(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 108 841 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
28.12.2022 Bulletin 2022/52

(21) Application number: **22177227.0**

(22) Date of filing: **03.06.2022**

(51) International Patent Classification (IPC):
E02F 9/20 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
E02F 9/267; E02F 9/207; E02F 9/2246; E02F 9/2253

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **17.06.2021 JP 2021101155**

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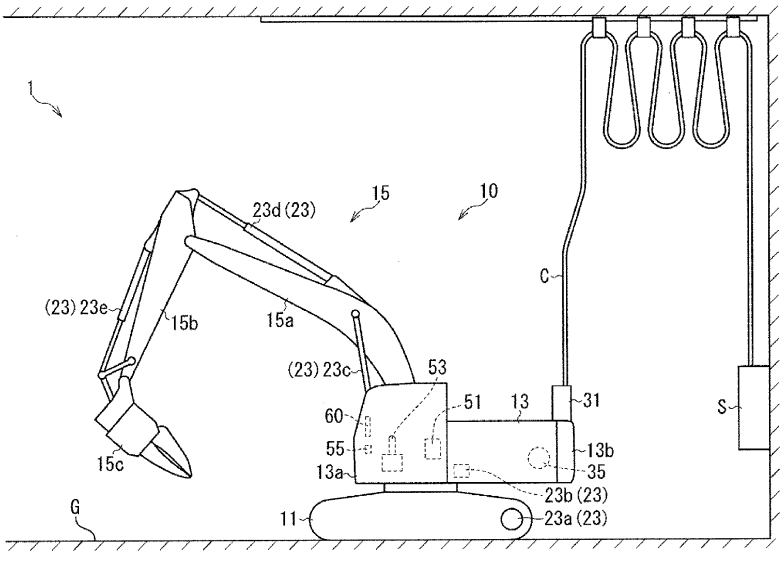
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(54) ELECTRIC WORK MACHINE

(57) Provided is an electric work machine that allows an operator to know information on the state of power supply to the motor. The electric work machine includes: a work machine body connectable to a power supply unit (S); an electric motor (35) mounted on the work machine body and driven by electric power supplied from a power supply unit (S); a hydraulic pump (21) mounted on the work machine body and driven by an electric motor (35) to discharge hydraulic fluid; a hydraulic actuator (23) mounted on the work machine body and actuated by hydraulic fluid; a motor controller (45) that detects a power supply state which is a state of supply of electric power from the power supply unit (S) to the electric motor (35); and a notification unit (60) that notifies an operator of information on the detected power supply state.

FIG.1



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Description

Technical Field

[0001] The present invention relates to an electric work machine including an electric motor.

Background Art

[0002] An electric work machine is described, for example, in FIG. 1 of Japanese Patent Application Publication No. 2018-184783. The electric work machine includes a work machine body, which is connected to a power supply unit through a power supply line. On the work machine body is mounted an electric motor, which can be powered by the power supply unit.

[0003] In this electric work machine, however, there can occur a situation where a power supply state, which is the state of power supply from the power supply unit to the electric motor, is inappropriate. The situation is, for example, that a wire or a connection terminal is defective, which is caused by, for example, erroneous connection, disconnection, poor contact. In addition, the electric work machine is incapable of allowing an operator to recognize the inappropriate power supply state.

Summary of Invention

[0004] It is an object of the present invention to provide an electric work machine connectable to a power supply unit to be supplied with electric power by the power supply unit, the electric work machine being capable of providing an operator with information on a state of supply of electric power to the electric work machine. The electric work machine includes a work machine body, an electric motor, a hydraulic pump, at least one hydraulic actuator, a motor controller, and a notification unit. The work machine body is connectable to the power supply unit. The electric motor is mounted on the work machine body and driven by electric power supplied from the power supply unit to drive the hydraulic pump. The hydraulic pump is mounted on the work machine body and driven by the electric motor to discharge hydraulic fluid. The at least one hydraulic actuator is mounted on the work machine body and moved by hydraulic fluid discharged by the hydraulic pump. The motor controller detects a power supply state which is a state of supply of electric power to the motor from the power supply unit. The notification unit notifies an operator of information on the power supply state detected by the motor controller.

Brief Description of Drawings

[0005]

FIG. 1 is a side view of an electric work machine according to an embodiment of the present invention.
FIG. 2 is a block diagram showing the main elements of the electric work machine.
FIG. 3 is a flowchart showing a process performed by a motor controller included in the main elements.

Description of Embodiments

[0006] A preferred embodiment will be described with reference to FIGS. 1 to 3.

[0007] FIG. 1 shows an electric work machine 1 according to the embodiment. The electric work machine 1 is a work machine operable by electric power supplied by a power supply unit S. The electric work machine 1 is a machine capable of making a work motion, for example, an electric construction machine capable of performing construction work. The electric work machine 1 may be, for example, either an electric excavator or an electric crane. The following is an explanation about the case where the electric work machine 1 is an electric excavator (specifically, an electric hydraulic excavator).

[0008] The electric work machine 1 is connectable to the power supply unit S through a power supply line C. The power supply unit S is a power supply for the electric work machine 1. The power supply unit S is an external power supply that is disposed outside the electric work machine 1. The power supply unit S may be either immobile or mobile. The immobile power source is, for example, a power supply facility that is fixed to a building (e.g., factory, etc.) in which the electric work machine 1 is used. The mobile power source is, for example, a portable power supply configured to be connected to the electric work machine 1 when the electric work machine 1 has to be moved, for example, a motor generator such as a diesel generator. The power supply line C is a wire or a cable that enables electric power to be transmitted from the power supply unit S to the electric work machine 1.

[0009] The electric work machine 1 includes a work machine body 10 and a plurality of elements shown in FIG. 2. The

plurality of elements include a hydraulic circuit 20, an electric motor device 30, a work machine controller 51, a work machine operation unit 53, an motor operation unit 55, and a notification unit 60.

[0010] The work machine body 10 includes a lower traveling body 11, an upper slewing body 13, and an attachment 15, as shown in FIG. 1.

[0011] The lower traveling body 11 is capable of traveling motion on the ground G. The lower traveling body 11 includes, for example, a pair of crawlers.

[0012] The upper slewing body 13 is mounted on the lower traveling body 11 capably of slewing. The upper slewing body 13 includes a cab 13a and a counterweight 13b. The cab 13a allows an operator to perform an operation for moving the electric work machine 1 in the cab 13a. The electric work machine 1 may be moved by either an operation applied by an operator in the cab 13a or a remote operation performed outside the electric work machine 1. The movement of the electric work machine 1 may, alternatively, be automatically controlled by a controller for performing automatic operation, for example, the work machine controller 51. The counterweight 13b is a weight for balancing the work machine body 10 in the front-rear direction.

[0013] The attachment 15 is attached to the upper slewing body 13 to make a work motion. The attachment 15 shown in FIG. 1 includes a boom 15a, an arm 15b, and a tip attachment 15c. The boom 15a is mounted on the upper slewing body 13 capably of being raised and lowered, that is, being brought into vertically rotational movement. The arm 15b is mounted on the boom 15a capably of vertically rotational movement relative to the boom 15a. The tip attachment 15c is mounted on the arm 15b capably of vertically rotational movement to serve as the distal end of the attachment 15. The tip attachment 15c illustrated in FIG. 1 is a device for grasping an object, e.g., a grapple. The tip attachment 15c may alternatively be a device for crushing or a bucket for excavating or scooping soil.

[0014] The hydraulic circuit 20 shown in FIG. 2 moves the work machine body 10 hydraulically. The hydraulic circuit 20 is installed on the work machine body 10. As shown in FIG. 2, the hydraulic circuit 20 includes a hydraulic pump 21, at least one hydraulic actuator 23, and at least one hydraulic control valve 25.

[0015] The hydraulic pump 21 is driven by an electric motor 35 included in the electric motor device 30 to thereby discharge hydraulic fluid. The hydraulic pump 21 may be either a fixed displacement type or a variable displacement type.

[0016] The hydraulic actuator 23 is driven by hydraulic fluid discharged by the hydraulic pump 21 to thereby actuate the work machine body 10.

[0017] The at least one hydraulic actuator 23 includes, in this embodiment, a plurality of hydraulic actuators 23 shown in FIG. 1, namely, a traveling motor 23a, a slewing motor 23b, a boom cylinder 23c, an arm cylinder 23d, and a tip attachment cylinder 23e. The traveling motor 23a is a hydraulic motor, which moves the lower traveling body 11 to cause the work machine body 10 to travel. The traveling motor 23a drives, for example, a pair of crawlers. The slewing motor 23b is also a hydraulic motor, which slews the upper slewing body 13 to the lower traveling body 11. The boom cylinder 23c is a hydraulic cylinder, which makes expansion and contraction motions to thereby raise and lower the boom 15a to the upper slewing body 13. The arm cylinder 23d is also a hydraulic cylinder, which makes expansion and contraction motions to rotationally move the arm 15b to the boom 15a. The tip attachment cylinder 23e is also a hydraulic cylinder, which makes expansion and contraction motions to rotationally move the tip attachment 15c to the arm 15b. The tip attachment 15c may include a hydraulic actuator for allowing the tip attachment 15c itself to make a work motion, for example, motions of gripping and releasing an object, for example, the hydraulic actuator being a hydraulic cylinder or a hydraulic motor.

