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(54) **CONTROL DEVICE FOR VEHICLE**

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(57) **ABSTRACT**

The vehicle includes an engine, a generator coupled to the engine, a high voltage battery capable of transmitting and receiving electric power to and from the generator, a low voltage battery that supplies electric power to an auxiliary device that drives the engine, and DC/DC converters provided between the high voltage battery and the low voltage battery. The electronic control device executes an increase control for increasing the engine rotational speed, which is the rotational speed of the engine, so that the counter electromotive force generated by the generator becomes equal to or higher than the battery voltage of the high voltage battery, and supplies electric power from the high voltage battery to the low voltage battery through DC/DC converter when the generator is in the power generation amount non-control state due to the occurrence of the abnormal state.

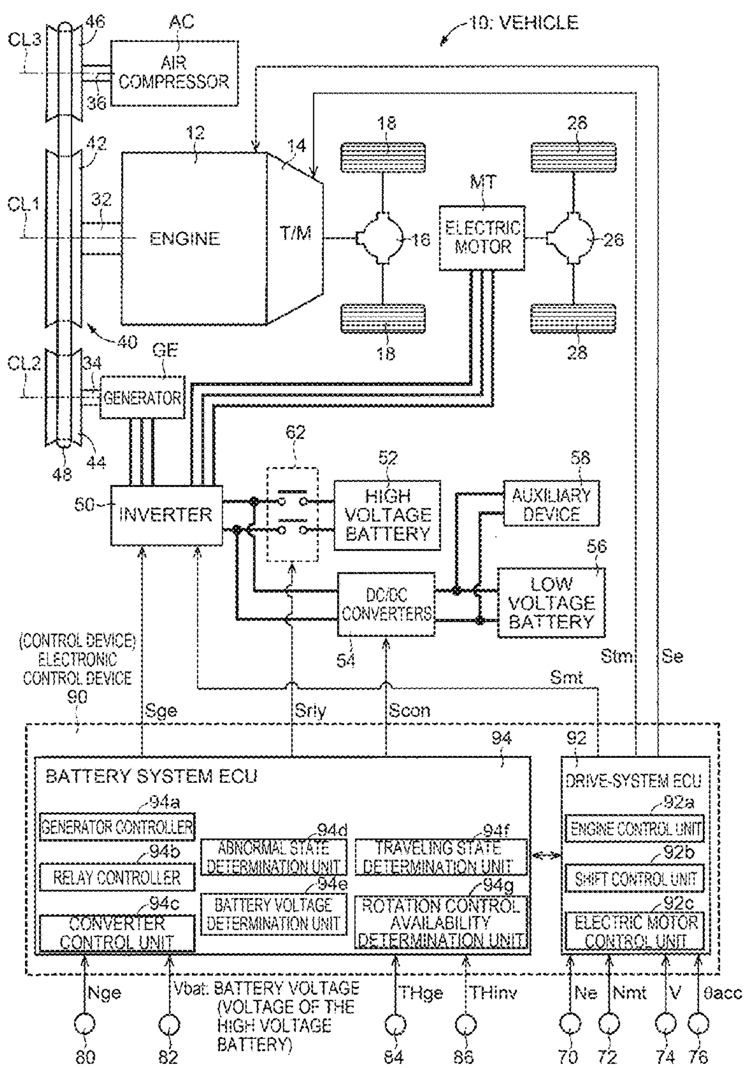
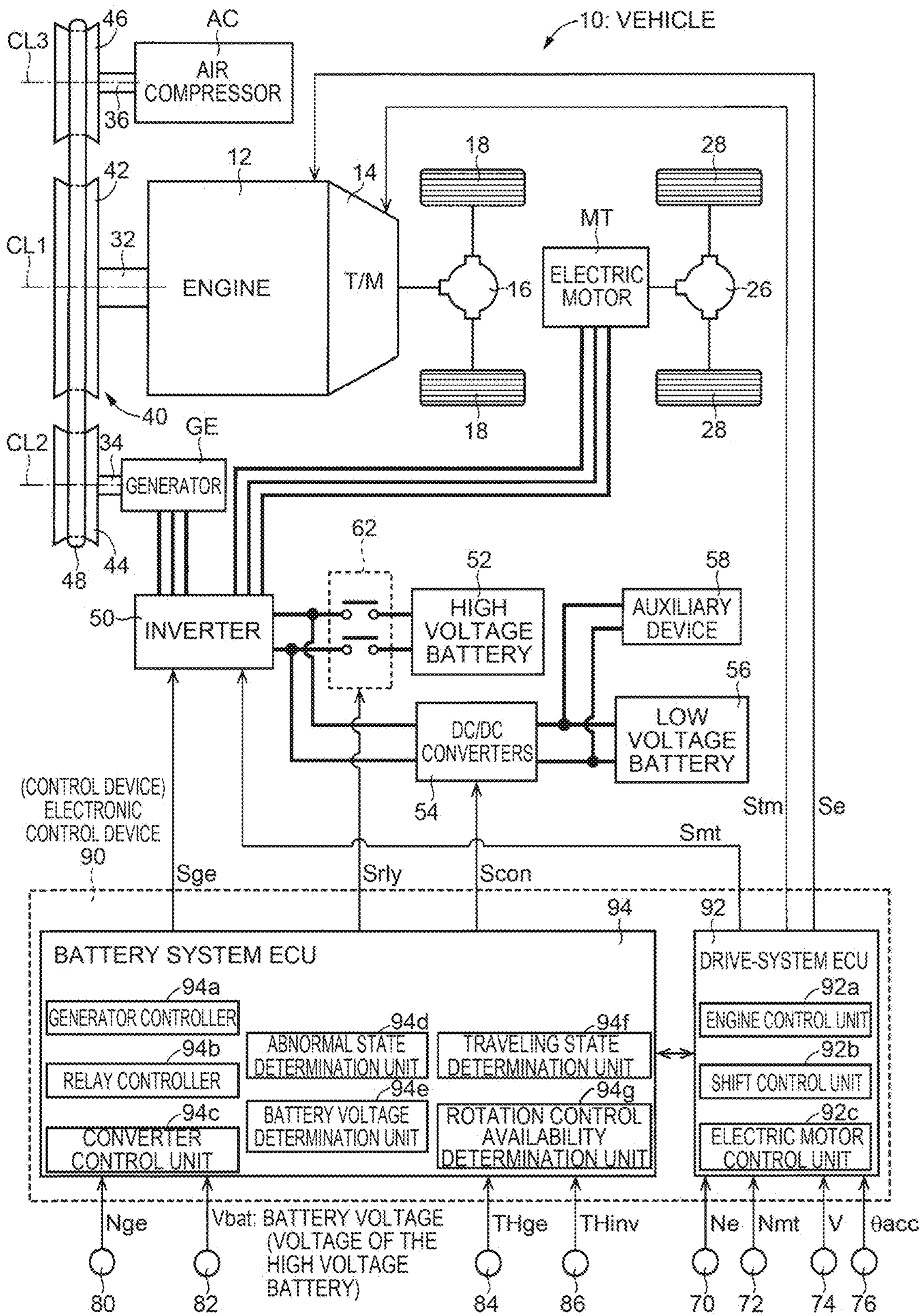


