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- (71) Applicant: INVENTIO AG [CH/CH]; Seestrasse 55, 6052 Hergiswil (CH).
- (72) Inventor: FERREIRA, Henrique; Professor Teófilo Cavalcante Filho Street 148, 03912-270 São Paulo (BR).
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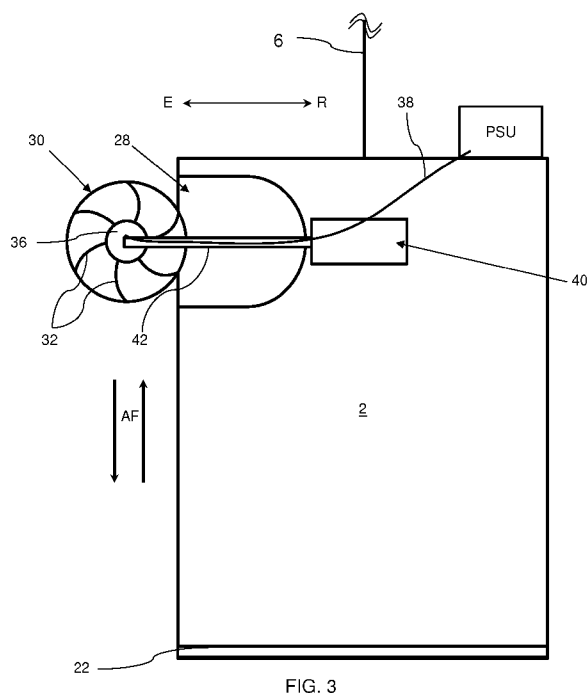
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(54) Title: ELECTRICAL ENERGY GENERATION FROM AIRFLOW WITHIN AN ELEVATOR



(57) Abstract: A method for generating electrical energy within an elevator (1) comprising the steps of providing a turbine (30;30') on an elevator car (2) that is movable along an elevator hoistway (12), and selectively exposing the turbine (30;30') to or concealing the turbine from airflow (AF) while the car (2) is moving along the hoistway (12).



Electrical Energy Generation from Airflow within an Elevator

The present invention relates to an elevator and particularly to the selective generation of electrical energy from a wind turbine while the elevator is in operation.

5 US-A1-2011/0025064 discloses a high-rise elevator having a wind power generation system using a stack effect of a high-speed elevator in a high-rise building. The stack effect is the air flowing through the elevator core or hoistway caused by pressure differential therein. To reduce the problems caused by the stack effect, the air current generated in the elevator hoistway is generally discharged to the outside. The system
10 described in US-A1-2011/0025064 provides a solution for supplying energy used in the high-rise building by permanently reusing the discharged wind as a wind power generation source instead of discharging the air current (wind) generated in the elevator core directly to the outside.

15 While this system may be beneficial for high-rise, high-speed elevators which exhibit the necessary pressure differentials resulting in a usable stack effect it is expensive to implement and is of limited use and efficiency within low to medium rise applications where pressure differentials are markedly less significant.

The above issues are, in at least some cases, addressed through the technologies described in the claims.

20 The invention provides a method and an elevator for the generation of electrical energy from a wind turbine while the elevator is in operation.

The method comprises the steps of providing a turbine on an elevator car that is movable along an elevator hoistway and selectively exposing the turbine to or concealing the turbine from airflow while the car is moving along the hoistway.

25 In a preferred example, the electrical energy generated by the turbine is supplied to a power storage unit (PSU) and accordingly can be used subsequently by electrical loads connected to the power storage unit.

Optionally, the method includes the step of evaluating whether the energy stored in the power storage unit is greater than a preset reference energy value. If not, the turbine can
30 be exposed so as to generate energy on subsequent trips to recharge the power storage

unit up to the preset reference energy value.

Alternatively, a travel direction of an elevator car and a mass differential between the car and a counterweight can be determined prior to an elevator trip. Through these steps the method can establish whether the elevator will operate in motoring mode or regenerative or inertial mode for the pending trip. In motoring mode electrical power is actively drawn from and consumed by an elevator drive from commercial power supplies to move the elevator on its trip. In inertial mode, the imbalance in mass between the car and counterweight actively assists the elevator in executing the desired trip so much so that the net power drawn from the commercial power supply is often negligible and in many instance the power is regenerated in the elevator drive.

For example, if the car including its passengers and load is heavier than the counterweight, then the elevator will operate in a motoring mode in the upward direction but in inertial mode for a downward trip.

If, on the other hand, the car including its passengers and load is lighter than the counterweight, then the elevator will operate in inertial mode in the upward direction but in motoring mode for a downward trip.

Preferably, when the elevator operates in motor mode and is thereby consuming substantial power from the commercial power supply, the turbine is concealed from the airflow. Conversely, the turbine can be beneficially exposed to the airflow when the elevator operates in inertial mode.

The invention also provides an elevator having an elevator car interconnected to a counterweight within an elevator hoistway, a turbine mounted to the car, and an actuator to selectively expose the turbine to or conceal the turbine from airflow while the car is moving along the hoistway.

In one embodiment, the car has a cavity and the actuator selectively extends the turbine from or retracts the turbine into the cavity.

In an alternative embodiment, the turbine is mounted within a vertical air channel mounted to or within the elevator car and the actuator selectively opens or closes an opening of the channel.

A travel path for the elevator is conventionally determined by a controller. In operation, the elevator controller receives signals from conventional landing operating panels and car operating panels to determine the travel path and direction that the elevator must undertake in order to satisfy passengers' travel requests.

5 Additionally, the controller may receive signals from a load measurement device mounted to the car.

Accordingly, prior to the start of a trip, the controller already knows the direction of the intended trip and can also determine, from the signals from a load measurement device, a mass differential between the car and a counterweight. Consequently, the controller can
10 establish whether the elevator will operate in motoring mode or inertial mode for the pending trip and issue signals to the actuator accordingly.

Preferably, the elevator further comprises a power storage unit electrically connected to the turbine so that energy generated can be transferred into an electrical energy bank within the power storage unit and can be stored for subsequent use. The electrical energy
15 bank may comprise batteries, capacitors, fuel cells or any other form of DC electrical energy storage.

Preferably, energy harvested within the power storage unit can be supplied to external electrical loads via one or more outputs. If the external load has the same voltage rating as the energy bank it can be supplied from a DC output connected directly to the energy
20 bank. Alternatively, the voltage from the energy bank can be bucked, boosted or otherwise transformed by a DC to DC converter to supply external electrical loads having different voltage ratings via a further DC output. Furthermore, a DC to AC inverter can be used to invert the DC power from the energy bank into AC power which can be supplied to external electrical loads via an AC output.

