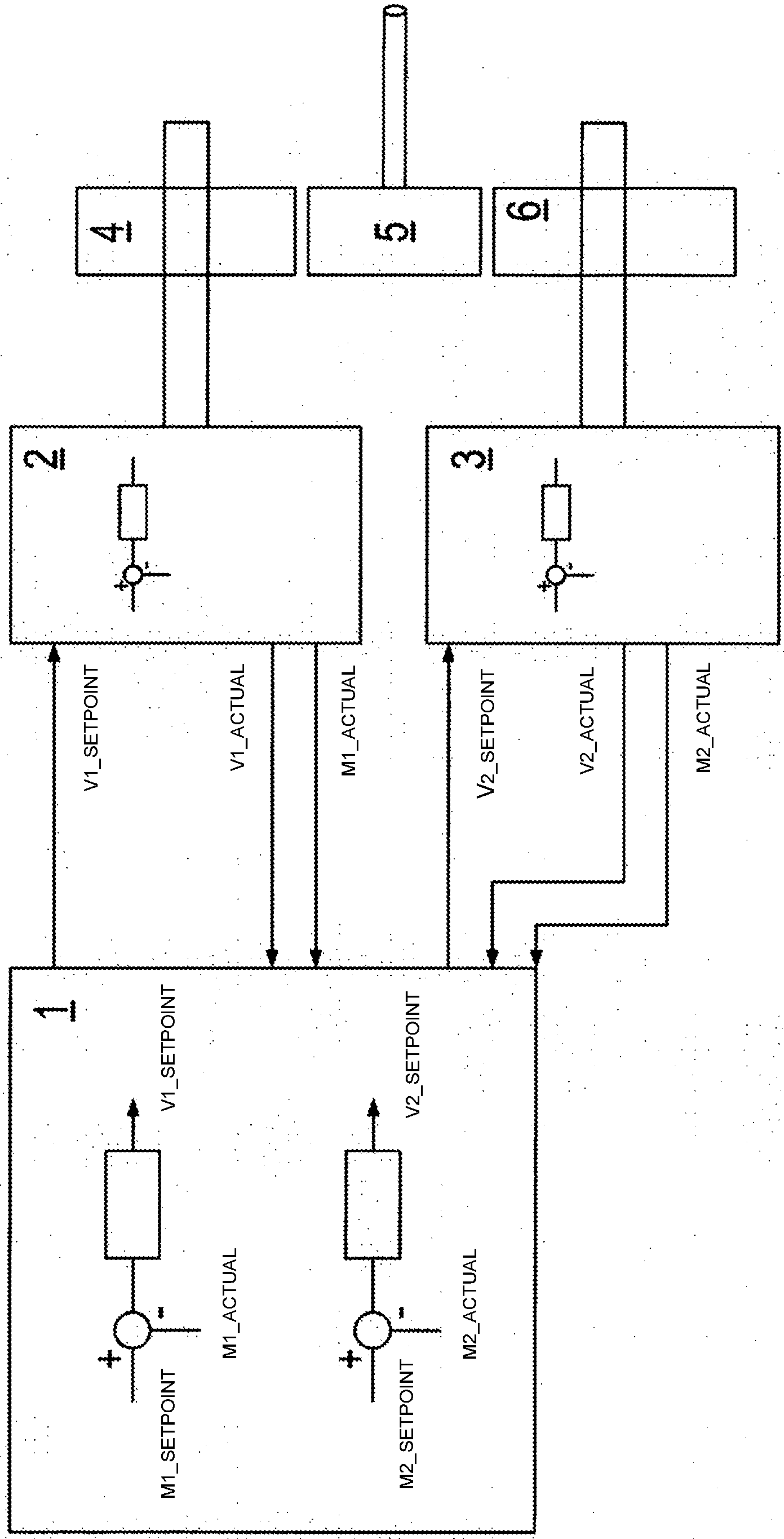
1
2
3
4
5
6
V1_SETPOINT
V1_ACTUAL
M1_ACTUAL
V2_SETPOINT
V2_ACTUAL
M2_ACTUAL
M1_SETPOINT
M2_SETPOINT
+
-