[0018] The at least one hydraulic control valve 25 in this embodiment includes a plurality of hydraulic control valves 25 corresponding to the plurality of hydraulic actuators 23, respectively. The plurality of hydraulic control valves 25 are provided in a plurality of fluid passages connecting the hydraulic pump 21 and the plurality of hydraulic actuators 23, respectively. The plurality of hydraulic control valves 25 makes opening and closing motions to change the direction and the flow rate of the supply of hydraulic fluid from the hydraulic pump 21 to the plurality of hydraulic actuators 23, respectively, thereby rendering respective motions of the plurality of hydraulic actuators 23 controllable.

[0019] The electric motor device 30 includes a power supply connection part 31, a power line 33, the electric motor 35, and a motor control device 40.

[0020] The power supply connection part 31 is, as shown in FIG. 1, a part connectable to a power supply unit S through the power supply line C. Specifically, the power supply connection part 31 is configured to be connectable to one end of the power supply line C. The power supply connection part 31 is mounted on the work machine body 10. The power supply connection part 31 is provided, for example, in the upper slewing body 13, being disposed, for example, in the vicinity of the counterweight 13b. The power supply connection part 31 includes, for example, a slip ring.

[0021] The power line 33 is, as shown in FIG. 2, an electric wire assembly which is connected to the electric motor 35 to enable electric power to be transmitted from the power supply unit S to the electric motor 35 through the power supply connection part 31 and the power line 33. The power line 33 and the electric motor 35 are mounted on the work machine body 10, being disposed, for example, inside the upper slewing body 13. The power line 33 is electrically connected to both the electric motor 35 and the power supply connection part 31. The power supply unit S is an AC power supply for outputting AC power having a plurality of phases (e.g., three phases), allowing the multi-phase AC

power to be supplied to the electric motor 35 through the power line 33. Specifically, the power line 33 includes respective wires corresponding to the plurality of phases, namely, a U-phase wire 33u, a V-phase wire 33v and a W-phase wire 33w.

[0022] The electric motor 35 is rotatably driven by supply of electric power thereto, thereby driving the hydraulic pump 21. The electric motor 35 is supplied with electric power from the power supply unit S via the power supply connection part 31. The electric motor 35 in this embodiment is an AC motor that is driven by multi-phase (three-phase in the drawing example) AC power. The electric motor 35 may be either an induction motor (e.g., a squirrel-cage motor, a wound motor) or a synchronous motor. The rotational speed during operation of the electric motor 35 may be either constant or variable.

[0023] The motor control device 40 is a device that performs control relating to the electric motor 35, being, for example, a control panel. The motor control device 40 includes a breaker 41, a wire connection changer 43, and the motor controller 45.

[0024] The breaker 41 is configured to shut off the circuit including the power line 33 upon an overcurrent through the power line 33. The breaker 41 is caused by heat to break the circuit (to bring the circuit into thermal trip). The breaker 41 is provided across the U-phase wire 33u the V-phase wire 33v and the W-phase wire 33w which are included in the power line 33. The breaker 41 inputs information to the motor controller 45 on whether or not the breaker 41 is breaking the circuit.

[0025] The wire connection changer 43 is provided for starting the electric motor 35. The wire connection changer 43 is, specifically, provided for rendering the current during starting of the electric motor 35 smaller than the current during running of the electric motor 35. More specifically, in the case where the electric motor 35 is a three-phase induction motor, the wire connection changer 43 performs star-delta starting. The wire connection changer 43, thus, changes the wire interconnection of the U-phase wire 33u, the V-phase wire 33v and the W-phase wire 33w in the power line 33. The wire connection changer 43 changes the wire interconnection in accordance with a command input from the motor controller 45. For the starting of the electric motor 35 (in a below-described starting phase), the wire connection changer 43 changes the wire connection into a wire connection for limiting the current in the electric motor 35, i.e., a connection for restricting an excessive increase in the current. Specifically, in the starting phase, the wire connection changer 43 brings the power line 33 into star connection. For running of the electric motor 35 (in a below-described running phase), the wire connection changer 43 makes a wire connection for enabling a full-load running of the electric motor 35 to be performed. Specifically, in the running phase, the wire connection changer 43 brings the power line 33 into delta connection. The wire connection changer 43 outputs information to the motor controller 45 on the state of the wire connection.

[0026] Each of the motor controller 45 and the work machine controller 51 is a computer including an input-output section for inputting and outputting signals, an arithmetic operation section for performing arithmetic operation (processing), and a storage section for storing information and the like. For example, respective functions of the motor controller 45 and the work machine controller 51 are provided by respective executions of the programs stored in respective storage sections of the motor controller 45 and the work machine controller 51 by the arithmetic operation sections.

[0027] The place is not limited where the motor controller 45 should be disposed. The motor controller 45 may be disposed either at a proper position of the work machine body 10, for example, inside the upper slewing body 13, or outside the work machine body 10.

[0028] The motor controller 45 detects a power supply state that is a state of supply of electric power from the power supply unit S to the electric motor 35. The motor controller 45 detects an abnormal power supply state that may affect the action of the hydraulic circuit 20. The above-described "affect the action of the hydraulic circuit unit 20" is, for example, causing in the hydraulic pump 21 a reverse rotation, a remarkable variation in the rotational speed, or too great or too low rotational speed. The motor controller 45 judges the power supply state with respect to at least two phases of the plurality of phases of the AC power, namely, the U-phase, the V-phase and the W-phase. The motor controller 45 may detect the power supply state with respect to all of the plurality of phases. The motor controller 45, in this embodiment, detects at least one of the respective voltages and currents of the U-phase wire 33u, the V-phase wire 33v and the W-phase wire 33w which are included in the power line 33. The, "at least one of voltage and current" is, thus, included in the examples of the "power supply state".

[0029] The motor controller 45 makes an abnormality judgment on whether or not the power supply state is abnormal. The driving state of the electric motor 35 has a plurality of operating phases, and the motor controller 45, as will be described later, judges which of the plurality of operating phases the driving state of the electric motor 35 is. The motor controller 45 includes a not-graphically-shown setting section, which sets the voltage and frequency to be provided to the electric motor 35. The setting by the setting section may be done through connection of a connector or an operation applied to a button, a switch, or the like. Based on the value set to the setting unit, a reference value used for the abnormality judgment is set as described later.

[0030] The motor controller 45 makes communication. The motor controller 45, for example, receives a signal from the breaker 41, the wire connection changer 43 and the motor operation unit 55. The motor controller 45 may receive a signal from the work machine operation unit 53. The motor controller 45, for example, transmits a signal to the wire connection changer 43 and the work machine controller 51. The motor controller 45 may transmit a signal to either the hydraulic control valve 25 or a not-graphically-shown valve for controlling the hydraulic control valve 25, for example, a

solenoid proportional valve. The communication performed by the motor controller 45 includes, for example, at least one of wired communication, wireless communication, and optical communication. This is the same for communication between devices other than the motor controller 45. The communication between the motor controller 45 and the work machine controller 51 may be, for example, CAN (Controller Area Network) communication. The motor controller 45 may be configured to change the signal to be transmitted to the work machine controller 51 according to the content of the abnormality of the power supply state. The type of communication between the work machine controller 51 and the notification unit 60 is also not limited, and may be, for example, CAN communication.

[0031] In the example shown in FIG. 2, the motor controller 45 is included in the motor control device 40 together with the breaker 41 and the wire connection changer 43. On the other hand, at least a part of the breaker 41, the wire connection changer 43, and the motor controller 45 do not have to be included in the motor control device 40 but may be configured independently of the motor control device 40.

[0032] The work machine controller 51, which is the mechatronics controller, controls the motion of the work machine body 10 and the like. The work machine controller 51 makes the notification unit 60 output a notification as described later. The work machine controller 51 is capable of performing various controls in accordance with the operation applied to the work machine operation unit 53. The work machine controller 51 may be either configured independently of the motor controller 45 or composed of a shared controller that is used also as the motor controller 45. As shown in FIG. 1, the work machine controller 51 according to this embodiment is installed on the work machine body 10, specifically, disposed in the cab 13a of the upper slewing body 13. Alternatively, the work machine controller 51 may be disposed outside the cab 13a of the work machine body 10 or outside the work machine body 10.

[0033] To the work machine operation unit 53 are applied operations for moving the electric work machine 1. The operations include respective operations for moving the hydraulic actuators 23. More specifically, to the work machine operation unit 53 are applied respective operations for moving the hydraulic control valves 25, whereby the plurality of hydraulic actuators 23 are operated. For example, the work machine operation unit 53 is provided in the work machine body 10 together with the motor operation unit 55, specifically provided in the cab 13a. In the case of a remote operation of the electric work machine 1, at least one of the work machine operation unit 53 and the motor operation unit 55 may be provided in a remote operation room where the remote operation is performed. For example, in the case of an automatic operation of the electric work machine 1, at least one of the work machine operation unit 53 and the motor operation unit 55 may be provided in a device (e.g., a tablet) for instructing the automatic operation. For example, in the case where the work machine operation unit 53 is provided in the cab 13a, the work machine operation unit 53 may output either an electric signal or a hydraulic signal (pilot pressure). In the case where the work machine operation unit 53 is provided outside the work machine body 10, the work machine operation unit 53 may output an electrical signal.