FIG. 1



10: VEHICLE
AC
AIR COMPRESSOR
46
36
CL3
42
12
14
CL1
32
ENGINE
T/M
18
28
MT
ELECTRIC MOTOR
16
26
40
GE
CL2
34
GENERATOR
44
48
62
52
58
HIGH VOLTAGE BATTERY
AUXILIARY DEVICE
50
INVERTER
56
DC/DC CONVERTERS
LOW VOLTAGE BATTERY
54
Stm
Se
Smt
(CONTROL DEVICE) ELECTRONIC CONTROL DEVICE
90
Sge
Srly
Scon
94
92
BATTERY SYSTEM ECU
94a
GENERATOR CONTROLLER
94b
RELAY CONTROLLER
94c
CONVERTER CONTROL UNIT
94d
ABNORMAL STATE DETERMINATION UNIT
94e
BATTERY VOLTAGE DETERMINATION UNIT
94f
TRAVELING STATE DETERMINATION UNIT
94g
ROTATION CONTROL AVAILABILITY DETERMINATION UNIT
DRIVE-SYSTEM ECU
92a
ENGINE CONTROL UNIT
92b
SHIFT CONTROL UNIT
92c
ELECTRIC MOTOR CONTROL UNIT
Nge
Vbat: BATTERY VOLTAGE (VOLTAGE OF THE HIGH VOLTAGE BATTERY)
THge
THinv
Ne
Nmt
V
θacc
80
82
84
86
70
72
74
76

