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(54) **HEAT CONTROL SYSTEM OF A TRANSFORMER**

(57) A heat exchange control system of a transformer, comprising a plurality of fans adapted to force the passage of air through one or more transformer windings in order to facilitate the heat exchange between such windings and the surrounding environment, actuation devices of said fans,
one or more inputs for receiving the thermal status of the

transformer and/or commands as a function of the thermal status of the transformer, and at least one control unit in communication with said one or more inputs and said actuation devices, said control unit being programmed to send actuation signals to the actuation devices so as to adjust the rotation speed of each fan as a function of the thermal status of the transformer.

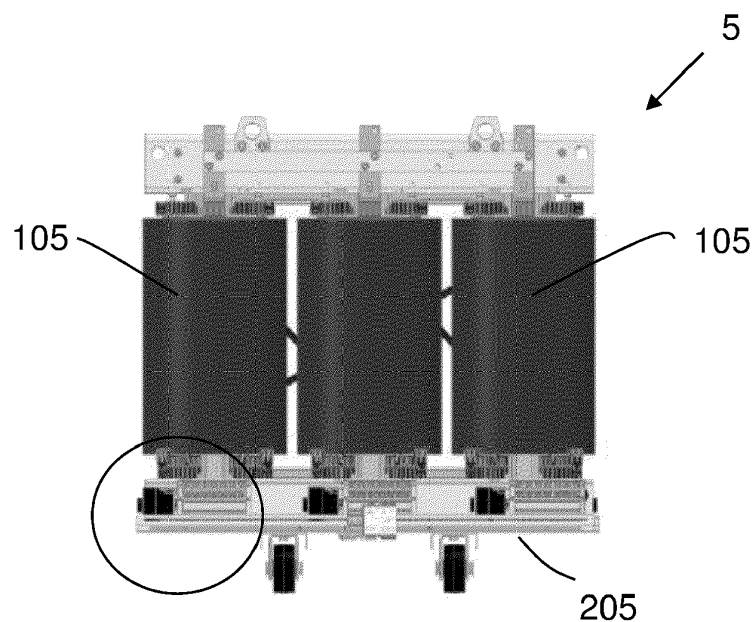


Fig. 3

Description

FIELD OF THE INVENTION

[0001] The invention relates to the field of MV/MV or MV/LV resin transformers for distributing electric energy.

BACKGROUND ART

[0002] MV/MV or MV/LV resin transformers for distributing electric energy are electric machines which, during the operation thereof, generate heat due to losses, which heat is to be kept within design limits for safety matters and to protect the transformer.

[0003] Due to the constructional nature thereof, the transformer autonomously disposes of the heat by virtue of the stack effect. The arrows in Figure 1 indicate the air flow from the bottom upwards, which causes the cooling of the transformer.

[0004] On the other hand, the natural up-draft is not sufficient to ensure an adequate cooling under critical use conditions, both of environmental and electric type, such as to maintain the transformer below the maximum operating temperature thereof.

[0005] For this reason, in the nineties the Applicant introduced and promoted ventilation systems mounted on board the machine to facilitate the disposal of the heat generated by the transformer. As shown in Figure 2, the idea was that of using fans to force the passage of the cooling air.

[0006] To date, these systems still are the only possibility for increasing the heat exchange of a transformer with the surrounding environment.

[0007] The traditional ventilation systems however have a series of limitations essentially due to the fact that they are ON/OFF type systems, i.e. without rotation speed adjustment, specifically:

1. Generation of thermal shock when they are actuated;
2. The air flow is not optimized based on the amount of heat to be disposed of;
3. The power consumption is not optimized due to the rotation speed always at maximum;
4. The noise generated is not optimized due to the rotation speed always at maximum;
5. The system wear is not optimized due to the rotation speed always at maximum;
6. The windings may have significantly different temperatures because the rotation speed of the fans for each coil is the same;
7. The traditional ventilation systems cannot remotely digitally communicate the status of the individual fans (operating method, breakdowns, or anomalies);
8. In the case of breakdown of one of the components, the traditional ventilation system is out of use.

[0008] It is the object of the present invention to provide

a ventilation system of MV/MV or MV/LV resin transformers which allows to at least partially overcome the aforesaid drawbacks.