25 In a preferred embodiment the power storage unit is mounted to the elevator car. Accordingly, energy harvested can be used to supply electrical loads within the car and this enables at least a reduction in the rating of any travelling cable used to power the electrical loads within the car if not enabling the design engineer to dispose of the travelling cable completely.

30 By way of example only, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings, of which:

FIG. 1 is an exemplary schematic showing an arrangement of components within an elevator according to the present invention;

FIG. 2 is a cross-sectional side view of the elevator car of FIG. 1 with a turbine in its fully retracted position;

5 FIG. 3 corresponds to the elevator car of FIG. 2 but instead illustrated the turbine in its fully extended position;

FIG. 4A is a perspective view of components of the turbine as used in the embodiment of FIGS. 1-3;

10 FIG. 4B is a perspective view of an alternative turbine for use in the elevator of FIGS. 1-3;

FIG. 5 illustrates an alternative embodiment to that depicted in FIGS. 1-3 which can be implemented on the elevator car of FIG. 1;

FIGS. 6A and 6B are plan views from above the car shown in FIG. 5 illustrating the two operational states of the actuator, respectively;

15 FIG. 7 is a schematic of an exemplary embodiment of a power storage unit in which energy generated by the turbines of FIGS. 1 – 6 is harvested;

FIG. 8 is a flowchart illustrating the steps in an embodiment of a method according to the present invention for generating electrical energy within an elevator according to any of FIGS. 1-6; and

20 FIG. 9 is a further flowchart illustrating an alternative or additional procedure to that depicted in FIG. 8.

FIG. 1 illustrates an exemplary embodiment of an arrangement of components within an elevator 1. An elevator car 2 and a counterweight 4 are supported on a traction member 6 within an elevator hoistway 12. In this example, the tension member 6 has a 1:1 roping ratio whereby it extends from an end connection fixed to the car 2 up the hoistway 12 for engagement through a wrap angle α with a traction sheave 14 which is rotated by an elevator drive 16, over a deflection pulley 18 and subsequently back down the hoistway 12 to a further end connection fixed to the counterweight 4. Naturally, the person skilled

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in the art will easily recognise that alternative roping arrangements are equally applicable and that the traction sheave 14 and its associated drive 16 can be mounted within the shaft 12 to provide what is conventionally known as a machine-room-less (MRL) installation, as shown, or alternatively can be provided in a separate and dedicated machine room.

5 In operation, an elevator controller 20 receives signals from conventional landing operating panels and car operating panels (not shown) to determine the travel path that the elevator must undertake in order to satisfy passengers' travel requests. Once the travel path has been determined, the controller 20 outputs signals to the drive 16 so that the traction sheave 14 can be rotated in the appropriate direction. The traction sheave 14
10 engages with the traction member 6 to vertically move the car 2 and counterweight 4 in opposing directions along guiderails (not shown) within the hoistway 12.

Additionally, from signals generated by a load measurement device 22 mounted to the elevator car 2, the controller 20 can monitor load within the car 2, and particularly, can determine whether the car 2 is overloaded while stationary at any landing. In this case an
15 overload alarm can be issued within the car 2 to allow some passengers to disembark from the car 2.

A specific feature of the car 2 shown in FIG. 1 is that it includes a cavity 28. The cavity 28 is better illustrated in and described with reference to FIGS. 2 and 3 which are cross-sectional side views of the car 2 illustrated in FIG. 1. As shown, the cavity 28 houses an
20 aerofoil-powered generator which may be more commonly known as a wind turbine 30. For convenience, the term turbine will be used in the following description. The turbine 30 includes a plurality of blades 36 mounted for concurrent rotation on a rotor shaft 34 connected to an electrical generator 36. The generator is supported on an arm 42 extending from an actuator 40. Electric cables 38 connect the generator 36 to a power
25 storage unit PSU mounted on the roof of the car 2. Preferably, the power storage unit PSU supplies power to the actuator 40 and the controller 20 issues command signals to the actuator 40 either through a wired signal network or more preferably wirelessly (not shown).

The actuator 40, upon instruction from the controller 20, is capable of horizontally
30 extending the arm 42, and thereby the turbine 30, outwards in direction E and retracting the arm 42 back into the cavity in direction R. In the fully retracted state as shown, the turbine 30 is completely housed within the cavity 28 and is not influenced by any air

flowing AF alongside the car 2 as it travels upwards and downwards within the hoistway 12.

FIG. 3 illustrates the contrary situation where the turbine 30 is fully extended in direction E. In this condition, any airflow AF alongside the car 2 as it travels upwards and downwards within the hoistway 12 will rotate the turbine 30 and electrical energy generated within the generator 36 will be transmitted for storage to the power storage unit PSU.

FIG. 4A is a perspective view of components of the turbine 30 as used in the embodiment of FIGS. 1-3. Such a turbine 30 is commonly referred to as a horizontal axis turbine because the rotor shaft 34 is horizontally aligned.

FIG. 4B is a perspective view of an alternative turbine 30' which can be interchanged with that previously described. In this turbine 30', the blades 32' are mounted for concurrent rotation on a vertically aligned rotor shaft 34'.

FIG. 5 illustrates an alternative embodiment to that depicted in FIGS. 1-3. For the avoidance of unnecessary repetition, components common to both embodiments have the same reference numerals and the description thereof given above shall continue to apply.

Instead of a cavity 28 within the car 2, in this embodiment a vertical air channel 60 is provided within or mounted to the elevator car 2. The channel 60 has openings 62 at the top and bottom permitting airflow AF through the channel 60 as the car 2 travels upwards and downwards within the hoistway 12. In this example, two of the vertical axis turbines 30' depicted in FIG. 4B are mounted within the channel 60.

Again, an actuator 40, e.g. with an extensible arm 42, is provided on the car 2. In this instance however the actuator 40 acts on a cover or seal 44 to selectively open or close an opening 62 of the channel 60.

FIGS. 6A and 6B are views from above the actuator 40 of FIG. 5 illustrating the two operation positions adopted by the actuator 40 to close or to open the opening 62 of the channel 60, respectively. In FIG. 6A the actuator 40 has extended the arm 42 and seal 44 in direction C to fully cover the opening 62 of the channel 60 (as shown in dash). In this condition, airflow AF is prevented from travelling through the channel 60.

In FIG. 6B, the actuator 40 has retracted the arm 42 and seal 44 in direction O, thereby exposing the opening 62 to any air flowing AF alongside the car 2 as it travels upwards and downwards within the hoistway 12. Any consequential air flow AF within the channel 60 will rotate the turbines 30' and electrical energy generated within the generators 36 will be transmitted via cables 38 for storage to the power storage unit PSU.