FIG. 2

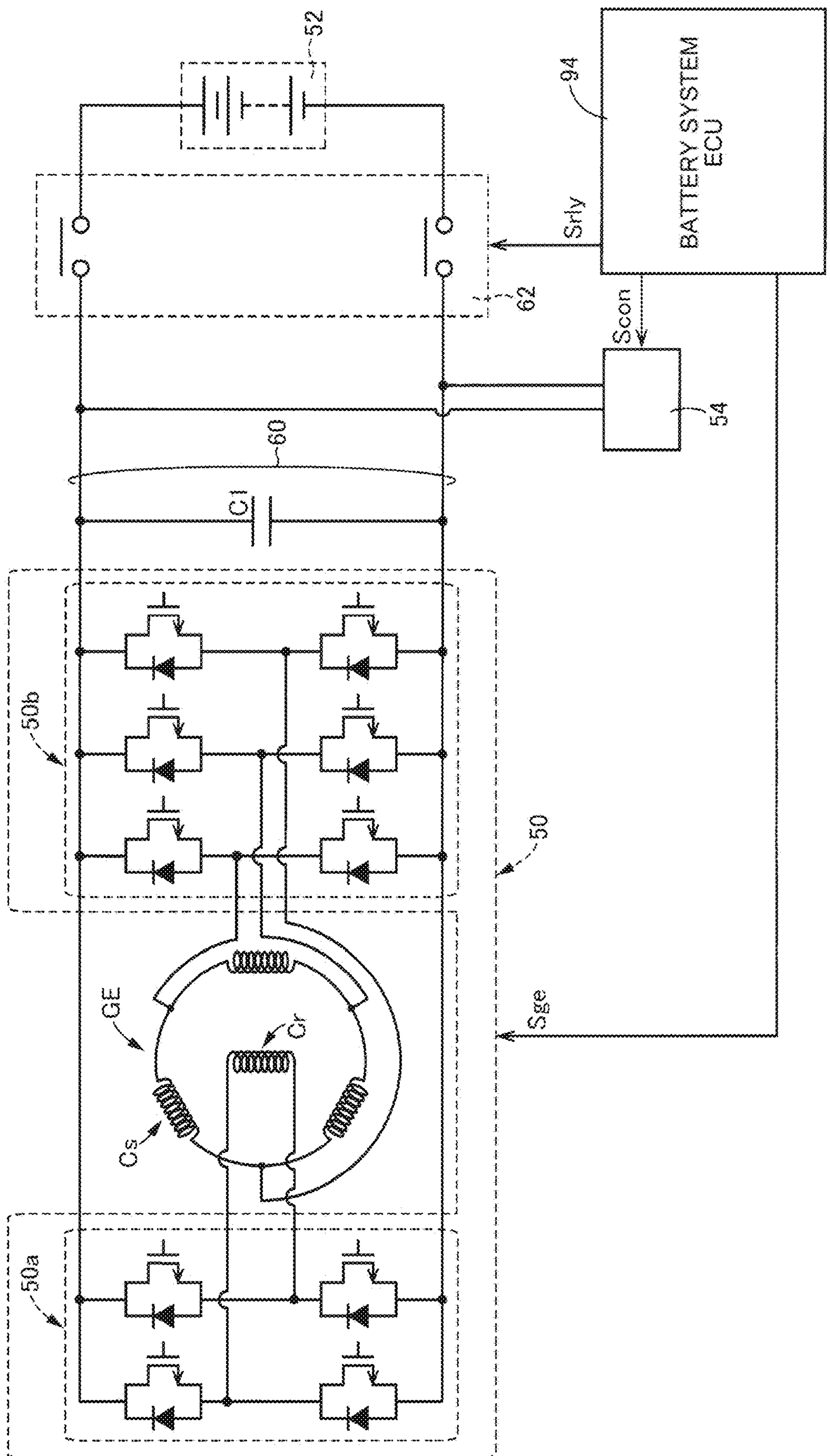
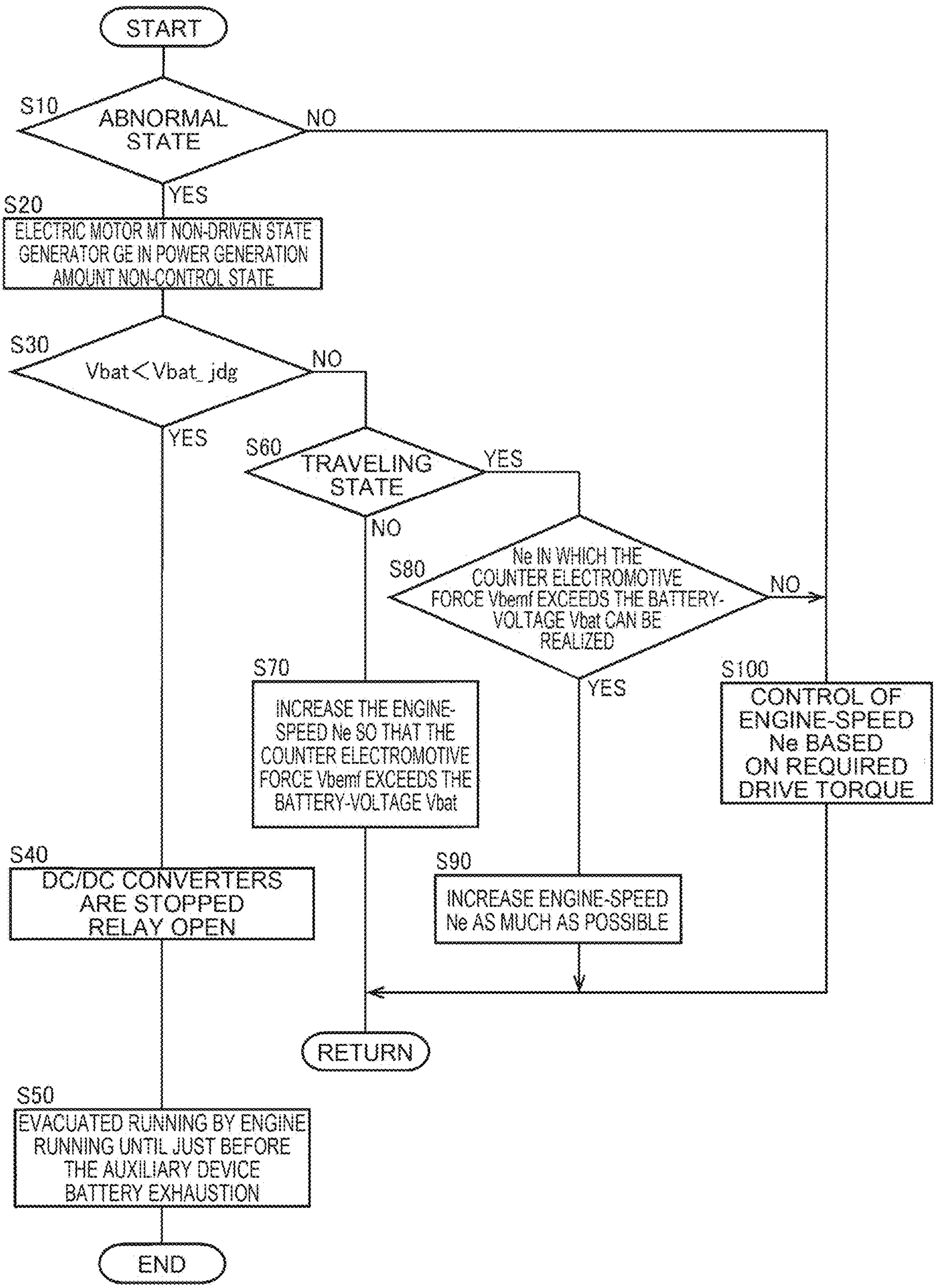