[0009] The invention achieves the object by a heat exchange control system of a transformer comprising a plurality of fans adapted to force the passage of air through one or more windings of the transformer in order to facilitate the heat exchange between such windings and the surrounding environment, actuation devices of said fans, one or more inputs for receiving the thermal status of the transformer and/or commands as a function of the thermal status of the transformer, and at least one control unit in communication with said one or more inputs and said actuation devices. The control unit is programmed to send actuation signals to the actuation devices so as to adjust the rotation speed of each fan as a function of the thermal status of the transformer.

[0010] The idea behind the invention is that of replacing the traditional asynchronous motors mounted to the ventilation bars with intelligent electronic motors based on BLDC (brushless DC) technology and providing the ventilation bar with one or more control boards capable of dialoging with the control unit in charge of monitoring the transformer and commanding the ventilation system.

[0011] Therefore, by virtue of this, it is possible to drive each aeration fan independently of one another by creating an optimized heat exchange control system for each situation of use of the transformer.

[0012] To this end, the system may advantageously comprise a plurality of sensors for measuring the temperature in one or more points of the transformer windings in communication with corresponding inputs of the control unit for reading the temperature values detected by said sensors. Such temperature values reach the control unit by means of the control unit of the transformer through a specific communication protocol. The control unit is configured to set the rotation speed of the fans, each independently of the other, on the basis of the detected temperature values.

[0013] The actuation devices of said fans advantageously comprise DC motors of the brushless type, driven with variable phase currents such as to generate a magnetic field of rotating stator. Said phases are advantageously determined by the control unit as a function of the rotation speed to be set.

[0014] There may be sensors coupled or couplable to the fans and/or motors, in communication with the control unit inputs, for reading the speed and/or position of the rotor of the motors. Here, the control unit may advantageously be configured to use such speed and/or position information as a feedback to control the rotation of the fans.

[0015] According to an aspect, the invention also relates to an MV/MV or MV/LV resin transformer for distributing electric energy comprising a plurality of windings placed side-by-side, bars adapted to support a plurality of fans arranged at the bottom on opposite sides of each winding so as to facilitate the air flow from the bottom

upwards in each winding, actuation devices of said fans mounted to the same support bars, at least one control unit configured to set the rotation speed of said fans to obtain the aforesaid heat exchange control system.

[0016] The transformer may advantageously comprise temperature sensors interfaced with a control unit configured to read the temperature of each winding and correspondingly communicate the speed value to be set for each fan to the control unit.

[0017] Further objects, features and advantages of the present invention will become more apparent from the following detailed description, provided by way of non-limiting example, and shown in the accompanying drawings, in which:

Figures 1 and 2 show a sectional view of transformers according to the prior art, with natural and forced up-draft, respectively, of the ventilation air of the windings.

Figures 3 and 4 show a side view and a bottom view, respectively, of a transformer with ventilation bars provided with fans with BLDC motors in an embodiment of the system according to the present invention.

Figure 5 shows a perspective view of the detail of the fan connected to a BLDC motor in Figures 3 and 4.

Figure 6 shows the block diagram of a system according to an embodiment of the invention.

Figure 7 shows the detail of the fan control unit of the diagram in Figure 6.

[0018] The following description of exemplary embodiments relates to the accompanying drawings. The same reference numerals in different Figures identify the same elements or similar elements. The following detailed description does not limit the invention. The scope of the invention is defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

[0019] With reference to the block diagram in Figure 6, a system for controlling the heat exchange of a transformer according to an embodiment of the invention comprises a control unit 2 interfaced with a plurality of devices 101 for actuating fans 1. Such actuation devices 101 advantageously comprise DC motors of the brushless type, and related drives.

[0020] The control unit 2 is a typical device with a microcontroller or microprocessor 102 provided with program memory 202 and input/output devices 302, 402, respectively, towards the actuation devices 1 and towards the control unit 3 of the transformer. Advantageously, there may be several control units which manage subgroups of fans.

[0021] The brushless DC (BLDC) motors are characterized by a rotor with a permanent magnet and a stator with coils typically arranged at 120°. By driving the coils

with conveniently out-of-phase currents, a stator rotating magnetic field may be generated, followed by the rotor magnet which is thus rotated.