In both of the embodiments illustrated in FIGS. 1 to 3 and FIGS. 5 to 6, respectively, any electrical energy generated by the turbines is supplied along the electrical cables 38, depicted schematically only, to an input DC_{in} to the power storage unit PSU which will be further described with reference to FIG. 7.

Within the power storage unit PSU, the electrical energy from the input DC_{in} can be feed through a DC to DC converter 46 and is ultimately stored in an energy bank 48, which in this instance comprises a plurality of rechargeable batteries 50. Naturally other forms of DC electrical energy storage such as capacitors, fuel cells etc. are equally feasible.

Power harvested in the DC energy bank 48 can be fed directly to a first DC output DC_{out1} and supplied further to electrical loads operating with the same voltage rating as the energy bank 48. Alternatively, the voltage from the energy bank 48 can be bucked, boosted or otherwise transformed by a further DC to DC converter 46 to supply external electrical loads having different voltage ratings via a second DC output DC_{out2} . Furthermore, a DC to AC inverter 52 can be used to invert the DC power from the energy bank 48 into AC power which is supplied to external electrical loads via an AC output AC_{out} . Accordingly the power harvested within the power storage unit PSU can be supplied to electrical loads within the car 2 such as the actuator 40, lighting, ventilation, operating panels etc.

In the embodiments previously described above, it is preferable that the actuator 40 is bi-stable in such a manner that electrical energy is only consumed by it to implement movement between the two opposing positions as illustrated in FIGS. 2-3 and FIGS. 6A-6B, respectively. The actuator 40 may be realised as electrical motor driving a screw thread between the two opposing positions. Alternatively, the actuator 40 may comprise an electromagnet to selectively engage or disengage a purely mechanical linkage, translating movement of the car 2 along in the hoistway 14 into movement between the two opposing positions. Such an actuator may include a roller or a wheel which when activated by the electromagnet rotatably engages a hoistway wall, a guide rail or even the

traction means 6 if it is in a 2:1 roping arrangement and thereby extends alongside the side walls of the car 2. The rotation of the roller or wheel is then translated by linkage to movement between the two opposing positions.

5 Modern elevator drives 16 have two basic operating modes, namely motoring mode M and inertial mode I. The drive 16 will operate in either of these two modes depending upon the mass differential between the car 2 and the counterweight 4, and also upon the direction of travel.

10 For example, if the mass of the car 2 including its passengers or other load is greater than the mass of the counterweight 4, the drive 16 adopts the motoring mode M in order to move the car 2 upwards. Similarly, the drive 16 is in motoring mode M when driving an empty car 2 downwards.

15 On the contrary, for an empty car 2, the inertia within the elevator system itself is sufficient to move the car 2 upwards and the drive 16 is in inertial mode I. Similarly, the inertia within the elevator system itself is also sufficient to move a full car downwards, in which case the drive 16 is inertial mode I.

The controller 20 is programmed primarily to activate the actuator 40 such that the turbines 30,30' generate electrical energy only when the drive 16 is in inertial mode I.

20 FIG. 8 is a flowchart illustrating the steps in an embodiment of a method according to the present invention for harvesting electrical energy within an elevator 1 according to any of the preceding embodiments.

25 As previously discussed, the elevator controller 20 receives signals from conventional landing operating panels and car operating panels to determine the travel path that the elevator must undertake in order to satisfy passengers travel requests. Accordingly, before the start of any new trip at step S1, the controller 20 already knows the intended direction of travel S2 for the elevator car 2.

Additionally, signals fed to the controller 20 from the load measurement device 22 can be compared against pre-programmed reference values indicative of the empty car mass and counterweight mass to determine in step S1 the mass differential between the car 2 and the counterweight 4.

Given the direction of travel from step S2 and the mass differential from step S3, the controller 20 can for any given trip determine in step S4 whether the drive 16 will run in motoring mode M or inertial mode I.

5 If the result from step S4 indicates that the drive 16 will adopt the motoring mode M, the controller 20 will signal the actuator 40 in step S5 to conceal the turbines 30,30' from the airflow AF before commencing the elevator trip.

So for the embodiment of FIGS. 1 to 3, the controller 20, in step S5, instructs the actuator 40 to fully retract the turbine 30, if it is extended, so that it is completely housed within the cavity 28 as shown in FIG. 2.

10 For the alternative embodiment illustrated in FIGS. 5 and 6, the controller 20, in step S5, commands the actuator 40 to extend the arm 42 and seal 44 in direction C to fully cover the opening 62 of the channel 60, as shown in FIG. 6A. In this condition, airflow AF is prevented from travelling through the channel 60.

15 On the contrary, if the result from step S4 indicates that the drive 16 will adopt the inertial mode I, the controller 20 will signal the actuator 40 in step S6 to expose the turbines 30,30' before commencing the elevator trip.

20 So for the embodiment of FIGS. 1 to 3, the controller 20, in step S6, instructs the actuator 40 to fully extend the turbine 30 in direction E as shown in FIG. 3. In this condition, any airflow AF alongside the car 2 as it travels upwards and downwards within the hoistway 12 will rotate the turbine 30 and electrical energy generated within the generator 36 will be transmitted for storage to the power storage unit PSU.

25 For the alternative embodiment illustrated in FIGS. 5 and 6, the controller 20, in step S6, commands the actuator 40 retract the arm 42 and seal 44 in direction O, thereby exposing the opening 62 to any air flowing AF alongside the car 2 as it travels upwards and downwards within the hoistway 12. Any consequential air flow AF within the channel 60 will rotate the turbines 30' and electrical energy generated within the generators 36 will be transmitted via cables 38 for storage to the power storage unit PSU.

The sequence concludes with step S7, when the controller 20 instructs the commencement of the elevator trip.

Although, as discussed above, the controller 20 is programmed primarily to control the turbines 30,30' so as to generate electrical energy only when the drive 16 is in inertial mode I, there may be occasions when it is necessary to temporarily override the sequence outlined in the flowchart of FIG. 8. If, for example, there is no travelling cable connected to the elevator car 2 and, instead, all electrical loads within the car 2 are supplied with energy from the power storage unit PSU, it is critical that there is sufficient energy within the power storage unit PSU for the electrical loads. In this instance, the controller 20 can follow the process steps outlined in the flowchart of FIG. 9.

In this sequence, before the start of any new trip at step S1, the controller 20 evaluates whether the energy stored in the E_{PSU} in the power storage unit PSU is greater than a preset reference energy value E_{REF} in step S8.