52
94
BATTERY SYSTEM
ECU
Srly
62
Scon
54
60
C1
50b
50
Sge
GE
Cr
Cs
50a

FIG. 3


START
S10
ABNORMAL STATE
NO
YES
S20
ELECTRIC MOTOR MT NON-DRIVEN STATE GENERATOR GE IN POWER GENERATION AMOUNT NON-CONTROL STATE
S30
Vbat＜Vbat_jdg
NO
YES
S60
TRAVELING STATE
YES
NO
S80
Ne IN WHICH THE COUNTER ELECTROMOTIVE FORCE Vbemf EXCEEDS THE BATTERY-VOLTAGE Vbat CAN BE REALIZED
NO
YES
S70
INCREASE THE ENGINE-SPEED Ne SO THAT THE COUNTER ELECTROMOTIVE FORCE Vbemf EXCEEDS THE BATTERY-VOLTAGE Vbat
S100
CONTROL OF ENGINE-SPEED Ne BASED ON REQUIRED DRIVE TORQUE
S40
DC/DC CONVERTERS ARE STOPPED RELAY OPEN
S90
INCREASE ENGINE-SPEED Ne AS MUCH AS POSSIBLE
RETURN
S50
EVACUATED RUNNING BY ENGINE RUNNING UNTIL JUST BEFORE THE AUXILIARY DEVICE BATTERY EXHAUSTION
END

CONTROL DEVICE FOR VEHICLE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-019022 filed on Feb. 9, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a control device for a vehicle. The vehicle includes an engine, a generator coupled to the engine, a high voltage battery that is able to perform power transfer with the generator, a low voltage battery that supplies power to an auxiliary device driving the engine, and a DC/DC converter provided between the high voltage battery and the low voltage battery.

2. Description of Related Art

[0003] A control device for a vehicle is known. The vehicle includes an engine, a generator coupled to the engine, a high voltage battery that is able to perform power transfer with the generator, a low voltage battery that supplies power to an auxiliary device driving the engine, a DC/DC converter provided between the high voltage battery and the low voltage battery, and an electric motor that is a traveling power source driven by power supplied from the high voltage battery. For example, the control device is described in Japanese Unexamined Patent Application Publication No. 2000-245009 (JP 2000-245009 A).