[0022] Therefore, the key part of the operation of a BLDC motor is the driving of the stator coils. To this end, mechanisms are required, which allow the direction and the application ranges of the current in each coil to be controlled, i.e. the phase changes and the duration of the stator currents to be controlled.

[0023] A way of controlling the BLDC motors consists in using square waves with variable duty cycle as driving signals (PWM - Pulse Width Modulation), which allows a complete control of the motor rotation to be carried out, both in terms of direction and rotation speed, as is well known to those skilled in the art.

[0024] According to an embodiment, the control unit 2, on the basis of the speed to be set for each individual motor, generates square waves for controlling the BLDC motors by means of drivers capable of supplying the power required for each coil. Such drivers may consist of discrete MOSFET bridges or, advantageously, integrated circuits which are suitable for this purpose, e.g. DRV10983.

[0025] The speed control of the fans is advantageously performed on the basis of the temperature of the windings detected by sensors 4. These sensors are temperature probes commonly employed to monitor the operation of the transformers.

[0026] The temperature sensors 4 are operatively connected to the control unit 3 which monitors the operation of the transformer. Said control unit 3 is in charge of translating the readings received from the temperature sensors into command signals. If the temperatures detected exceed the thresholds programmed in the control unit 3, it manages the actuators, for example the alarm relays, in addition to processing the command signal for the ventilation system. Moreover, said control unit 3 communicates the values read by the temperature sensors, or directly the related generated actuation commands, to the control unit 2 by means of a communication line 103.

[0027] The same communication line 103 may be used to transmit statuses related to the fans 1, e.g. breakdowns, or the actual rotation speed, to the control unit 3. To this end, further sensors, here speed/position sensors, for example encoders or Hall effect sensors, coupled to the shaft of each motor and preferably interfaced with the control unit 2 may be used, the data of which may be used both as a feedback to better operate the actuation control of the fan motors and to send status information to the control unit 3. The same motors may also be provided with internal sensors which signal an abnormal increase of ambient temperature where they are located, with consequent implementation of safety measures if they are operating excessively beyond the maximum limits allowed.

[0028] As mentioned, the control unit of the fans 2 typically is in communication with a control unit of the transformer 3 to receive commands and/or send operating

statues from/to said control unit 3. Thereby, a complete control system is obtained, in which in addition to the temperature, other parameters may also be involved for adjusting the speed of the fans, and therefore of the heat exchange between transformer and external environment.

[0029] The control unit, which is typically provided with safety relays, monitors the operation of the transformer and advantageously comprises a remote communication interface, e.g. of the RS485, Ethernet or Wireless type, for sending operating data and receiving setting commands of the operation of the transformer and/or of the fans.

[0030] By virtue of this, transformers may be built, which provide a very effective and highly reliable system for managing the heat exchange by even using the same support bars of the fans currently used, with an apparent advantage in terms of retrofitting existing systems. Indeed, it will be sufficient to replace the fans with brush motors with fans with BLDC motors and a control unit on the same support bar to provide the existing transformers with an evolved heat exchange control system. Figures 3 and 4 show an installation example of a fan with a BLDC motor (shown in detail in Figure 5) in a ventilation bar of a traditional transformer.

[0031] Overall, transformer (5), typically an MV/MV or MV/LV resin transformer for distributing electric energy, comprises a plurality of windings (105) placed side-by-side, bars (205) adapted to support a plurality of fans (1) arranged at the bottom on opposite sides of each winding (105) so as to facilitate the air flow from the bottom upwards in each winding, actuation devices (101) of said fans (1) mounted to the same support bars (205), at least one control unit (2) configured to set the rotation speed of the fans (1), to obtain the heat exchange control system described.

[0032] By virtue of the variable speed of the motors and the digital communication of the control system, various advantages are achieved, including:

1. Reduction of the thermal shock of the transformer by virtue of the early actuation of the ventilation system at reduced speed.
2. The air flow generated is not fixed, rather is a function of the temperature detected by the sensors inserted in the transformer windings.
3. The electric consumption is reduced by virtue of the increased efficiency of the brushless systems and the lower average rotation speed.
4. The average noise is lower because the system rarely needs to operate at the same speed for long periods.
5. By eliminating the continuous ON/OFF switching cycles at the maximum power, mechanical and electric stresses are reduced to the benefit of the average lifetime of the fan.
6. The speed of each individual fan is associated with the temperature of the coil it cools, with the con-

sequent advantage of having an increased thermal uniformity of the electric machine (reduction of thermo-mechanical stresses).