Fig. 1

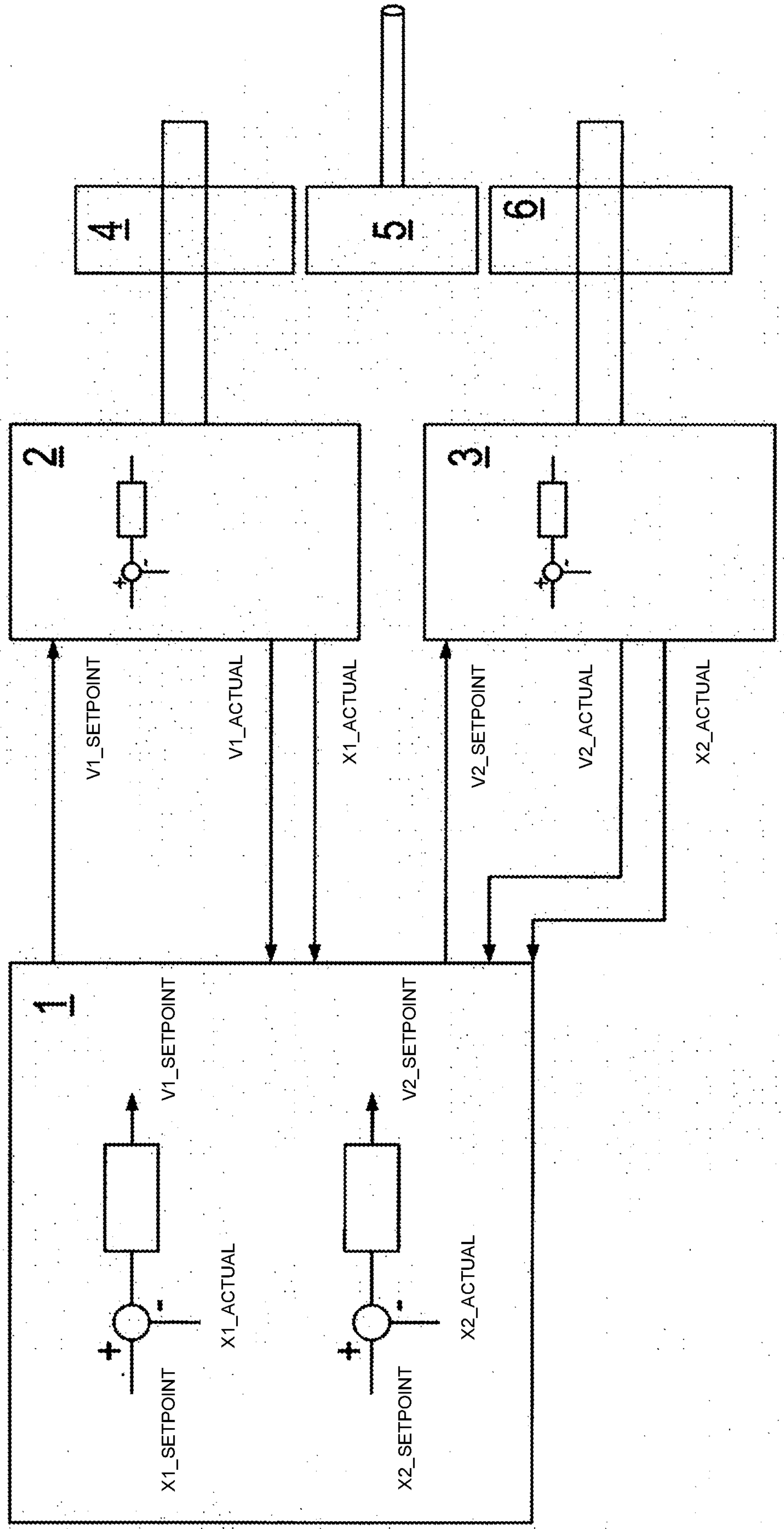
1
2
3
4
5
6
V1_SETPOINT
V1_ACTUAL
X1_ACTUAL
V2_SETPOINT
V2_ACTUAL
X2_ACTUAL
X1_SETPOINT
X2_SETPOINT
+
-

Fig. 2