SUMMARY

[0004] In the control device for a vehicle described in JP 2000-245009 A, when an abnormality of a traveling electric motor is detected, damage of the electric motor is held to a minimum limit by setting the electric motor to a "non-driven state" in which the electric motor is not driven and controlled. In this case, since power with an output voltage of the generator that is lowered is directly or indirectly supplied to the low voltage battery and the auxiliary device, the low voltage battery and the auxiliary device function as normal. Therefore, even when the electric motor is in the non-driven state, travel with a traveling power source as the engine is possible.

[0005] Incidentally, when an abnormality of the generator is detected, for example, it is conceivable to hold damage of the generator to a minimum limit by setting the generator to a "power generation amount non-control state" in which the generator is not adjusted to an excitation current of a rotor coil corresponding to a rotational speed of the generator. In this case, there is a risk that a power supply from the generator to the high voltage battery is interrupted. If a power supply from the high voltage battery to the low voltage battery and the auxiliary device continues by the DC/DC converter even when the electric motor to which power is supplied from the high voltage battery is in the non-driven state, a power storage amount of the high voltage battery gradually decreases. As a result, there is a risk that auxiliary device battery exhaustion, in which a power supply to the auxiliary device is no longer possible, occurs and traveling is not possible with the traveling power source set as the engine.

[0006] The present disclosure has been made in view of the circumstances as a background, and an objective of the present disclosure is to provide a control device for a vehicle that can suppress a decrease in a travelable distance of the vehicle even when a generator is set to a power generation amount non-control state due to an occurrence of an abnormal state.

[0007] The main point of the present disclosure is a control device for a vehicle including an engine, a generator coupled to the engine, a high voltage battery that is able to perform power transfer with the generator, a low voltage battery that supplies power to an auxiliary device driving the engine, the low voltage battery having a lower voltage than a voltage of the high voltage battery, and a DC/DC converter provided between the high voltage battery and the low voltage battery, in which

[0008] when the generator is set to a power generation amount non-control state due to an occurrence of an abnormal state, the control device executes an increase control that causes a rotational speed of the engine to increase so that a counter electromotive force generated in the generator becomes equal to or more than a voltage of the high voltage battery, and the control device supplies power from the high voltage battery to the low voltage battery via the DC/DC converter.

[0009] According to the present disclosure,

[0010] when the generator is set to a power generation amount non-control state due to an occurrence of an abnormal state, an increase control is executed that causes a rotational speed of the engine to increase so that a counter electromotive force generated in the generator becomes equal to or more than a voltage of the high voltage battery, and power is supplied from the high voltage battery to the low voltage battery via the DC/DC converter.

[0011] When the generator is set to the power generation amount non-control state, an increase control is executed so that a counter electromotive force generated in the generator becomes equal to or more than a voltage of the high voltage battery. As a result, a power supply from the high voltage battery to the low voltage battery voltage battery is continued by the DC/DC converter. As a result, since a decrease of a power storage amount of the high voltage battery is suppressed and an occurrence of auxiliary device battery exhaustion is suppressed, a decrease in a travelable distance of the vehicle is suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0013] FIG. **1** is a schematic configuration diagram of a vehicle including an electronic control device according to an embodiment of the present disclosure, and is a functional block diagram illustrating a main part of a control function for various types of control in the vehicle;

[0014] FIG. **2** is an explanatory view of the high voltage battery, the inverter, the generator, DC/DC converter, and the battery system ECU shown in FIG. **1**; and

[0015] FIG. **3** is an example of a flowchart illustrating a main part of a control operation of the electronic control device illustrated in FIG. **1**.

DETAILED DESCRIPTION OF EMBODIMENTS

[0016] Hereinafter, examples of the present disclosure will be described in detail with reference to the drawings. Note that, in the following embodiments, the drawings are appropriately simplified or modified, and the dimensional ratios, shapes, and the like of the respective portions are not necessarily drawn accurately.

[0017] FIG. **1** is a schematic configuration diagram of a vehicle **10** including an electronic control device **90** according to an embodiment of the present disclosure, and is a functional block diagram illustrating a main part of a control function for various types of control in the vehicle **10**.

[0018] The vehicle **10** includes, in order from the engine **12** side, a transmission **14** and a front wheel differential **16** in a power transmission path between the engine **12** and the pair of front wheels **18**. At the same time, a rear wheel differential **26** is provided in a power transmission path between the electric motor MT and the pair of rear wheels **28**. These are well known configurations. The vehicle **10** includes a belt transmission device **40**, a generator GE, an inverter **50**, a high voltage battery **52**, a DC/DC converter **54**, a low voltage battery **56**, an auxiliary device **58**, a system main relay **62** (hereinafter, simply referred to as "relay **62**"), and an air compressor AC, which are well known in the art. Further, the vehicle **10** includes an electronic control device **90**.