7. The system may dialog directly with the control unit of the transformer, which is also arranged for remotely transmitting data via RS485, ETH or Wi-Fi; therefore, the operating status of the system and possible abnormalities may be known.

8. If one of the components of the system breaks, the system enters the SAFETY mode and autonomously actuates the fans so as to limit the thermal increase of the transformer which would be out of control; the only required condition obviously is the presence of electric power to the fans.

Claims

1. A system for controlling the heat exchange of a transformer, the system comprising:

a plurality of fans (1) adapted to force the passage of air through one or more windings of the transformer in order to facilitate the heat exchange between such windings and the surrounding environment;

devices for actuating said fans (101),

characterized in that it comprises one or more inputs for receiving the thermal status of the transformer and/or commands as a function of the thermal status of the transformer and at least one control unit (2) in communication with said one or more inputs and said actuation devices (101), said control unit (2) being programmed to send actuation signals to the actuation devices (101) so as to adjust the rotation speed of each fan (1) as a function of the thermal status of the transformer.

2. A system according to claim 1, wherein there is a control unit (3) for controlling the transformer, the control unit of the fans (2) being in communication with said control unit (3) to receive commands and/or send operating statues from/to said control unit (3).
3. A system according to claim 2, comprising a plurality of sensors (4) for measuring the temperature in one or more points of the transformer windings in communication with corresponding inputs of the control unit (3) for reading the temperature values detected by said sensors (4), the control unit (2) being configured to set the rotation speed of the fans (1), each independently of the other, on the basis of the detected temperature values.
4. A system according to one or more of the preceding claims, wherein the actuation devices (101) of said fans (1) comprise DC motors of the brushless type,

driven with variable phase currents such as to generate a magnetic field of rotating stator, said phases being determined by the control unit (2) as a function of the rotation speed to be set.

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5. A system according to one or more of the preceding claims, wherein there are sensors coupled or coupleable to the fans (1) and/or to the motors (101), said sensors being in communication with inputs of the control unit (2) to read the speed and/or position of the rotor of the motors, the control unit (2) being configured to use such speed and/or position information as a feedback to control the rotation of said fans (1). 10
6. A system according to one or more of the preceding claims, wherein said control unit (3) is configured to send speed information to be set for at least part of the fans (1) to the control unit (2) on the basis of the operating parameters of the transformer. 15
7. A system according to one or more of the preceding claims, wherein the control unit (3) comprises a remote communication interface for sending operating data and receiving setting commands of the operation of the transformer and/or of the fans (1). 20
8. A system according to one or more of the preceding claims, wherein the control unit (2) is programmed to drive the fans (1) at a safety speed when the control unit (3) provides an indication of breakdown or the communication between the control unit (2) and the control unit (3) is interrupted. 25
9. An MV/MV or MV/LV resin transformer (5) for distributing electric energy, comprising a plurality of windings (105) placed side-by-side, bars (205) adapted to support a plurality of fans (1) arranged at the bottom on opposite sides of each winding (105) so as to facilitate the air flow from the bottom upwards in each winding, actuation devices (101) of said fans (1) mounted to the same support bars (205), at least one control unit (2) configured to set the rotation speed of said fans (1) to obtain a heat exchange control system according to one or more of the preceding claims. 30
10. A transformer (5) according to claim 9, wherein there are a control unit (3) and sensors (4) for detecting the temperature of the windings (105) in communication with said control unit (3), which control unit is configured to read the temperature of each winding and correspondingly communicate the speed value to be set for each fan (1) to the control unit (2). 35