[0034] To the motor operation unit 55 is applied an operation with respect to the electric motor 35 shown in FIG. 2 by an operator. Specifically, the motor operation unit 55 includes a key switch 55a and a start switch 55b. To the key switch 55a is applied respective operations for starting and stopping the electric motor 35. For example, each of the key switch 55a and the start switch 55b is a switch changeable between "on" and "off". The key switch 55a may be a switch for activating the work machine body 10. The key switch 55a may be replaced with a switch or a touch panel to which a button operation or a rotational operation is applied. The same applies to the start switch 55b.

[0035] The start switch 55b is operated for causing the starting of the electric motor 35. As will be described later, when the start switch 55b is turned on while the key switch 55a is turned on, the electric motor 35 is started. In FIGS. 2 and 3, the key switch 55a is indicated as a "key SW", and the start switch 55b is indicated as a "start SW". The key switch 55a and the start switch 55b may be a shared single switch or respective switches independent of each other.

[0036] The notification unit 60 performs notification to an operator. The notification unit 60 outputs information on the power supply state detected by the motor controller 45. The notification unit 60, when the motor controller 45 judges the power supply state to be abnormal, outputs information on the abnormality (e.g., the content of the abnormality). The notification unit 60 may be output information on the power supply state other than the information on the abnormality, for example, the information that the current, the voltage, the frequency and the power supply state is normal. The notification by the notification unit 60 may be performed through either display or voice.

[0037] The notification unit 60 is, preferably, configured to provide the notification to an operator who intends the work machine body 10 shown in FIG. 1 to be moved. For example, the notification unit 60 is preferably disposed at a position where the notification unit 60 can provide a notification to an operator who intends to apply an operation to the work machine operation unit 53. Specifically, it is preferable to locate the notification unit 60 in the vicinity of the work machine operation unit 53. The notification unit 60 may be provided in the work machine body 10, for example, the upper slewing body 13, or in the front cab 13a. The notification unit 60 may include a display screen, namely, a cluster gauge, disposed in the cab 13a. Alternatively, the notification unit 60 may be provided outside the work machine body 10, for example, in a remote operation room where a remote operation is performed, or in a device for instructing an automatic operation, such as a tablet. The notification unit 60 may perform notification on not only the information on the power supply state to the electric motor 35 but also other information. For example, the notification unit 60 may be used also for notifying information on the work machine body 10, such as an abnormality. This allows an operator to receive respective notifi-

cations on both the information on the power supply state and other information from a shared single device.

[0038] The motor controller 45 determines the current operating phase out of a plurality of operating phases. The plurality of operating phases include a pre-starting phase, a starting phase, and a running phase.

[0039] The pre-starting phase is a state where the rotation of the electric motor 35 is being stopped. The pre-starting phase is, specifically, a state where the motor controller 45 is operating whereas the rotation of the electric motor 35 is stopped. For example, the pre-starting phase is a state where the key switch 55a is switched on whereas the rotation of the electric motor 35 is stopped.

[0040] The starting phase is a state where the electric motor 35 is being started. More specifically, the starting phase is a state where the rotational speed of the electric motor 35 is being increased from a state where the rotation of the electric motor 35 had been stopped. The starting phase is the operating phase between the pre-starting phase and the running phase.

[0041] The running phase is a state where the start of the electric motor 35 has been completed and the electric motor 35 is running. The running phase is a state where the electric motor 35 is being rotated wherein the variation in the rotational speed of the electric motor device 30 is lower than that in the starting phase. The plurality of operating phases may include other operating phases in addition to the pre-starting phase, the starting phase, and the running phase. Besides, at least a part of the pre-starting phase, the starting phase, and the running phase is allowed not to be set in the motor controller 45.

[0042] Next will be described a specific example of processing executed by the motor controller 45 with reference to a flowchart shown in FIG. 3.

[0043] In step S11, the motor controller 45 judges whether or not the key switch 55a is on. At the time of judgment that the key switch 55a is turned on (YES in step S11), the motor controller 45 starts communication with the work machine controller 51. For example, the motor controller 45 may start the communication after the lapse of a predetermined time (e.g., three seconds) from the turning-on of the key switch 55a. The motor controller 45, alternatively, may be configured to start the operation thereof, that is, to start the process shown in FIG. 3, at the time of the judgment that the key switch 55a is turned on.

[0044] At the time of the judgment that the key switch 55a is turned on (YES in step S11), the motor controller 45 starts the control operation in the pre-starting phase (step S21). The motor controller 45 judges whether or not any pre-starting abnormality is present (step S22), the pre-starting abnormality being abnormality in the pre-starting phase. Specifically, the motor controller 45 judges whether or not the power supply state is abnormal in the pre-starting phase. Specific details of the pre-starting abnormality and the abnormality in the other operating phases will be described later.

[0045] If judging that the pre-starting abnormality is present (NO in step S22), the motor controller 45 makes the notification unit 60 notify information on the power supply state (step S22n). Specifically, the motor controller 45 transmits information on the power supply state to the work machine controller 51, and the work machine controller 51 makes the notification unit 60 notify the information on the power supply state. The same applies to the notification in the other operating phases. At this time, the notification unit 60 may notify the details of the judged abnormality (e.g., "reverse phase", "undervoltage", etc. which will be described later). This also applies to the notification in the other operating phases. The notification allows an operator to know the details of the abnormality. The notification unit 60 may notify the value of the voltage, the value of the current, the frequency and the like. This also applies to the notification in the other operating phases.

[0046] If judging that any pre-starting abnormality is present, the motor controller 45 may terminate the control operation without starting the electric motor 35 after making the notification unit 60 notify (step S22n). Starting the electric motor 35 in the inappropriate power supply state due to the pre-starting abnormality may damage the electric motor 35 or the associated equipment therewith, such as elements included in the hydraulic circuit 20. Prohibiting the electric motor 35 from starting in the case of presence of the pre-starting abnormality allows the equipment to be prevented from damage. The motor controller 45, however, may start the electric motor 35 immediately after making the notification unit 60 notify (step S22n) when judging that the pre-starting abnormality is present.

[0047] If judging that no pre-starting abnormality is present (YES in step S22), the motor controller 45 judges whether or not the start switch 55b is on (step S23). At the time of the judgment that the start switch 55b is turned on (YES in step S23), the motor controller 45 terminates the control for the pre-starting phase and starts the control for the starting phase (step S31) to start the electric motor 35. Specifically, the motor controller 45 makes the wire connection be changed by the wire connection changer 43 into the connection for the starting of the electric motor 35, namely, the star connection in this embodiment. At this point in time, the motor controller 45 starts the below-described starting timer.

[0048] In the starting phase, i.e., during the starting of the electric motor 35, the rotational speed of the hydraulic pump 21 is lower than the rotational speed for allowing the hydraulic actuator 23 to move properly. In short, the rotational speed of the hydraulic pump 21 is insufficient. Besides, in the starting phase, the torque of the hydraulic pump 21 is less than the torque for allowing the hydraulic actuator 23 to move properly. In short, the torque of the hydraulic pump 21 is also insufficient. For the reason, the motor controller 45 may execute a control to prevent the hydraulic actuator 23 from being moved in the starting phase. Specifically, the motor controller 45 may be configured to block the input of a command

from the work machine operation unit 53 to the hydraulic control valve 25, for example, to perform lever locking, in the starting phase. The motor controller 45, conversely, may allow the hydraulic actuator 23 to be moved in the starting phase.

[0049] Next, in step S32, the motor controller 45 judges whether or not any starting abnormality is present, the starting abnormality being one in the starting phase. Specifically, the motor controller 45 judges whether or not the power supply state is abnormal during the starting phase.

[0050] If judging that any starting abnormality is present (NO in step S32), the motor controller 45 makes the notification unit 60 notify the information on the power supply state, for example, the details of the abnormality (step S32n). The motor controller 45 thereafter may either execute the next step S33 while keeping the starting of the electric motor 35 or stop the starting of the electric motor 35 and terminate the control operation as indicated by the two-dot chain line in FIG. 3.

[0051] If judging that no starting abnormality is present (YES in step S32), the motor controller 45 continues the starting of the electric motor 35, and judges whether or not a predetermined starting time has elapsed from the start of the starting phase (the start of the starting timer) (step S33). The predetermined starting time is a required time for starting of the electric motor 35 or a time corresponding to the required time, for example, 3 seconds, being stored in the motor controller 45. If the predetermined starting time has not yet elapsed (NO in step S33), the motor controller 45 keeps the starting phase and continues the judgment on whether the presence or absence of the starting abnormality (step S32).

[0052] Upon the lapse of the predetermined starting time (YES in step S33), the motor controller 45 terminates the control for the starting phase and starts the control for the running phase (step S41). Specifically, the motor controller 45 makes the wire connection be changed by the wire connection changer 43 into the wire connection for the running of the electric motor 35, namely, the delta connection in this embodiment.

[0053] Next, the motor controller 45 judges whether or not any abnormality in the running phase, namely, any running abnormality, is present (step S42). In detail, the motor controller 45 judges, in the running phase, whether or not the power supply state is abnormal.

[0054] If judging that the running abnormality is present (NO in step S42), the motor controller 45 makes the notification unit 60 notify information on the power supply state, for example, the detail of the abnormality (step S42n). The motor controller 45 may thereafter either continue the operation of the electric motor 35 and perform the process of the next step S43 or stop the operation of the electric motor 35 and terminate the control operation as indicated by the two-dot chain line in FIG. 3.