[0019] The engine **12** is a well-known internal combustion engine and is a traveling power source a pair of front wheels **18** of the vehicle **10**. In the engine **12**, the engine torque Te[Nm] which is the output torque of the engine **12** is controlled by controlling the auxiliary device **58** such as a throttle actuator, a fuel injection device, and an ignition device provided in the engine **12** by the electronic control device **90**. The auxiliary device **58** is a device for causing the main body of the engine **12** to function. In this specification, the torque, the power, the driving force, and the force (power) are consensus unless otherwise specified.

[0020] The transmission **14** is constituted by, for example, a known torque converter or an automatic transmission.

[0021] The electric motor MT is a rotary electric machine having at least an electric motor function among an electric motor function and a generator function, and is, for example, a three-phase synchronous motor generator of a so-called motor generator. The electric motor MT is a traveling power source the pair of rear wheels **28** of the vehicles **10**. The electric motor MT corresponds to an "electric motor" in the present disclosure.

[0022] The generator GE is a rotary electric machine having at least a generator function among an electric motor function and a generator function. The generator GE includes a stator (=stator) and a rotor (=rotor), which are not shown. For example, in the generator GE, a stator coil Cs (see FIG. **2**) is wound around the stator, and a permanent magnet of a surface-magnet type or an embedded magnet type is provided on the rotor, and a rotor coil Cr (see FIG. **2**) is wound around the rotor. The generator GE corresponds to the "generator" in the present disclosure. When the rotor is rotated, the generator GE generates a rotating magnetic field in which the magnetic flux generated by the permanent magnet and the magnetic flux generated by the electromagnet formed by the excitation current flowing through the rotor coil Cr are rotated. As a result, a counter electromotive force Vemf is generated in the stator coil Cs, and the generator GE generates electricity. Further, in the generator GE, when three-phase alternating current is supplied to the stator coil Cs, the rotor **10** is rotated. When the generator GE is generating electricity, the generator GE functions as an alternator. When the output torque, which is the power running torque, is output from the generator GE, the generator GE functions as a starter motor that outputs the cranking torque to the engine **12**. The generator GE of the present embodiment has both an electric motor function and a generator function.

[0023] The belt transmission device **40** connects the engine **12**, the generator GE, and the air compressor AC to each other. The belt transmission device **40** is a known belt-type transmission device including a crank pulley **42** connected to the crankshaft **32** of the engine **12** so as not to be relatively rotatable, a generator pulley **44**, a AC pulley **46**, and a belt **48** wound between the crank pulley **42**, the generator pulley **44**, and AC pulley **46**. The generator pulley **44** is connected to the rotor shaft **34**, which is a rotating shaft of the rotor **20** of the generator GE, so as not to be relatively rotatable. AC pulley **46** is connected to the drive shaft **36** of the air compressor AC so as not to be relatively rotatable. The crankshaft **32**, the rotor shaft **34**, and the drive shaft **36** are rotating members having the first axis CL**1**, the second axis CL**2**, and the third axis CL**3** as rotational centerlines, respectively. The first axis CL**1**, the second axis CL**2**, and the third axis CL**3** are parallel to each other. The belt **48** is an endless ring-shaped transmission member capable of transmitting power between the engine **12** and the generator GE. For example, the belt **48** is an endless annular compression type transmission belt capable of transmitting power between the crank pulley **42** and the generator pulley **44**, or an endless annular tension type transmission belt.

[0024] The generator GE is connected to the high voltage battery **52** via inverters **50**. The inverter **50** is a power supply circuit controlled by the electronic control device **90** to convert a direct current into an alternating current or convert an alternating current into a direct current. For example, the inverter **50** controls the excitation current Icr flowing through the rotor coil Cr of the generator GE by Pulse Width Modulation (PWM) controlling the direct current supplied from the high voltage battery **52**. Further, the inverter **50** converts the three-phase alternating-current generated electric power Wge generated by the generator GE into a direct current and outputs the direct current to the high voltage battery **52**. The inverters **50** also control the excitation current Ics that converts the direct current supplied from the high voltage battery **52** into three-phase alternating current and flows to the stator-coil Cs of the generator GE.