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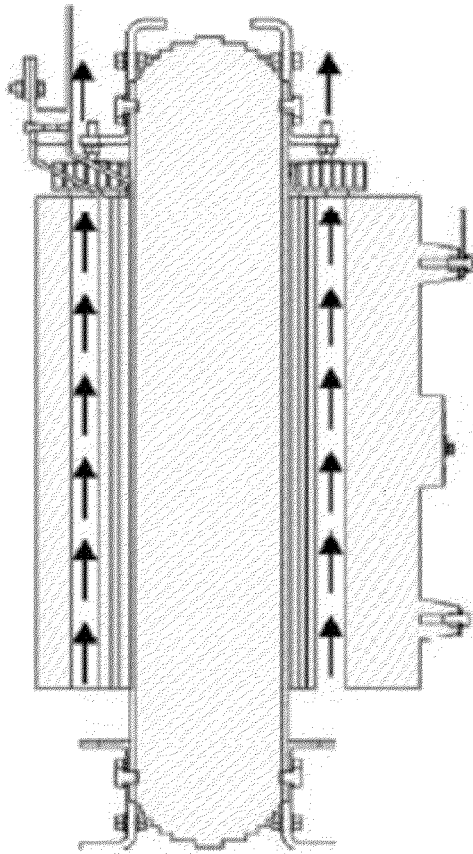


Fig. 1

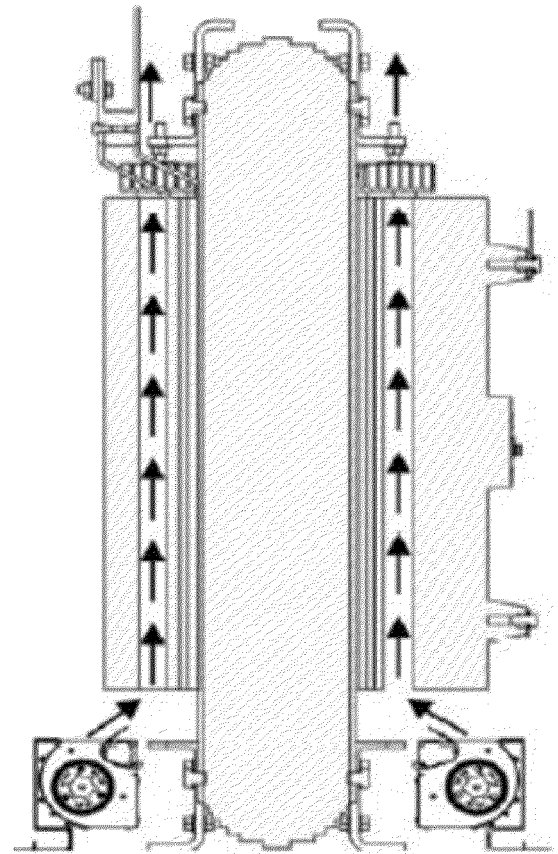