[0055] If judging that no running abnormality is present (YES in step S42), the motor controller 45 judges whether or not the key switch 55a is off (step S43). If the key switch 55a has not been turned off yet (NO in step S43), the motor controller 45 continues the running of the electric motor 35 and the judgment on whether or not the running abnormality is present (step S42).

[0056] At the time of judging that the key switch 55a is turned off (YES in step S43), the motor controller 45 stops the running of the electric motor 35 and terminates the control operation. For example, the motor controller 45 may be configured to be stopped completely after a predetermined time (e.g., about 30 seconds) from the time of judging that the key switch 55a is turned off. When the key switch 55a is off, the motor controller 45 stops communication with the work machine controller 51. For example, the motor controller 45 may be configured to stop communication with the work machine controller 51 after a predetermined time (e.g., about 30 seconds) from the time of judging that the key switch 55a is turned off. When the key switch 55a is off, the motor controller 45 may cancel the judgment on the abnormality. The motor controller 45, alternatively, may cancel the judgment on the abnormality based on other conditions than that the key switch 55a is turned off.

[0057] The detail of the abnormality judged by the motor controller 45 can be set variously. Examples of the abnormalities include reverse phase, overvoltage, undervoltage, open phase in voltage, overcurrent, undercurrent, open phase in current, overfrequency, underfrequency, thermal trip, and abnormal wire-connection.

[0058] The motor controller 45 stores a plurality of abnormality judgment conditions which are set with respect to the plurality of operating phases. Each of the plurality of abnormality judgment conditions is a condition for judging that the power supply state is abnormal. Preferably, the plurality of abnormality judgment conditions are suitably set for the plurality of operating phases, respectively. For example, even with respect to the content of a common abnormality, e.g., reversed phase, different abnormality judgment conditions may be set for the operating phases, respectively. For example, it is permissible that the specific abnormality judgment condition set for the first operating phase is not set for the second operating phase that is different from the first operating phase. Alternatively, for the content of the common abnormality (e.g., undervoltage), abnormality judgment conditions different from each other may be set for the operating phases, respectively. For example, respective operating phases may be given different threshold values for abnormality judgment, respectively. The following Table 1A shows a concrete example of the correspondence of the contents of the abnormality, the operating phase, and the abnormality judgment condition.

Table 1

Abnormality judgment condition			
Content of abnormality	Operating phase		
	Pre-starting phase	Starting phase	Running phase
Reverse phase	Reverse order of phase	None	None
Undervoltage	A state of Vmi□Vs-Va (e.g., 5% of Vs) continues for abnormality judgment time Ta (e.g., 3 sec) or more.	A state of Vmi□Vs-Vb (e.g., 20% of Vs) continues for abnormality judgment time Tb (e.g., 1 sec) or more.	A state of Vmi ≦ Vs-Vc (e.g., 10% of Vs) continues for abnormality judgment time Tc (e.g., 5 sec) or more.
Overvoltage	A state of Vmi□Vs+Vd (e.g., 5% of Vs) continues for abnormality judgment time Td (e.g., 3 sec) or more.	A state of Vmi□Vs-Ve (e.g., 20% of Vs) continues for abnormality judgment time Te (e.g., 1 sec) or more.	A state of Vmi ≧ Vs+Vf (e.g., 10% of Vs) continues for abnormality judgment time Tf (e.g., 5 sec) or more.
Open phase in voltage	A state of Vmi□Vs-Vg (e.g., 70% of Vs) continues for abnormality judgment time Tg (e.g., 3 sec) or more.	A state of Vmi□Vs-Vh (e.g., 70% of Vs) continues for abnormality judgment time Th (e.g., 1 sec) or more.	A state of Vmi ≦ Vs-Vi (e.g., 70% of Vs) continues for abnormality judgment time Ti (e.g., 5 sec) or more.
Overfrequency	A state of Fmi ≦ Fs+Fj (e.g., 5% of Fs) continues for abnormality judgment time T) (e.g., 3 sec) or more.	A state of Fmi ≦ Fs+Fk (e.g., 10% of Fs) continues for abnormality judgment time Tk (e.g., 5 sec) or more.	A state of Fmi ≦ Fs+Fk (e.g., 10% of Fs) continues for abnormality judgment time Tk (e.g., 5 sec) or more.
Underfrequency	A state of Fmi ≦ Fs-Fm (e.g., 5% of Fs) continues for abnormality judgment time Tm (e.g., 3 sec) or more.	A state of Fmi ≦ Fs-Fn (e.g., 10% of Fs) continues for abnormality judgment time Tn (e.g., 5 sec) or more.	A state of Fmi ≦ Fs-Fn (e.g., 10% of Fs) continues for abnormality judgment time Tn (e.g., 5 sec) or more.
Undercurrent	None	None	A state of Is-Io (e.g., 95% of Is) <Imi ≦ Is-Ip (e.g., 80% of Is) continues for abnormality judgment time To (e.g., 5 sec) or more.
Overcurrent	None	None	A state of Imi ≧ Is * Rq (e.g., 150%) continues for abnormality judgment time Tq (e.g., 5 sec) or more.
Open phase in current	None	None	A state of Imi ≦ Is-Ir (e.g., 95% of Is) continues for abnormality judgment time Tr (e.g., 5 sec) or more.
Thermal trip	On	On	On
abnormal wire-connection	None	None	Iav1 * Rj (e.g., 150%) >Iav2

[0059] The contents of the abnormalities shown in Table 1 and the abnormality judgment conditions corresponding thereto are as follows.

(Reverse Phase)

[0060] The motor controller 45 judges whether or not the phase rotation of the AC power input to the electric motor 35 is reverse (i.e., whether or not the reverse phase is present). The reverse phase is causable by, for example, a misconnection of at least a part of the power supply line C, the power supply connection part 31, and the power line 33.

The reverse phase may bring the electric motor 35 into reverse rotation and bring the hydraulic pump 21 into reverse rotation to thereby damage the hydraulic pump 21. The motor controller 45, for example, detects the waveform of the voltage or current of the power line 33 to thereby detect the phase order, further judging whether or not the detected phase order is equal to a preset phase order.

[0061] In the example shown in Table 1, the presence or absence of an abnormality judgment condition, which is a condition for judging whether or not the phase is reversed, differs depending on the operating phase. Specifically, the abnormality judgment condition with respect to the reverse phase is provided for neither of the starting phase and the running phase but for only the pre-starting phase. The motor controller 45, therefore, judges the presence or absence of the reverse phase only in the pre-starting phase, while not judging the presence or absence of the reverse phase in neither of the starting phase and the running phase.

[0062] The abnormality judgment condition described in Table 1 is an example, to which the abnormality judgment condition should not be limited. For example, in addition to the pre-starting phase, can be provided an abnormality judgment condition with respect to the reverse phase in also at least one of the starting phase and the running phase. Such allowability of variably setting abnormality judgment conditions to the operating phases is the same for the other abnormalities.

(Undervoltage)

[0063] The motor controller 45 judges whether or not the voltage Vmi input to the electric motor 35 is too low. Regarding the voltage Vmi, for example, either of undervoltage, overvoltage and open phase can be caused by connection of an inappropriate power supply to the electric work machine 1. The motor controller 45, for example, judges whether or not the voltage in each of the electric wires of the power line 33 corresponding to the phases, namely, the U-phase wire 33u, the V-phase wire 33v and the W-phase wire 33w, is too low, or too large, or whether or not any open phase therein is present. The motor controller 45 compares the detected voltage Vmi of the power line 33 with a predetermined threshold value to thereby judge whether or not the voltage is too low (which is the same for overvoltage and open phase in voltage).

[0064] Specifically, in the pre-starting phase, the motor controller 45 judges the voltage Vmi to be too low when a state where the detected voltage Vmi is equal to or more than a threshold value, which is the value obtained by subtracting an undervoltage judgment value Va from the set voltage value Vs (= Vs-Va) in the example shown in Table 1, continues for a preset abnormality judgment time Ta (e.g., 3 seconds) or more. Thus, the abnormal judgment condition with respect to undervoltage in the pre-starting phase in this example is that the state of Vmi □ Vs-Va continues for the abnormality judgment time Ta or more.

[0065] In the example shown in Table 1, the motor controller 45 judges: whether or not the voltage Vmi is too low; whether or not the voltage Vmi is too high; whether or not there occurs open phase in voltage; whether or not the frequency Fmi of the AC power input to the electric motor 35 is too high; and whether or not the frequency Fmi is too low, in each of the pre-starting phase, the starting phase and the running phase. Respective abnormality judgment conditions in the pre-starting phase, the starting phase, and the running phase are different from each other.

[0066] The appropriate voltage in the power line 33 depends on the operating phase of the electric motor 35. Specifically, the voltage during the starting of the electric motor 35 is lower than that before pre-starting or during the running. Hence, the threshold value of the voltage for judging whether or not the voltage is too low in the starting phase is preferably smaller than the threshold value in the pre-starting phase, and also preferably smaller than the threshold value in the running phase. The threshold value in the running phase may be smaller than the threshold value in the pre-starting phase. In the example shown in Table 1, each of the undervoltage judgment values Va to Vc is set so as to render the threshold value for the undervoltage judgment in the pre-starting phase (= Vs-Va) smaller than the threshold value in the starting phase (=Vs-Vb), and so as to render the threshold value in the running phase (=Vs-Vc) smaller than the threshold value in the pre-starting phase and greater than the threshold value in the starting phase.