[0025] By controlling the inverters **50** by the electronic control device **90**, the excitation current Icr[Nm of the generator GE is adjusted. The excitation current Icr is adjusted according to, for example, a generator rotational speed Nge [rpm] which is a rotational speed of the generator GE. When the excitation current Ier is the same, the higher the generator rotational speed Nge, the larger the generated electric power Wge. When the generator rotational speeds Nge are the same, the generated electric power Wge increases as the excitation current Ier increases. Therefore, in order to obtain the required generated electric power Wge, when the generator rotational speed Nge is relatively low, the excitation current Ier is adjusted to be large. When the generator rotational speed Nge is relatively high, the excitation current Icr is adjusted so as to be small.

[0026] The high voltage battery **52** is a rechargeable secondary battery. The high voltage battery **52** is used to supply electric power to the electric motor MT and the generator GE, or to charge the generated electric power Wmt at the electric motor MT and the generated electric power Wge at the generator GE by regeneration. The high voltage battery **52** is a battery capable of transmitting and receiving electric power to and from the generator GE.

[0027] The low voltage battery **56** is a rechargeable secondary battery. The low voltage battery **56** is used to supply power to an electric load including an auxiliary device **58** (for example, a throttle actuator, a fuel injection device, an ignition device, various sensors, a switch, and the like). Due to application differences, the low voltage battery **56** has a lower voltage than the high voltage battery **52**. That is, the battery voltage Vbat of the high voltage battery **52** is higher than that of the low voltage battery **56**. For example, the low voltage battery **56** is 12 [V] while the high voltage battery **52** is at a higher voltage. The battery voltage Vbat is the battery voltage of the high voltage battery **52** and corresponds to the "voltage of the high voltage battery" in the present disclosure.

[0028] DC/DC converters **54** are provided between the high voltage battery **52** and the low voltage battery **56**, and are power supply circuits that step up or step down the direct current. For example, DC/DC converters **54** step down the direct current supplied from the high voltage battery **52**, and output a direct current having a voltage lower than that of the high voltage battery **52** to the low voltage battery **56**.

[0029] The relay **62** is a switch that disconnects and supplies electric power between the high voltage battery **52** and the inverters **50** and DC/DC converters **54**.

[0030] The air compressor AC is a well-known air compressor.

[0031] Here, the crank pulley **42** is defined as a radial R1 [mm], the generator pulley **44** is defined as a radial R2 [mm], and the radial R2 divided by the radial R1 is defined as a predetermined rotational ratio α (=R2/R1) in the belt transmission device **40**.

[0032] The air compressor AC can be switched between an operating state and a stopped state. For example, AC pulley **46** is connected to the drive shaft **36** of the air compressor AC via a not-shown clutch. When the clutch is brought into the engaged state, the rotation of AC pulley **46** is transmitted to the drive shaft **36**, and thus the air compressor AC is brought into the operating state. When the clutch is released, AC pulley **46** idles with respect to the drive shaft **36**, and thus the air compressor AC is stopped.

[0033] The electronic control device **90** includes a drive-system ECU **92** and a battery system ECU **94** that function as a control device for controlling each unit of the vehicles **10**. Note that the electronic control device **90** corresponds to a "control device" in the present disclosure. The drive-system ECU **92** is an ECU that mainly controls the operation of the drive system including the engine **12**, the transmission **14**, and the electric motor MT of the vehicle **10**. The battery system ECU **94** is an ECU that mainly controls the operation of the battery system including the generator GE, the relays **62**, and DC/DC converters **54**. For example, the drive-system ECU **92** and the battery system ECU **94** in the electronic control device **90** are respectively connected to a communication network using Controller Area Network (CAN) communication circuit. This allows ECU to input and output data to and from each other. ECU includes, for example, a so-called microcomputer including a CPU, RAM, ROM, an input/output interface, and the like. CPU performs various kinds of control of the vehicles **10** by performing signal-processing in accordance with a program stored in ROM in advance while using a temporary storage function of RAM.

[0034] The drive-system ECU **92** receives various types of signals and the like based on the detected values by various sensors and the like provided in the vehicles **10**. Examples of the various sensors include an engine rotational speed sensor **70**, an electric motor rotation speed sensor **72**, a vehicle speed sensor **74**, and an accelerator operation amount sensor **76**. The various types of signals include, for example, an engine rotational speed Ne [rpm] which is a rotational speed of the engine **12**, an electric motor rotational speed Nmt [rpm] which is a rotational speed of the electric motor MT, a vehicle speed V [km/h], and an accelerator operation amount θacc [%] as an acceleration operation amount representing a magnitude of the acceleration operation by the driver. The electric motor rotation speed sensor **72** is, for example, a resolver capable of detecting a phase representing a rotation position of a rotor of the electric motor MT, that is, capable of detecting a rotation angle and a rotation speed.