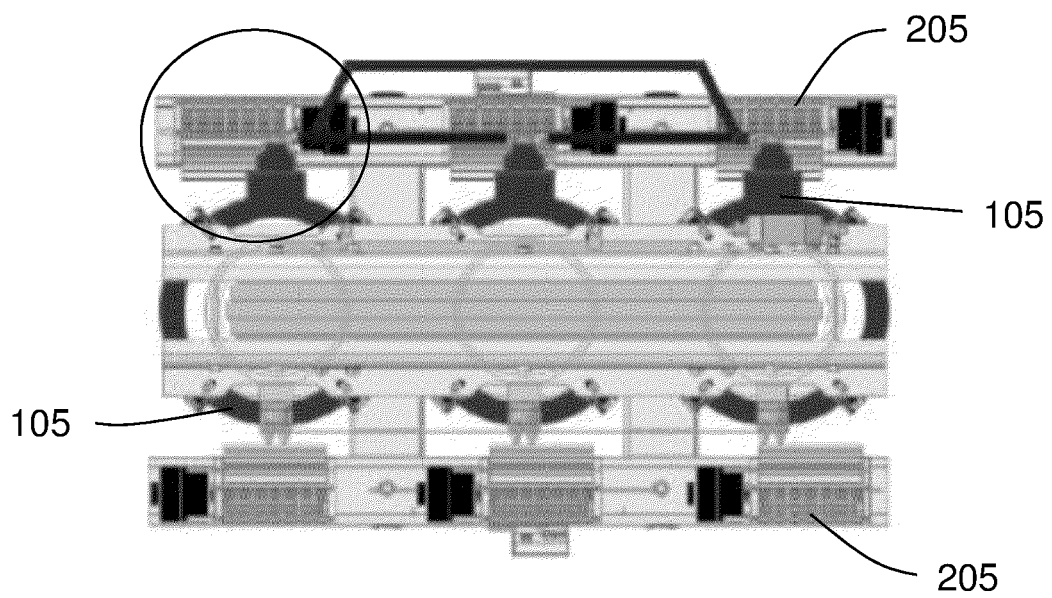
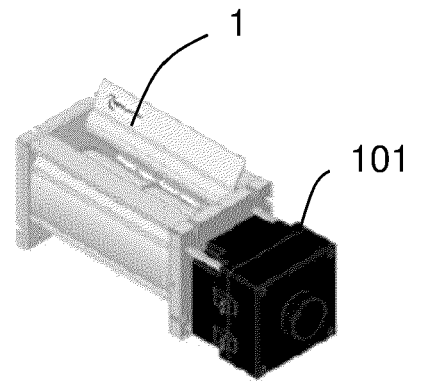
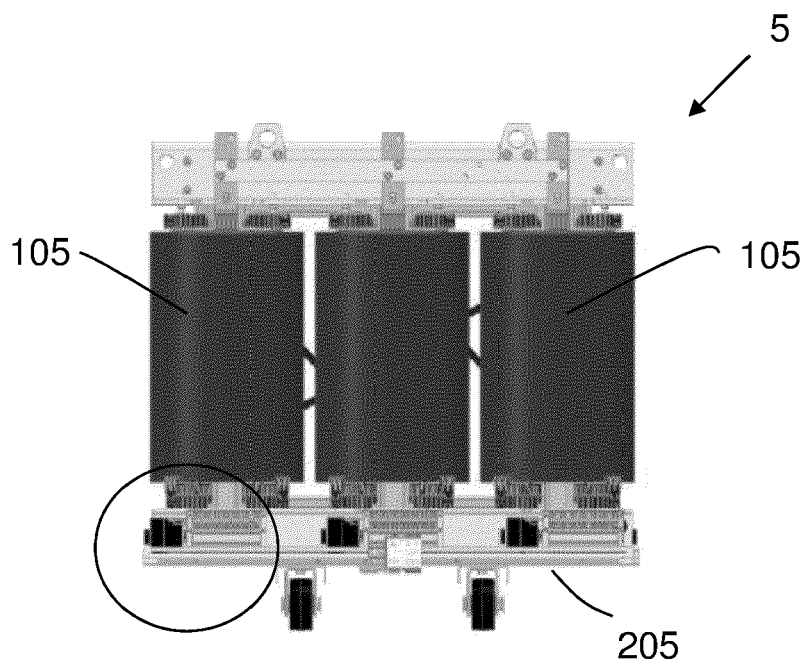