If the result determined in step S8 is negative, indicating a low level of energy stored in the PSU, the controller 20 will signal the actuator 40 in step S9 to expose the turbines 30,30' before commencing the elevator trip in step S10. Accordingly, the turbines 30,30' are exposed to the airflow AF during the trip and therefore generate energy regardless of whether the drive 16 is operating in motoring M or inertial I mode.

This sequence of steps S1, S8 and S9 is repeated for each subsequent elevator trip until the determination in step S8 is positive, indicating that there is sufficient energy within the power storage unit PSU. At this stage, the controller 20 reverts to the sequence steps S2 to S7 of the flowchart of FIG. 8 so that the turbines 30,30' only generate electrical energy when the drive 16 is in inertial mode I.

A further embodiment of the invention is also conceivable in which the turbines 30,30' are not electrically connected to the power storage unit PSU but instead are connected to and are used exclusively to supply a specific electrical load such that when power is demanded by the electrical load, the turbines 30,30' are exposed to the airflow AF. Conversely, when no power is required by the electrical load the turbines 30,30' can be concealed from the airflow AF.

Having illustrated and described the principles of the disclosed technologies, it will be apparent to those skilled in the art that the disclosed embodiments can be modified in arrangement and detail without departing from such principles. In view of the many possible embodiments to which the principles of the disclosed technologies can be

applied, it should be recognized that the illustrated embodiments are only examples of the technologies and should not be taken as limiting the scope of the invention. Rather, the scope of the invention is defined by the following claims and their equivalents.

Claims

1. A method for generating electrical energy within an elevator (1) comprising the steps of:
5 providing a turbine (30;30') on an elevator car (2) that is movable along an elevator hoistway (12); and
selectively exposing the turbine (30;30') to or concealing the turbine from airflow (AF) while the car is moving along the hoistway.
- 10 2. A method according to claim 1, further comprising the step of supplying electrical energy generated by the turbine to a power storage unit (PSU).
3. A method according to claim 2, further comprising the step of evaluating (S8) whether the energy stored (E_{PSU}) in the power storage unit is greater than a preset
15 reference energy value (E_{REF}).
4. A method according to claim 3, further comprising the step of exposing (S9) the turbine when the level of energy stored in the power storage unit is less than the reference level.
20
5. A method according to claim 1 or claim 2, further comprising the steps of determining a travel direction of an elevator car (S2) and determining a mass differential (S3) between the car and a counterweight (4).
- 25 6. A method according to claim 5, wherein the turbine is concealed (S5) from the airflow when the elevator operates in motor mode (M).
7. A method according to claim 5, wherein the turbine is exposed (S6) to the airflow when the elevator operates in inertial mode (G).
- 30 8. An elevator (1) comprising:
an elevator car (1) interconnected to a counterweight (4) within an elevator hoistway (12);
a turbine (30;30') mounted to the car; and
35 an actuator (40) to selectively expose the turbine to or conceal the turbine from airflow (AF) while the car is moving along the hoistway.

9. An elevator according to claim 8, wherein the car has a cavity (28).

5 10. An elevator according to claim 9, wherein the actuator selectively extends the turbine (30) from or retracts the turbine into the cavity.

11. An elevator according to claim 8, wherein the turbine (30') is mounted within a vertical air channel (60).

10 12. An elevator according to claim 11, wherein the actuator selectively opens or closes an opening (62) of the channel.

13. An elevator according to any of claims 8 to 12, further comprising a controller (20) determining a travel path for the elevator.

15 14. An elevator according to claim 13 where the controller issues signals to control the actuator.

20 15. An elevator according to claim 13 or 14 where the controller receives signals from a load measurement device (22) mounted to the car.