[0067] Respective abnormality judgment times for the operating phases may be different from each other. For example, the abnormality judgment time in the starting phase may be shorter than the abnormality judgment time in the starting phase. Besides, the abnormality judgment time in the starting phase may be shorter than the abnormality judgment time in the running phase. Besides, the abnormality judgment time in the pre-starting phase may be shorter than the abnormality judgment time in the running phase. In the example shown in Table 1, the abnormality judgment time Ta with respect to undervoltage in the pre-starting phase (e.g., 3 seconds) is longer than the abnormality judgment time Tb in the starting phase (e.g., 1 second), while being shorter than the abnormality judgment time Tc in the running phase (e.g., 5 seconds).

[0068] The abnormality judgment condition with respect to undervoltage in the pre-starting phase in the example shown in Table 1 is, as described above, that a state where the voltage Vmi input to the electric motor 35 is equal to or more than Vs (set voltage value) - Va continues for the abnormality judgment time Ta (e.g., 3 seconds) or more. The set voltage value Vs, which is stored in the motor controller 45, is set in the not-graphically-shown setting unit through, for example, the connection of connectors. The set frequency Fs to be described later is also set in the same manner. The undervoltage judgment values Va, Vb, Vc are determined, for example, based on the set voltage value Vs. Specifically,

the value of the undervoltage judgment value Va is, for example, a value obtained by multiplying the set voltage value Vs by a predetermined ratio. The overvoltage judgment values Vd, Ve, Vf and the open-phase judgment voltage value Vg, Vh, Vi to be described later is the same. In the example shown in Table 1, the undervoltage judgment value Va, Vb and Vc are set to, for example, 5%, 20%, and 10% of the set voltage value Vs, respectively.

[0069] The abnormality judgment condition is not limited to the example shown in Table 1. For example, each of the undervoltage judgment values Va to Vc does not absolutely have to be a value determined on the basis of the set voltage value Vs, i.e., the relative value to the set voltage value Vs, but may be an absolute value (e.g., 10V). This also applies to thresholds for other abnormality judgment conditions. Besides, each of the specific numerical values described in Table 1 ("-5%", "3 seconds", etc.) is merely exemplified in order to allow the magnitude relationship of the respective thresholds to be easily grasped.

(Overvoltage)

[0070] The motor controller 45 judges whether or not the voltage Vmi input to the electric motor 35 is too high. Specifically, the motor controller 45 judges the detected voltage Vmi to be too high when a state where the voltage Vmi is not lower than the threshold value continues for the preset abnormality judgment time or more. Thus, the abnormality judgment condition with respect to overvoltage is that a state where the voltage Vmi is equal to or more than the threshold value continues for the abnormality judgment time or more. In the example shown in Table 1, the threshold in the pre-starting phase is a value obtained by adding the overvoltage judgment value Vd to the set voltage value Vs (e.g., 5% of the set voltage value Vs) (= Vs+Vd); the threshold in the starting phase is a value obtained by subtracting an overvoltage judgment value Ve (e.g., 20% of the set voltage value Vs) from the set voltage value Vs (= Vs-Ve); and the threshold in the running phase is a value obtained by adding an overvoltage judgment value Vf to the set voltage value Vs (e.g., 10% of the set voltage value Vs) (= Vs + Vf). Respective abnormality judgment times Td, Te and Tf in the pre-starting phase, the starting phase, and the running phase are, for example, 3 seconds, 1 second, and 5 seconds, respectively.

[0071] The voltage during the starting of the electric motor 35 is lower than respective voltages during the pre-starting and the running. It is, therefore, preferable that the threshold value for judging whether or not the voltage Vmi is too high in the starting phase is smaller than the threshold value in the pre-starting phase. Besides, it is preferable that the threshold value in the starting phase is smaller than the threshold value in the running phase. The threshold value in the pre-starting phase may be smaller than the threshold value in the running phase.

(Open phase in voltage)

[0072] The motor controller 45 judges whether or not the electric motor 35 is in the state of open phase, that is, in this embodiment, whether or not there is being a lack of at least one of the U phase, the V phase, and the W phase. The motor controller 45 can judge whether or not the open phase is present based on the detected voltage or current with respect to each of the U-phase wire 33u, the V-phase wire 33v and the W-phase wire 33w. In other words, the open phase judged by the motor controller 45 may be either an open phase judged on the basis of a voltage, namely, an open phase in voltage, or an open phase detected on the basis of a current, namely, an open phase in current that will be described later. The open phase is causable by, for example, connection of improper power supply to the electric work machine 1, misconnection or disconnection in at least one of the power supply line C, the power supply connection part 31 and the power line 33.

[0073] Specifically, the motor controller 45 according to this embodiment judges that the open phase in voltage has been caused, when a state where the detected voltage Vmi is equal to or lower than the threshold value continues for a predetermined abnormality judgment time or more. Thus, the abnormality judgment condition with respect to open phase in voltage is that a state where the voltage Vmi is equal to or less than the threshold value continues for the abnormality judgment time or more. The threshold value may be either constant regardless of the operating phase or variable depending on the operating phase. In the example shown in Table 1, the threshold in the pre-starting phase is a value obtained by subtracting an open-phase judgment voltage value Vg (e.g., 70% of the set voltage value Vs) from the set voltage value Vs (= Vs-Vg); the threshold in the starting phase is a value obtained by subtracting an open-phase judgment voltage value Vh (e.g., 70% of the set voltage value Vs) from the set voltage value Vs (= Vs-Vh); and the threshold in the running phase is a value obtained by subtracting the open-phase judgment voltage value Vi (e.g., 70% of the set voltage value Vs) from the set voltage value Vs (= Vs-Vi). Respective abnormality judgment times Tg, Th, Ti in the pre-starting phase, the starting phase, and the running phase are, for example, 3 seconds, 1 second, and 5 seconds, respectively.

(Overfrequency)

[0074] The motor controller 45 judges whether or not the frequency Fmi of the AC power input to the electric motor

35 is too high. The frequency Fmi can be rendered abnormal (too high or too low) by, for example, connection of improper power supply to the electric work machine 1. The frequency Fmi input to the electric motor 35, when being too high, brings the electric motor 35 into a state of being rotated at a higher rotational speed than the expected rotational speed, namely, an overspeed state, which brings the hydraulic pump 21 into overspeed state and may render the speed of the hydraulic actuator 23 too high. The motor controller 45 can detect the frequency Fmi by, for example, detecting the waveform of the voltage or current of the power line 33, and can judge whether or not the frequency Fmi is too high and whether or not the frequency Fmi is too low by comparison of the thus detected frequency Fmi with a preset threshold.

[0075] Specifically, the motor controller 45 judges that the detected frequency Fmi is too high when a state where the detected frequency Fmi is equal to or greater than the threshold continues for a preset abnormality judgment time or more. Thus, the abnormality judgment condition with respect to overfrequency is that a state where the frequency Fmi is equal to or greater than the threshold continues for the abnormality judgment time or more.

[0076] Respective abnormality judgment conditions with respect to the overfrequency or underfrequency in the pre-starting phase, the starting phase and the running phase may be different from each other, or respective abnormality judgment conditions in at least two operating phases may be equal to each other. Respective thresholds of the frequency for judging whether or not the frequency is too high or too low in the operating phases may be different from each other or may be constant regardless of the operating phase. For example, it is possible that the threshold for judgment of the overfrequency or underfrequency in the starting phase and the threshold in the running phase are equal to each other but different from the threshold in the pre-starting phase. Alternatively, it is also possible that the threshold value in the pre-starting phase is smaller than the threshold value in the starting phase and that the threshold value in the pre-starting phase is smaller than the threshold value in the running phase. In the example shown in Table 1, the threshold value with respect to overfrequency in the pre-starting phase is a value obtained by adding an overfrequency judgment value Fj (e.g., 5% of the set frequency Fs) to the set frequency Fs (= Fs+Fj), and the threshold in each of the starting phase and the running phase is a value obtained by adding an overfrequency judgment value Fk (e.g., 10% of the set frequency Fs) to the set frequency Fs (= Fs+Fk).

[0077] Regarding the abnormality judgment time included in the abnormality judgment condition with respect to overfrequency and underfrequency, the abnormality judgment time in the pre-starting phase may be shorter than the abnormality judgment time in the running phase or the abnormality judgment time in the starting phase. In the case where the operating phase is shifted to the running phase while a state where the frequency Fmi detected when the operating phase is the starting phase is equal to or more than the threshold value is kept, the frequency Fmi may be judged to be abnormal (overfrequency or underfrequency) when the sum of the continuation time of the starting phase and the continuation time of the operating phase is equal to or more than the abnormality judgment time in the starting phase. Alternatively, it is also possible to suspend judging it abnormal (overfrequency or underfrequency) until the continuation time from the point in time of shift to the running phase becomes equal to or longer than the abnormality judgment time in the running phase.

[0078] In the example shown in Table 1, the abnormality judgment condition with respect to overfrequency in the pre-starting phase is "a state where the detected frequency Fmi is equal to more than the sum of the set frequency Fs and the overfrequency judgment value Fj (e.g., 5% of the set frequency Fs) (= Fs + Fj) continues for an abnormality judgment time (e.g., 3 seconds) or more."