Fig. 2



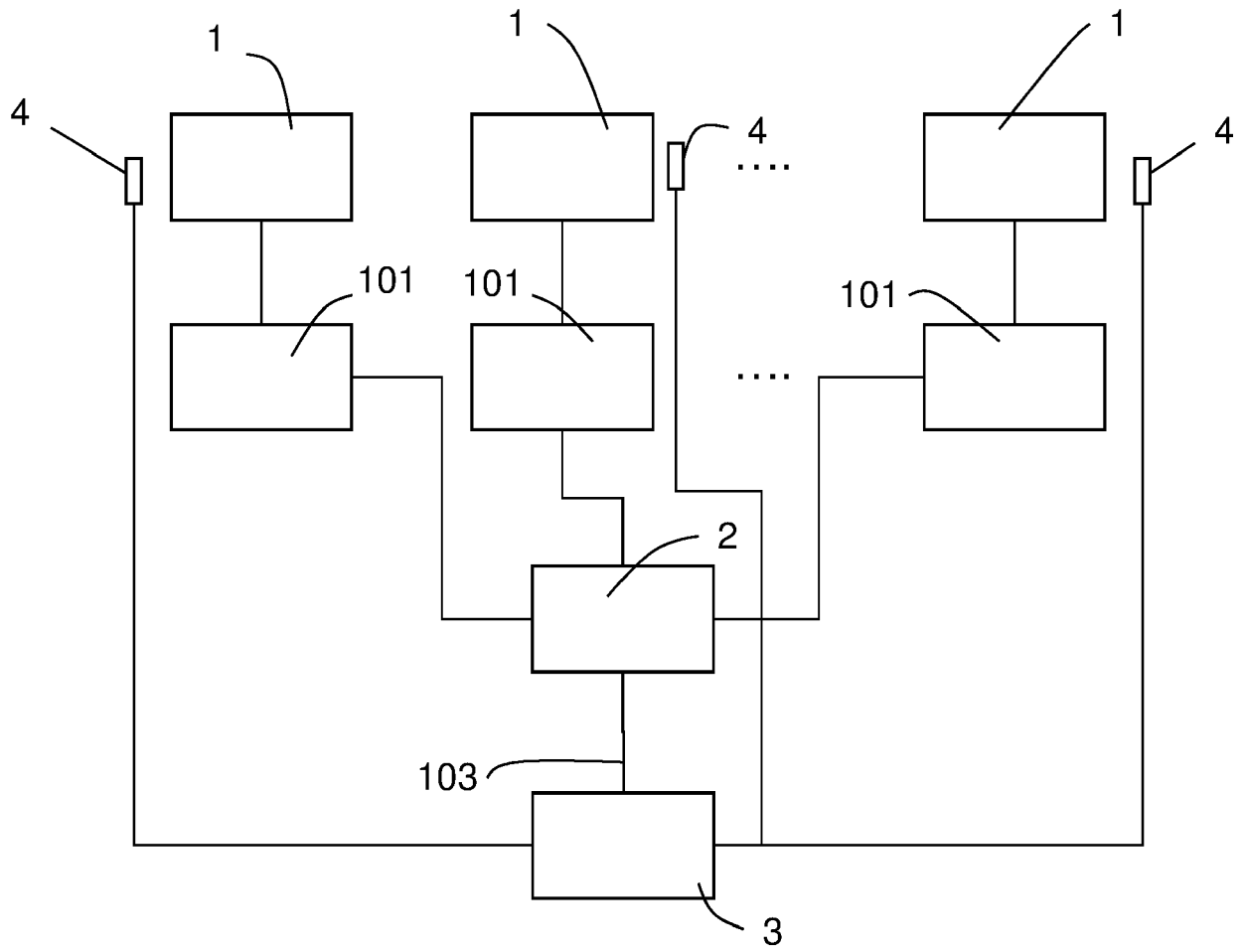


Fig. 6

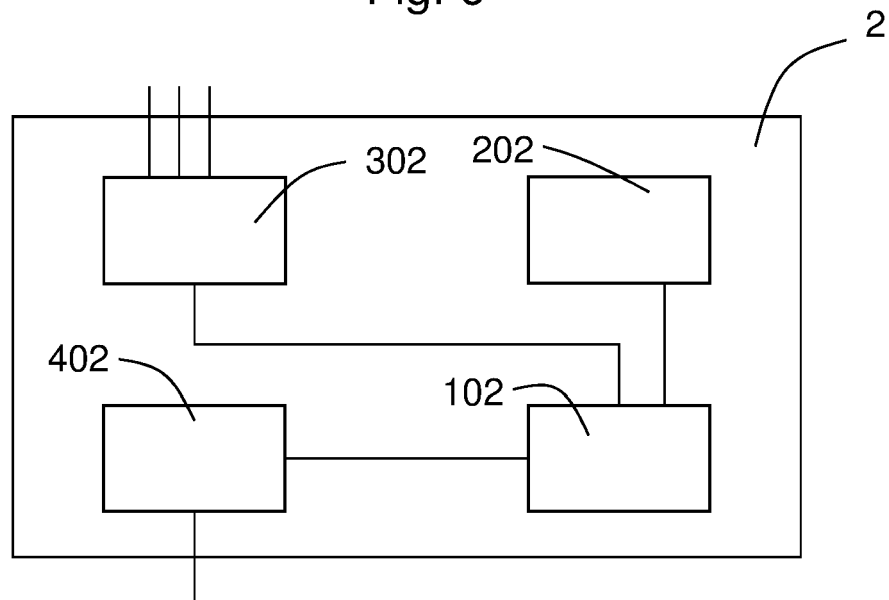


Fig. 7



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 Application Number
EP 20 16 8886

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