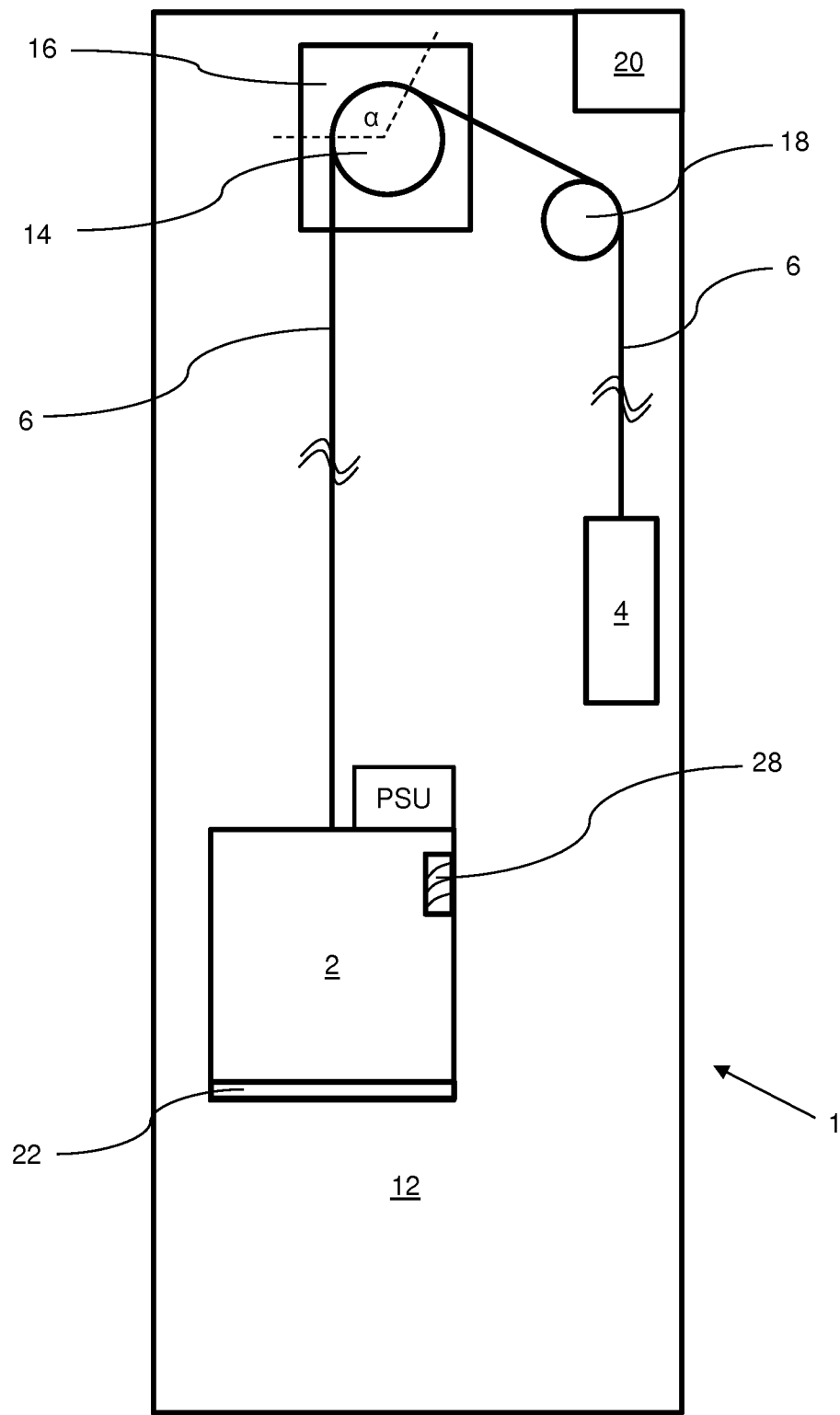


FIG. 1

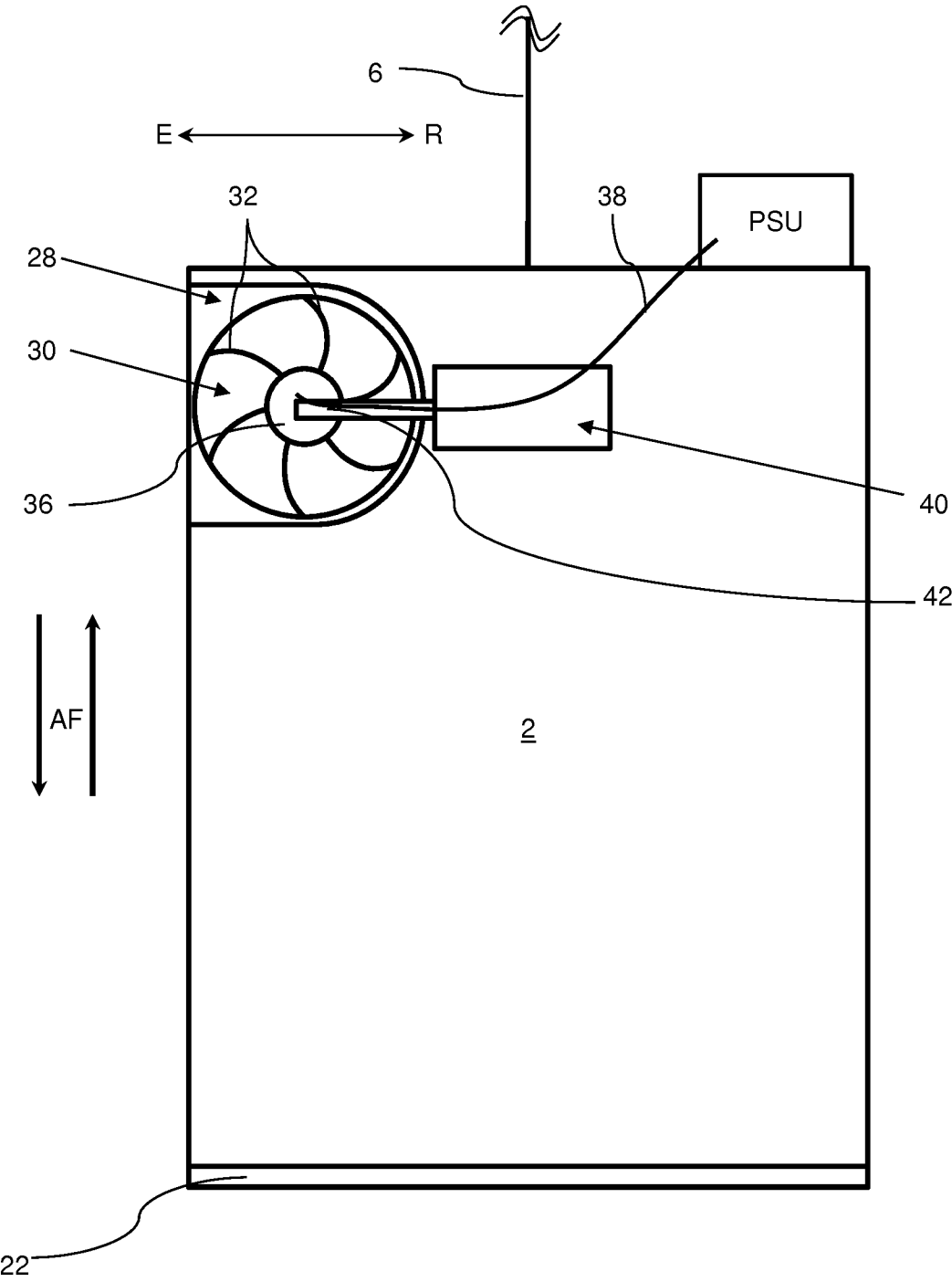


FIG. 2

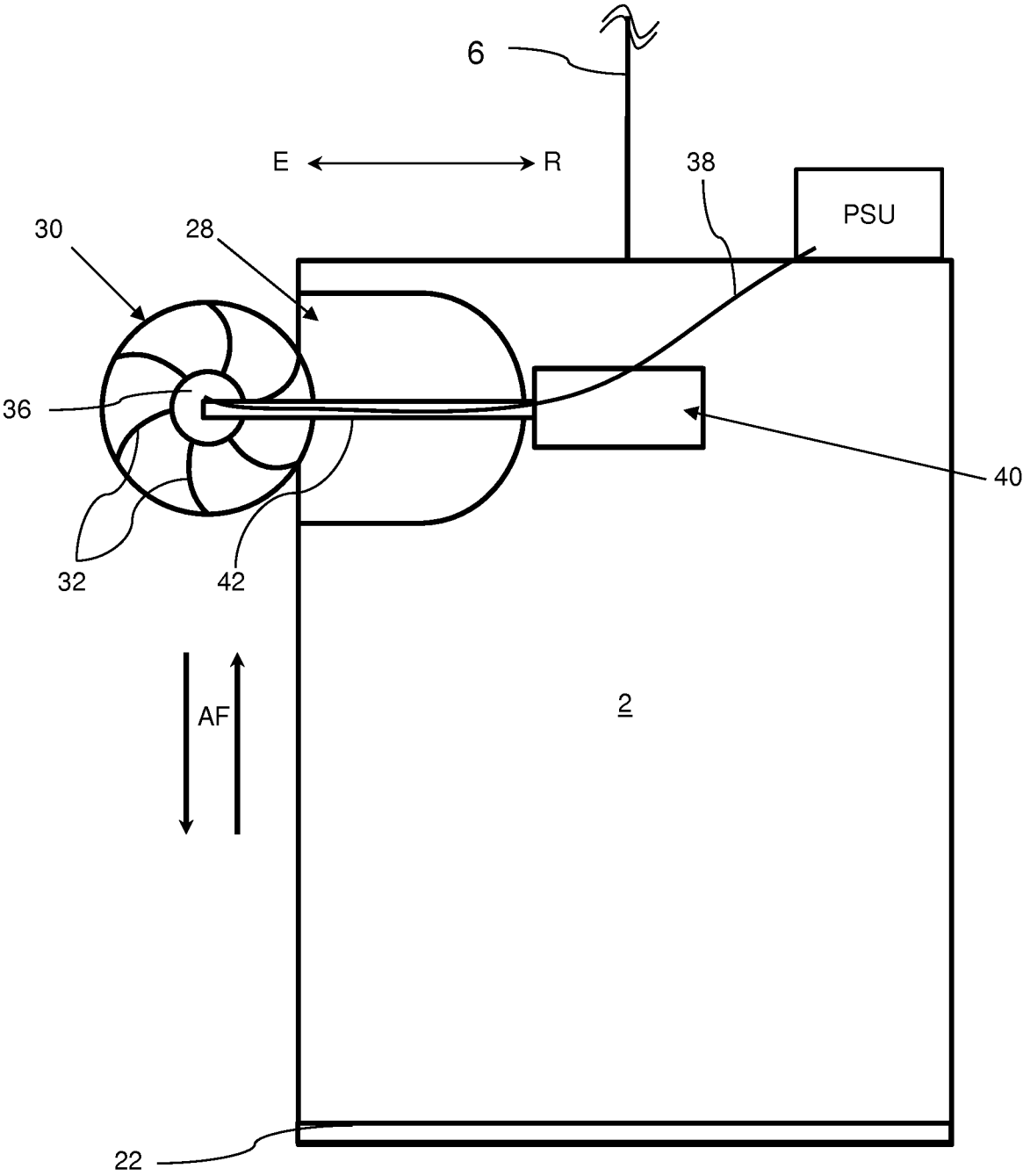


FIG. 3

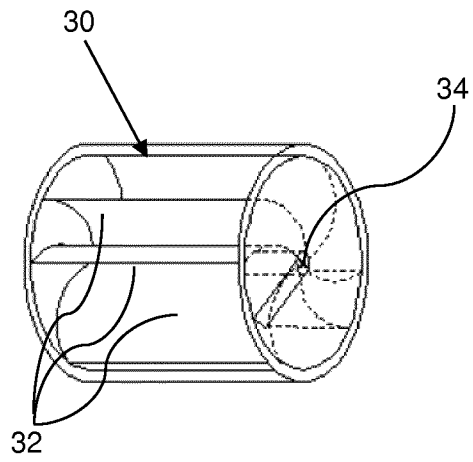


FIG. 4A

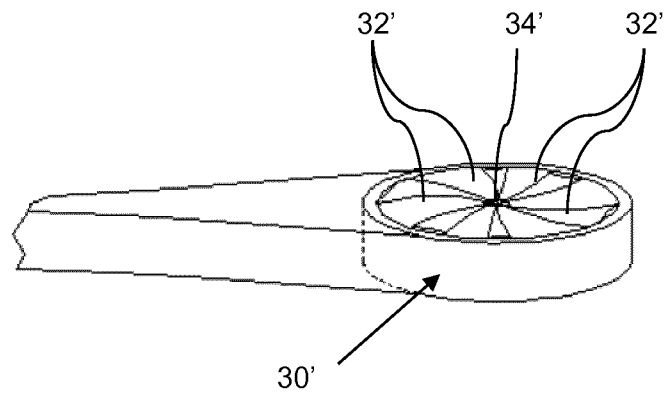


FIG. 4B

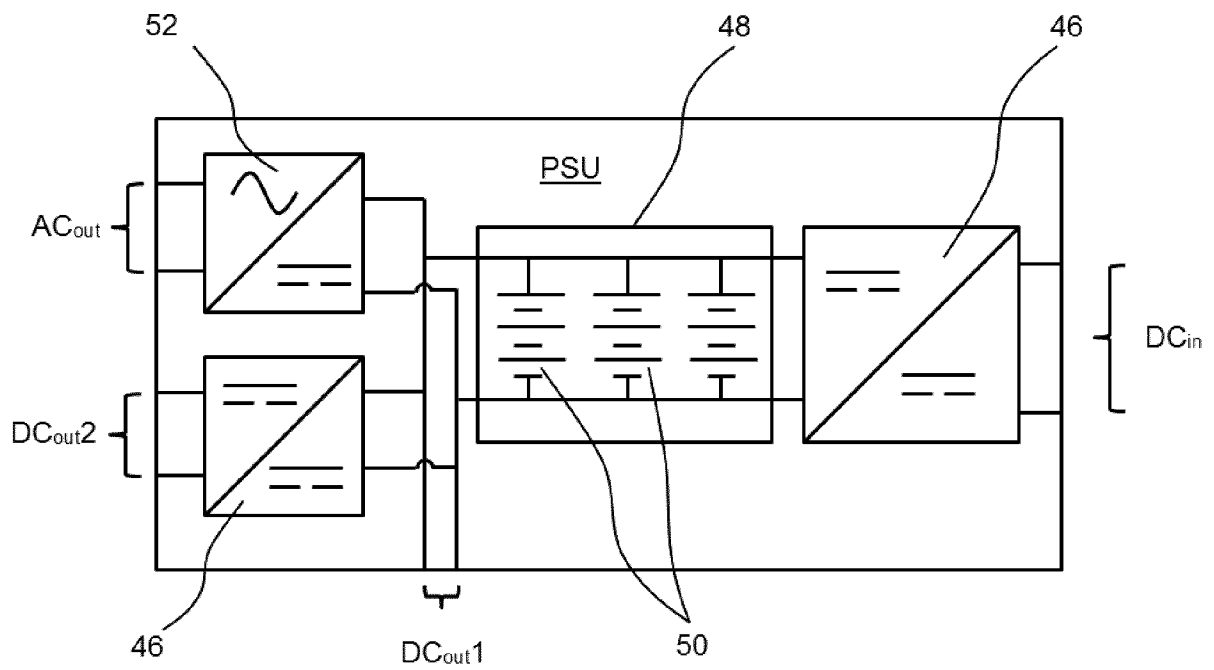