(Underfrequency)

[0079] The motor controller 45 makes also judgment on whether or not the frequency Fmi of the AC power input to the electric motor 35 is too low. The frequency Fmi input to the electric motor 35, when being too low, causes a speed insufficiency where the rotational speed of the electric motor 35 is lower than the expected rotational speed, thereby rendering the rotational speed of the hydraulic pump 21 insufficient, which may render the operating speed of the hydraulic actuator 23 insufficient.

[0080] The abnormality judgment condition with respect to the frequency under-judgment in this embodiment is that a state where the detected frequency Fmi is equal to or lower than a threshold value continues for a preset abnormality judgment time or more. The threshold value in the pre-starting phase may be smaller than the threshold value in the starting phase and may be smaller than the threshold value in the operating phase. For example, the threshold in the pre-starting phase in the example shown in Table 1 is a value obtained by subtracting an underfrequency judgment value Fm (e.g., 5% of the set frequency Fs) from the set frequency Fs (= Fs-Fm), and the threshold values in each of the starting phase and the running phase is a value obtained by subtracting an underfrequency judgment value Fn (e.g., 10% of the set frequency Fs) from the set frequency Fs (= Fs-Fn).

(Undercurrent)

[0081] The motor controller 45 judges whether or not the current Imi flowing through the electric motor 35 is abnormal.

The abnormality of the current Imi includes undercurrent, overcurrent and open phase in current. The abnormality of the current Imi is causable by, for example, connection of an improper power supply to the electric work machine 1. The motor controller 45 according to this embodiment judges whether or not each of undercurrent, overcurrent and open phase in current has been caused in at least two wires of the U-phase wire 33u, the V-phase wire 33v and the W-phase wire 33w in the power line 33. The motor controller 45 compares the current Imi detected in the power line 33 with a preset threshold value to thereby judge whether or not the abnormality of the current Imi (each of undercurrent, overcurrent and open phase in current) is present.

[0082] Respective abnormality judgment conditions with respect to undercurrent, overcurrent and open phase in current may be set only in a part of the plurality of operating phases. In the example shown in Table 1, respective abnormal judgment conditions with respect to undercurrent, overcurrent and open phase in current are set only in the running phase, while not being set in either of the pre-starting phase and the starting phase. In this example, therefore, the motor controller 45 makes no judgment on the presence or absence of either of undercurrent, overcurrent and open phase in current in the pre-starting phase and the starting phase but makes a judgment only in the running phase. It is, however, also possible that the abnormality judgment condition with respect to at least one of undercurrent, overcurrent and open phase in current is set in not only the running phase but also at least one of the pre-starting phase and the starting phase.

[0083] In this embodiment, the abnormality judgment condition with respect to undercurrent is that a state where the detected current Imi is within a certain abnormality judgment range continues for a preset abnormality judgment time or more. The abnormal condition with respect to undercurrent in the pre-starting phase in the example shown in Table 1 is "a state where the detected current Imi is greater than the value obtained by subtracting an undercurrent judgment minimum value Io (e.g., 95% of the set current value Is) from the set current value Is (= Is-Io) and equal to or less than the value obtained by subtracting an undercurrent judgment maximum value Ip (e.g., 80% of the set current value Is) from the set current value Is (= Is-Ip), namely, the state of Io <Imi □ Ip, continues for a predetermined abnormality judgment time To (e.g., 5 seconds) or more. Each of the undercurrent judgment minimum value Io and the undercurrent judgment maximum value Ip is not limited to one to be calculated on the basis of the set current value Is but also allowed to be, for example, a fixed value determined independently of the set current value Is.

(Overcurrent)

[0084] The abnormality judgment condition for judgment on whether or not the current Imi flowing through the electric motor 35 is too great is that a state where the detected current Imi is equal to or greater than the threshold value continues for a preset abnormality judgment time To (e.g., 5 seconds) or more. In the example shown in Table 1, the threshold value is a value obtained by multiplying the set current value Is by a preset ratio Rq (= Is×Rg), the ratio Rq being a value greater than 100% (for example, 150%).

(Open phase in current)

[0085] The abnormality judgment condition with respect to open phase in current is that a state where the detected current Imi is equal to or less than a threshold value continues for a preset abnormality judgment time Tr (e.g., 5 seconds) or more. In the example shown in Table 1, the threshold value is a value obtained by subtracting an open-phase judgment current value Ir from the set current value Is (=Is-Ir), the open-phase judgment current value Ir being, for example, 95% of the set current value Is. In the example shown in Table 1, the open-phase judgment current value Ir is equal to the undercurrent judgment minimum value Io which is set for judgment on the undercurrent.

(Thermal trip)

[0086] The motor controller 45 detects whether or not any thermal trip is present, that is, in this embodiment, whether or not the circuit is shut off by the breaker 41. This detection is performed at all times in each of the pre-starting phase, the starting phase, and the running phase. The motor controller 45 judges that an abnormality is present when the circuit is shut off by the breaker 41, that is, judges that the abnormality judgment condition for the thermal trip is satisfied.

(Abnormal wire-connection)

[0087] The motor controller 45 judges whether or not the state of the wire-connection provided by the wire connection changer 43, namely, the wire-connection state, is normal. Specifically, the motor controller 45 judges whether or not the wire connection changer 43 has shifted the wire-connection from the star connection to the delta connection upon the shift of the operating phase from the starting phase to the running phase. When judging that the wire-connection has not been shifted from the star connection to the delta connection by the wire connection changer 43, the motor controller 45 judges the wire connection to be abnormal, that is, the abnormal judgment condition with respect to abnormal wire-

connection is satisfied.

[0088] The abnormality judgment condition, in the examples shown in Table 1, is that the value obtained by multiplying the first current average value Iav1 by a preset ratio Rj1 (=Iav1×Rj1) is greater than a second current average value Iav2. The first current average value Iav1 is the average value of the current Imi in a first judgment period preset in the starting phase, and the ratio Rj is, for example, 150%. The second current average value Iav2 is the average value of the current Imi in a second judgment periods preset in the running phase. In the present embodiment, the first judgment period is a period from a start point in time when the operating phase is shifted from the pre-starting phase to an end point in time when a predetermined time (e.g., 2 to 2.5 seconds) elapses from the start point in time, and the second judgment period is a period from a start point in time when the operating phase is shifted from a starting phase to the running phase to an end point in time when a predetermined time (e.g., 0.5 to 1 second) elapses from the start point in time.

[0089] Specific examples of causing the above-described abnormality in the power supply state is as follows. There can be, for example, a case where the work machine body 10 of the electric work machine 1 shown in FIG. 1 is transported to the vicinity of the working area by a transport vehicle (e.g., a trailer), and, thereafter, self-travels to be unloaded from the transport vehicle by itself and to be moved from the transport vehicle to the working area in order to be carried into a working area (yard) from the outside of the working area. For such self-travel, the work machine body 10 has to be connected with the power supply unit S wherein, if the work machine body 10 cannot be connected with a fixed power supply unit installed in the operation area as the power supply unit S, a portable power supply (generator) has to be connected to the work machine body 10. In short, there can be a case where the work machine body 10 has to be enabled to self-travel by supply of electric power from the portable power supply as the power supply unit S to the work machine body 10. In this case, after the arrival at the operation area, the work machine body 10 should be connected with a power supply facility installed in the operation area as the power supply unit S instead of the portable power supply. Thus shifting the power supply unit S to be connected to the work machine body 10 from the portable power supply to the fixed power supply, that is, the power supply facility, involves a plurality of times of re-connections of the electric wires such as re-connection between the power supply connection part 31 and the power supply line C. The plurality of times of re-connection of the electric wires, if including a erroneous connection, may render the state of power supply to the electric motor 35 abnormal.

[0090] There can be also a case of occurrence of at least one of abnormality in the power supply unit S, abnormality in the power supply line C (e.g., disconnection), abnormality in the power supply connection part 31 (e.g., contact failure), abnormality in the power line 33 (e.g., disconnection) and the like, during the use of the electric work machine 1, that is, during work. This may render the state of power supply to the electric motor 35 shown in FIG. 2 abnormal.

[0091] The electric work machine 1, if operated in such abnormal state of power supply to the electric motor 35, may involve a problem in the electric motor 35. Examples of such problems include breakage of the electric motor 35 and failure of the electric motor 35 in exerting its original performance, e.g., failure in producing its original output. The problem of the electric motor 35 may cause damage in the hydraulic pump 21 or the hydraulic actuator 23 driven by the electric motor 35, or may disable them from exerting their original performance.

[0092] In contrast, the electric work machine 1 according to the embodiment allows the power supply state to be notified to an operator through the notification unit 60, which enables the operator to easily notice the abnormal state of the power supply to the electric motor 35, thereby assisting the operator to take appropriate measures as to the power supply state to the electric motor 35. This can restrain the electric work machine 1 from being operated during the inappropriate power supply state to thereby cause a problem. Examples of the problem include damage in the equipment constituting the electric work machine 1, for example, at least one of the electric motor 35, the hydraulic pump 21, the hydraulic actuator 23 and the others, and failure of the equipment in exerting its original performance.

[0093] The above embodiments may be variously modified. For example, the configuration (e.g., arrangement, shape, etc.) of each component of the above embodiment may be changed. For example, it is permissible to change the connection of the components shown in FIG. 2 and to change the order of the steps of the flowchart shown in FIG. 3 or omit a part of the steps. The set values, thresholds, ranges, and the like (e.g., thresholds of the abnormality judgment conditions) may be constant or variable manually, or may be automatically changeable in accordance with some conditions. For example, the number of components may be varied and some of the components may be omitted. For example, fixing or coupling of components to each other may be performed directly or indirecty. For example, the elements described as a plurality of members or parts different from each other may be configured as a single member or part. For example, the element described as a plurality of members or parts may be divided into a plurality of members or parts that are different from each other.

[0094] As described above, there is provided an electric work machine connectable to a power supply unit to be supplied with electric power from the power supply unit, the electric work machine being capable of providing an operator with information on a state of supply of electric power to the electric work machine. The electric work machine includes a work machine body, an electric motor, a hydraulic pump, at least one hydraulic actuator, a motor controller, and a notification unit. The work machine body is connectable to the power supply unit. The electric motor is mounted on the work machine body and driven by electric power supplied from the power supply unit to drive the hydraulic pump. The

hydraulic pump is mounted on the work machine body and driven by the electric motor to discharge hydraulic fluid. The at least one hydraulic actuator is mounted on the work machine body and moved by hydraulic fluid discharged by the hydraulic pump. The motor controller detects a power supply state which is a state of supply of electric power to the motor from the power supply unit. The notification unit notifies an operator of information on the power supply state detected by the motor controller.

[0095] The notification unit, thus notifying the operator of information on the power supply state detected by the motor controller, that is, the state of supply of electric power from the power supply unit to the electric motor, can restrain the electric work machine from being actuated in spite of the inappropriate power supply state.

[0096] The electric motor, preferably, is driven by a plurality of phases of AC power, the power supply state detected by the motor controller including at least one of voltage and current with respect to at least two phases of the plurality of phases. This makes it possible to judge whether or not the power input to the electric motor is in the reverse phase, that is, whether or not the electric motor is rotated in the reverse direction, thereby enabling it to be judged whether or not the hydraulic pump is rotated in the reverse direction. Besides, the temporal change in at least one of the voltage and the current allows the frequency of the AC power input to the motor to be detected, thereby allowing the rotational speed of the motor and further that of the hydraulic pump to be detected. This enables abnormality to be detected in the flow rate of hydraulic fluid discharged from the hydraulic pump and further abnormality in the speed of the hydraulic actuator.

[0097] The motor controller is preferably configured to make an abnormality judgment which is a judgment on whether or not the power supply state is abnormal. Specifically, in the case where the driving state of the motor controller includes a plurality of operating phases, it is preferable that the motor controller stores a plurality of abnormality judgment conditions for making the abnormality judgment, the plurality of abnormality judgment conditions being given for the plurality of operating phases, respectively. This enables respective appropriate abnormality judgments corresponding to the plurality of operating phases to be made. For example, the power supply state can be restrained from being judged to be abnormal in spite of actual normality and/or from being judged to be normal in spite of actual abnormality, namely, from being erroneously judged.

[0098] The plurality of operating phases preferably include a pre-starting phase in which the rotation of the electric motor is stopped, a starting phase in which the electric motor is starting, and a running phase in which the electric motor is running after the starting. This enables the abnormality judgment to be suitably made in correspondence to the operating state of the motor in the process of the motor from a stopped state to a running state.

[0099] Preferably, the at least one hydraulic actuator includes a traveling motor for bringing the work machine body into traveling motion. In the work machine, which includes the traveling motor that brings the work machine body into self-travel and requires supply of electric power for the self-travel, erroneous connection is likely to occur as compared with a work machine that makes no self-traveling by use of electric power. It is, therefore, effective that the notification unit notifies an operator of the power supply state.

Provided is an electric work machine that allows an operator to know information on the state of power supply to the motor. The electric work machine includes:

a work machine body connectable to a power supply unit (S); an electric motor (35) mounted on the work machine body and driven by electric power supplied from a power supply unit (S); a hydraulic pump (21) mounted on the work machine body and driven by an electric motor (35) to discharge hydraulic fluid; a hydraulic actuator (23) mounted on the work machine body and actuated by hydraulic fluid; a motor controller (45) that detects a power supply state which is a state of supply of electric power from the power supply unit (S) to the electric motor (35); and a notification unit (60) that notifies an operator of information on the detected power supply state.

Claims

1. An electric work machine connectable to a power supply unit to be supplied with electric power from the power supply unit, comprising:

   a work machine body connectable to the power supply unit;
   an electric motor mounted on the work machine body and driven by electric power supplied from the power supply unit;
   a hydraulic pump mounted on the work machine body and driven by the electric motor that is driven by the electric power to discharge hydraulic fluid;
   at least one hydraulic actuator mounted on the work machine body and actuated by hydraulic fluid that is discharged by the hydraulic pump;
   a motor controller that detects a power supply state which is a state of supply of electric power to the electric motor from the power supply unit; and

a notification unit that notifies an operator of information on the power supply state detected by the motor controller.

2. The electric work machine according to claim 1, wherein the electric motor is driven by an AC power having a plurality of phases, the power supply state detected by the motor controller including at least one of voltage and current for at least two phases of the plurality of phases.

3. The electric work machine according to claim 1 or 2, wherein the motor controller is configured to make an abnormality judgment, which is a judgment on whether or not the power supply state is abnormal, the driving state of the motor including a plurality of operating phases, and the motor controller stores a plurality of abnormality judgment conditions for making the abnormality judgment, the plurality of abnormality judgment conditions being set for the plurality of operating phases, respectively.

4. The electric work machine according to claim 3, wherein the plurality of operating phases includes a pre-starting phase in which rotation of the electric motor is stopped, a starting phase in which the electric motor is starting, and a running phase in which the electric motor is running after the starting.

5. The electric work machine according to any one of claims 1 to 4, wherein the at least one hydraulic actuator includes a traveling motor for bringing the work machine body into traveling motion.

FIG.1

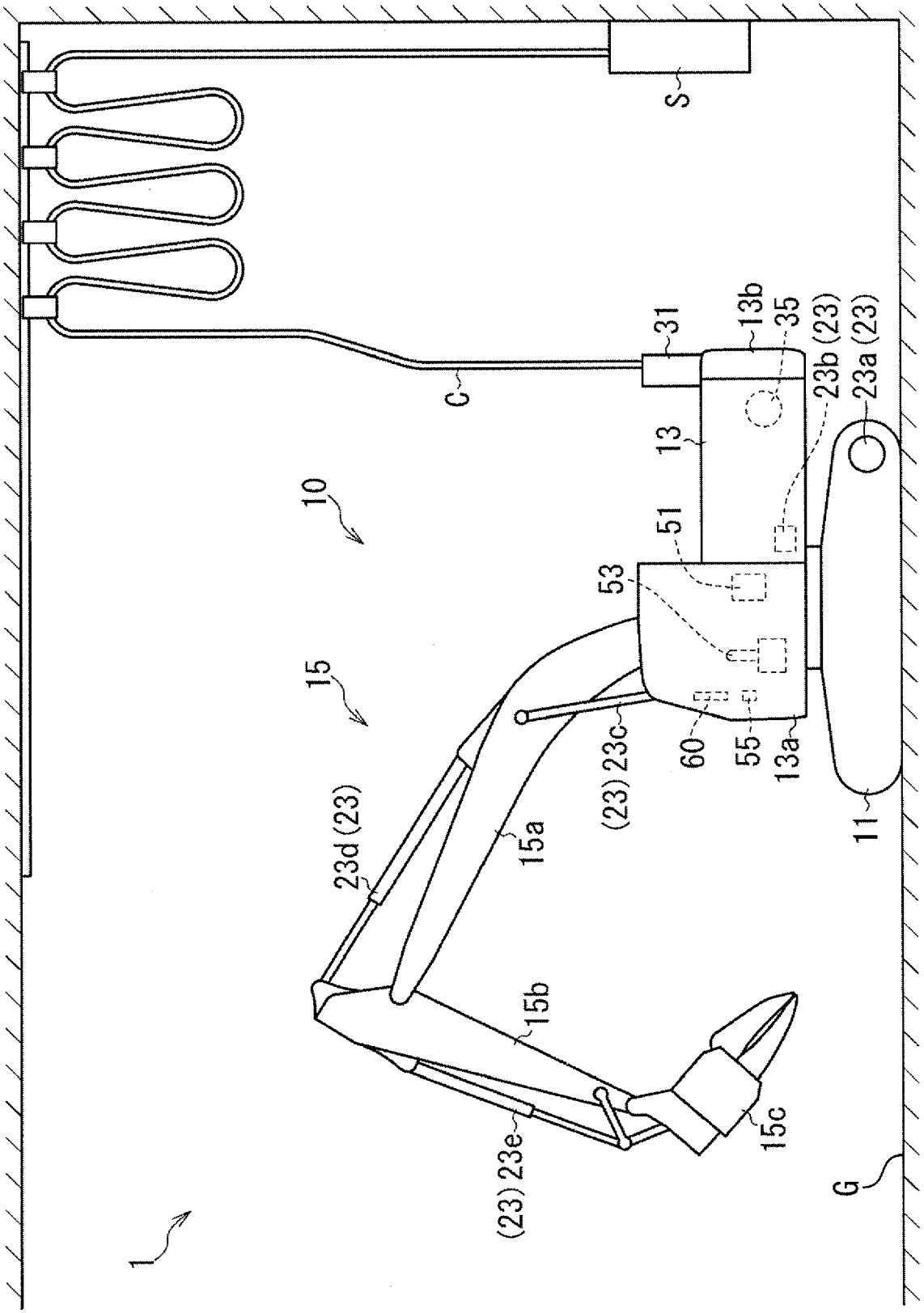

S
C
31
13b
35
23b (23)
23a (23)
13
10
51
53
15
23c (23)
60
55
13a
11
23d (23)
15a
15b
15c
(23) 23e
G
1