FIG. 7

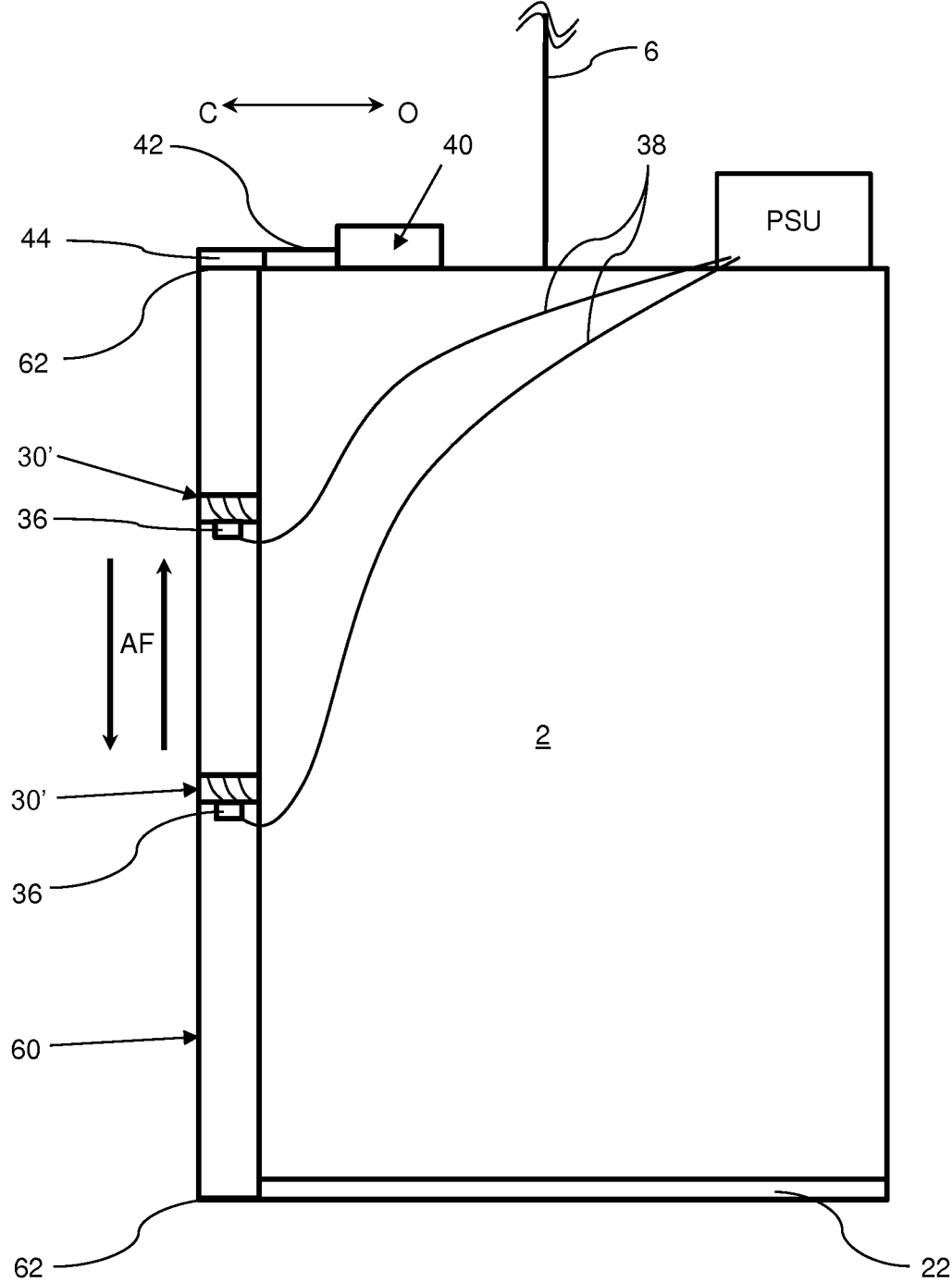


FIG. 5

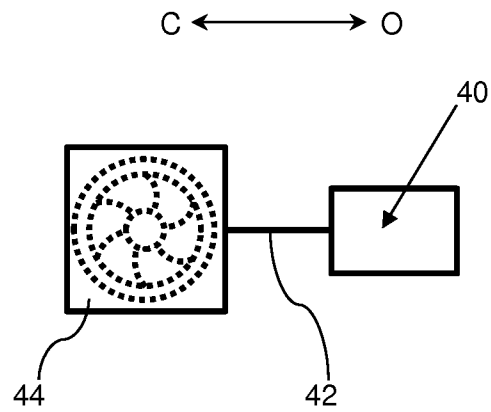


FIG. 6A

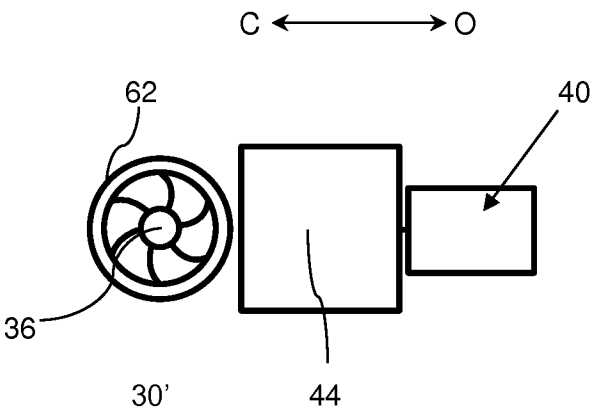


FIG. 6B

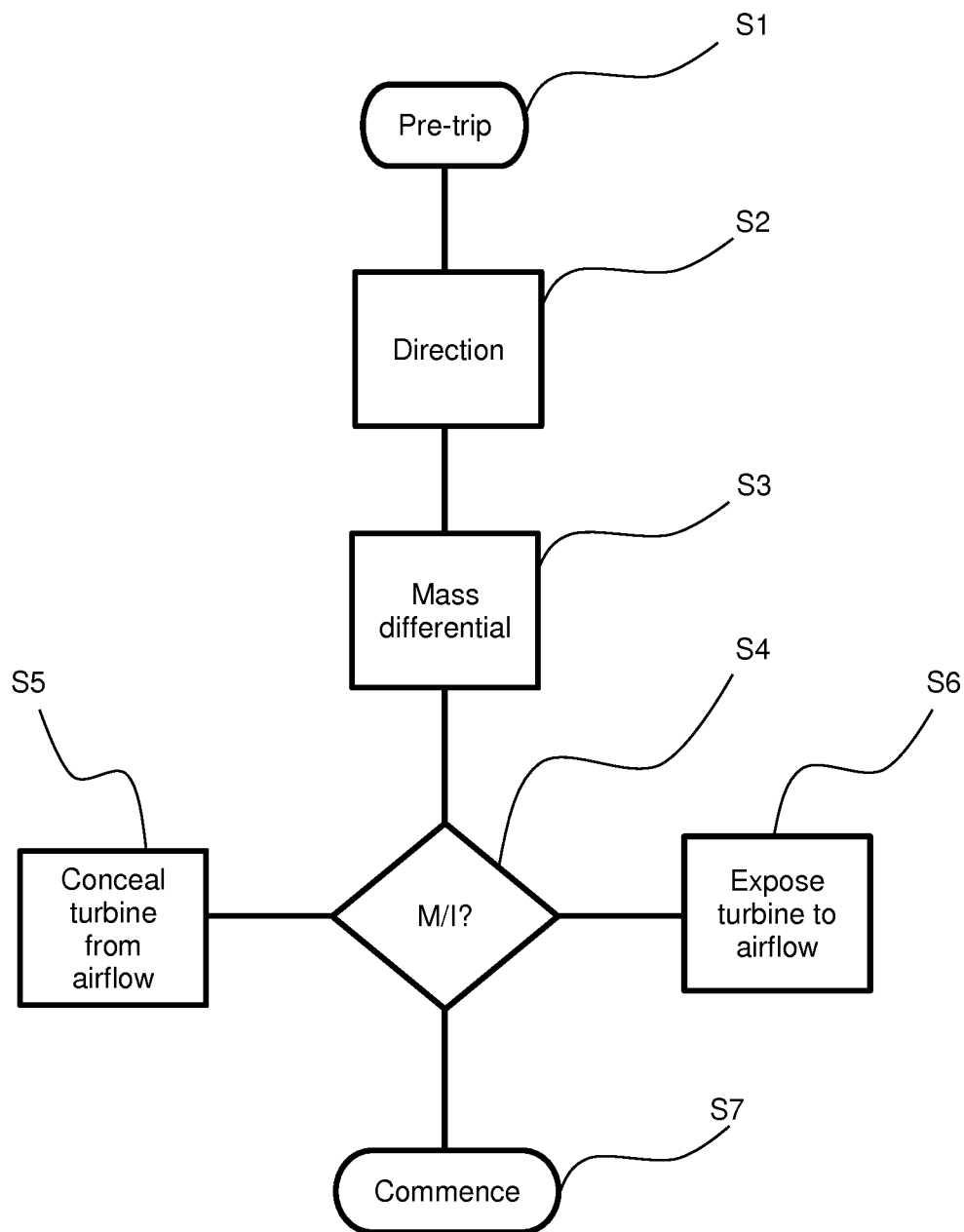


FIG. 8

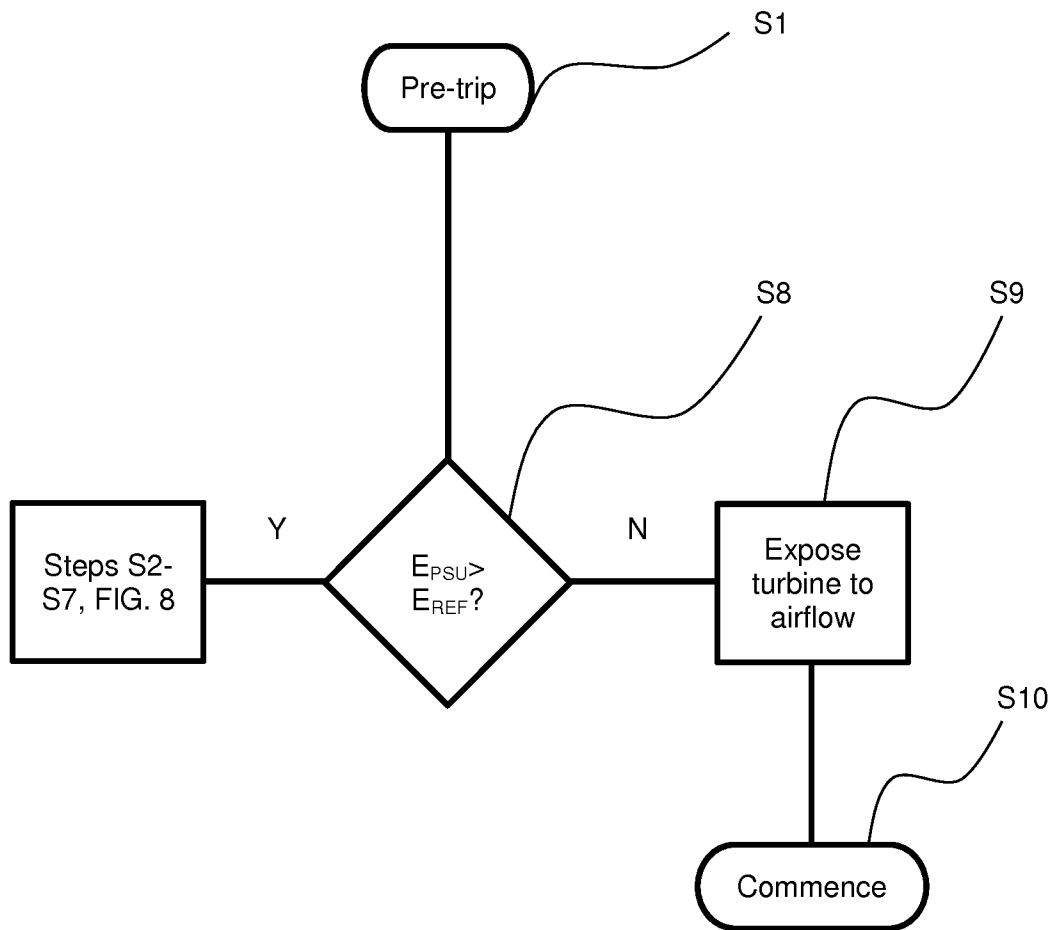


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/056960

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D9/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 101 381 937 B1 (THYSENKRUPP ELEVATOR KOREA LTD [KR]) 7 April 2014 (2014-04-07) figure 1	1-15
A	----- KR 2011 0073749 A (NAT UNIV CHUNGBUK IND ACAD [KR]) 30 June 2011 (2011-06-30) figures 1-7	1-15
A	----- JP H08 310762 A (MITSUBISHI ELECTRIC BILL TECH) 26 November 1996 (1996-11-26) abstract; figures 1-4	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

13 June 2016

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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