FIG.2

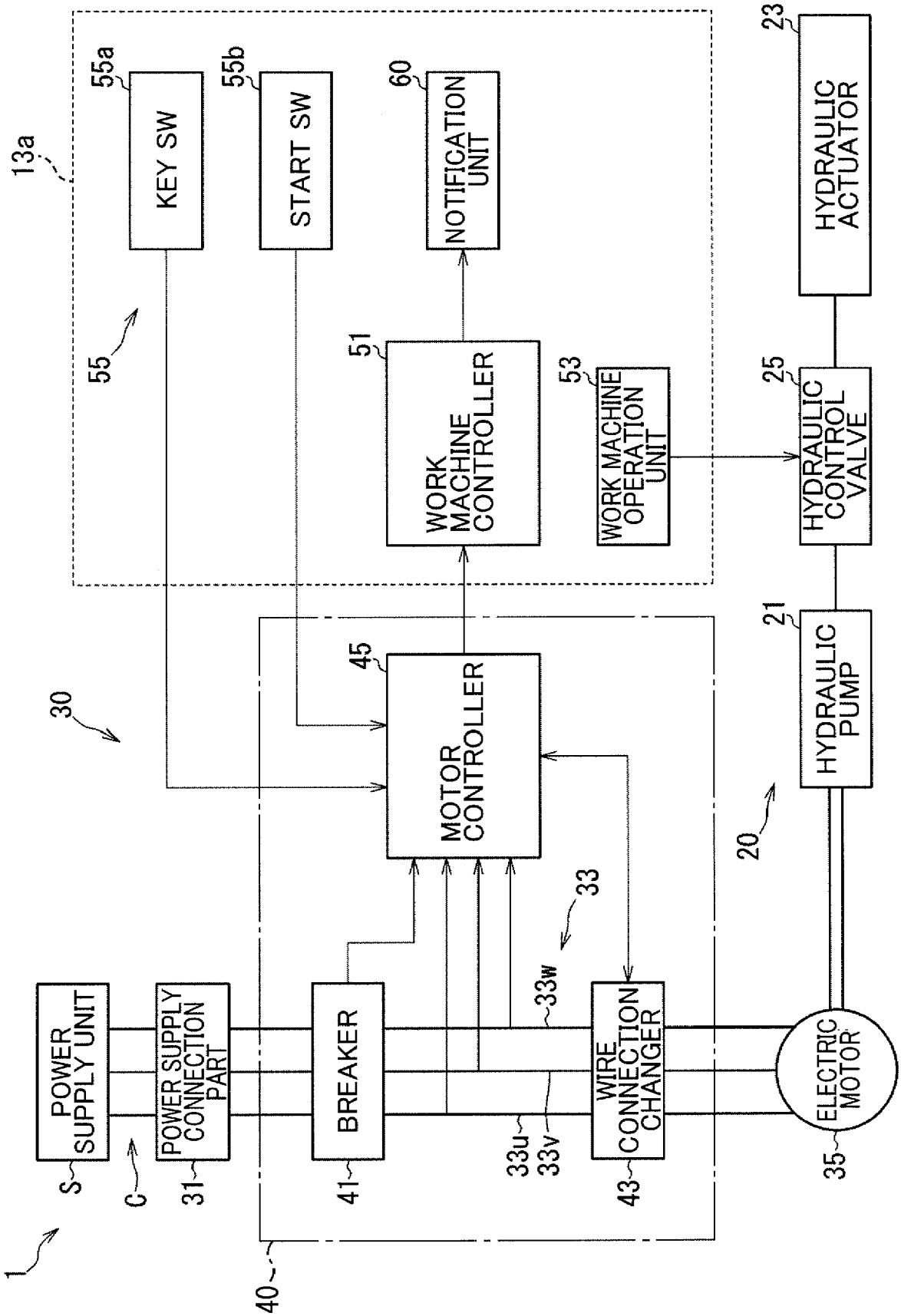
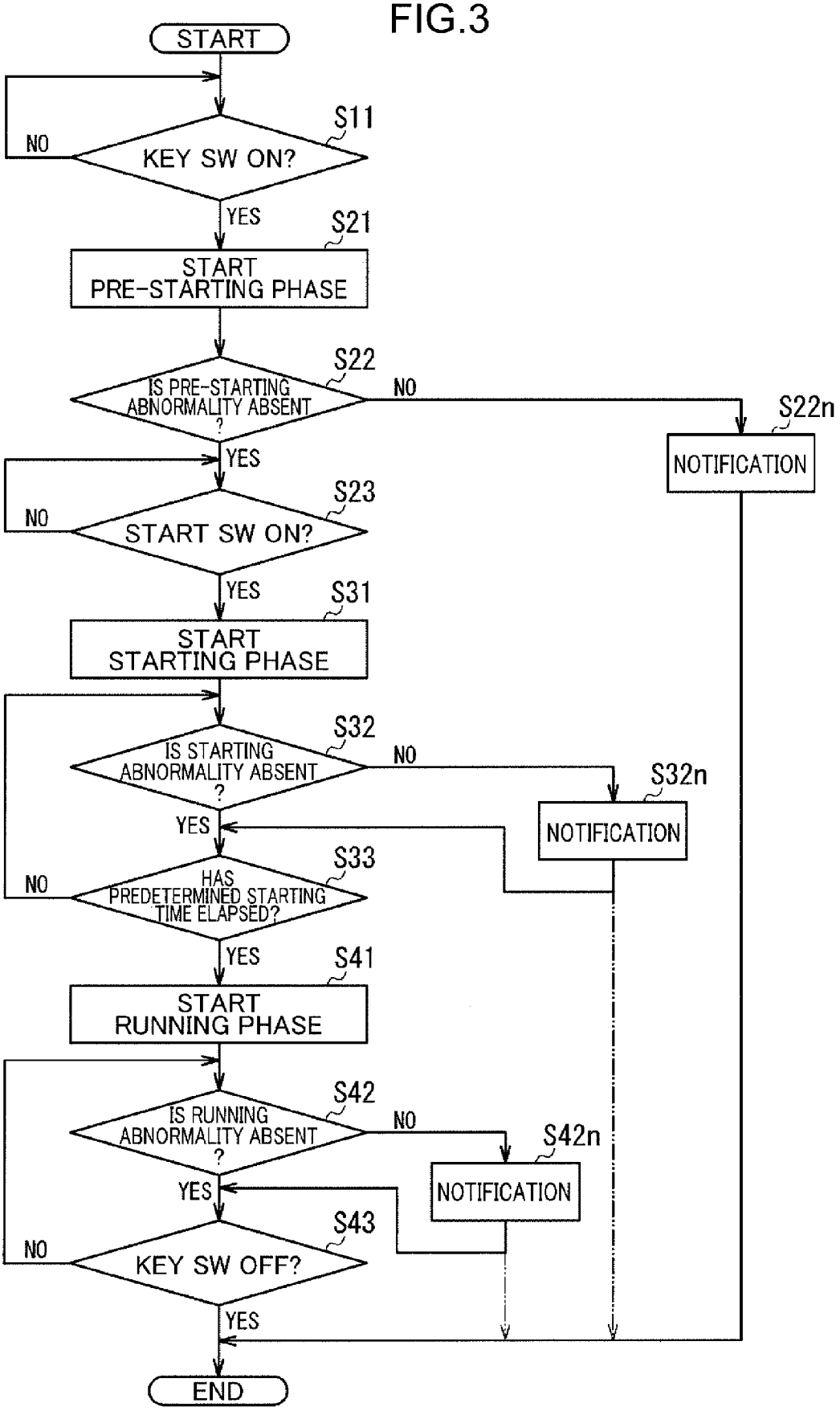

1
13a
55
55a
KEY SW
55b
START SW
60
NOTIFICATION UNIT
51
WORK MACHINE CONTROLLER
53
WORK MACHINE OPERATION UNIT
23
HYDRAULIC ACTUATOR
25
HYDRAULIC CONTROL VALVE
21
HYDRAULIC PUMP
20
30
45
MOTOR CONTROLLER
33
33w
33u
33v
S
POWER SUPPLY UNIT
C
31
POWER SUPPLY CONNECTION PART
41
BREAKER
43
WIRE CONNECTION CHANGER
35
ELECTRIC MOTOR
40

FIG.3


START
S11
KEY SW ON?
NO
YES
S21
START PRE-STARTING PHASE
S22
IS PRE-STARTING ABNORMALITY ABSENT ?
NO
S22n
NOTIFICATION
YES
S23
START SW ON?
NO
YES
S31
START STARTING PHASE
S32
IS STARTING ABNORMALITY ABSENT ?
NO
S32n
NOTIFICATION
YES
S33
HAS PREDETERMINED STARTING TIME ELAPSED?
NO
YES
S41
START RUNNING PHASE
S42
IS RUNNING ABNORMALITY ABSENT ?
NO
S42n
NOTIFICATION
YES
S43
KEY SW OFF?
NO
YES
END

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EUROPEAN SEARCH REPORT

Application Number
EP 22 17 7227

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 November 2022	Dreyer, Christoph

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