[0035] The battery system ECU **94** receives various types of signals and the like based on the detected values of various sensors and the like provided in the vehicle **10**. Examples of the various sensors include a generator rotation speed sensor **80**, a battery voltage sensor **82**, a generator temperature sensor **84**, and an inverter temperature sensor **86**. The various types of signals include, for example, a generator rotational speed Nge [rpm] which is a rotational speed of the generator GE, a generator temperature THge which is a temperature of the generator GE, and an inverter temperature THinv which is a temperature of the inverter **50**. The generator rotation speed sensor **80** is, for example, a resolver capable of detecting a phase representing a rotation position of a rotor of the generator GE, that is, capable of detecting a rotation angle and a rotation speed.

[0036] Various command signals are outputted from the drive-system ECU **92** to the respective apparatuses included in the vehicles **10**. Each device provided in the vehicle **10** is, for example, an engine **12**, a transmission **14**, an inverter **50**, or the like. Various command signals are, for example, an engine control signal Se for controlling the engine **12**, a shift control signal Stm for executing shift control of the transmission **14**, and an electric motor control signal Smt for executing rotational control of the electric motor MT via the inverter **50**.

[0037] Various command signals are outputted from the battery system ECU **94** to the respective apparatuses included in the vehicles **10**. The devices included in the vehicles **10** are, for example, inverters **50**, relays **62**, and DC/DC converters **54**. The various command signals are, for example, a generator control signal Sge for controlling the excitation current Icr and the excitation current Ics of the generator GE via the inverter **50**, a converter control signal Scon for controlling the voltage-conversion of the relay control signal Srly, DC/DC converter **54** for controlling the opening and closing of the relay **62**, and the like.

[0038] Hereinafter, the generator GE is brought into the power generation amount non-control state due to the occurrence of the abnormal state. In the generator GE, the "power generation amount control state" refers to a state in which the excitation current Icr is adjusted and controlled in accordance with the generator rotational speed Nge. The "power generation amount non-control state" refers to a state in which the excitation current Ier is set to a predetermined constant value (for example, zero) regardless of the generator rotational speed Nge.

[0039] The drive-system ECU **92** functionally includes an engine control unit **92***a*, a shift control unit **92***b*, and an electric motor control unit **92***c*. The battery system ECU **94** functionally includes a generator control unit **94***a*, a relay control unit **94***b*, a converter control unit **94***c*, an abnormal state determination unit **94***d*, a battery voltage determination unit **94***c*, a traveling state determination unit **94***f*, and a rotation control availability determination unit **94***g*.

[0040] During vehicle running, the engine control unit **92***a* controls the engine torque Te so as to realize the required drive torque Trdem for the vehicle **10**. The shift control unit **92***b* performs shift control of the transmission **14**, and the electric motor control unit **92***c* controls the motor torque Tmt which is the torque of the electric motor MT. The required drive torque Trdem is the driving torque requested by the driver to the vehicle **10**. The required drive torque Trdem is calculated, for example, by applying the actual accelerator operation amount θacc and the actual vehicle speed V to a map in which the relation between the accelerator operation amount θacc and the vehicle speed V and the required drive torque Trdem is experimentally or designedly predetermined and stored.

[0041] In the power generation control of the generator GE, the generator control unit **94***a* adjusts the excitation current Ier so that the generated electric power Wge required by the generator GE can be obtained by using the power of the engine **12**. That is, the generator control unit **94***a* sets the generator GE to the power generation quantity control status.

[0042] The relay control unit **94***b* controls the opening and closing of the relay **62**.

[0043] The converter control unit **94***c* performs switching control between the operating state and the stopped state with respect to the operating state of DC/DC converter **54**.

[0044] The abnormal state determination unit **94***d* determines whether or not an abnormal state in which the generator GE needs to be in the power generation amount non-control state has occurred. For example, when the generator temperature THge exceeds the predetermined temperature determination value THge_jdg, it is determined that an abnormal state has occurred. The predetermined temperature determination value THge_jdg is a determination value determined experimentally or designedly in order to determine that an abnormal state in which the generator GE needs to be in a power generation amount non-control state has occurred. For example, when the generator rotational speed Nge is not a value corresponding to the engine rotational speed Ne or when the phase representing the rotational position of the rotor of the generator GE does not change, it is determined that an abnormal state has occurred. These may be caused, for example, by a failure of the generator rotation speed sensor **80**.

[0045] When the abnormal state determination unit **94***d* determines that an abnormal state has occurred, the generator control unit **94***a* sets the generator GE to the power generation amount non-control state, and the electric motor control unit **92***c* sets the electric motor MT to the non-driven state. For example, the generator control unit **94***a* sets the excitation current Icr to zero. This is to suppress abnormally increasing the generated electric power Wge even when the actual generator rotational speed Nge is higher by using only the permanent magnets as the magnetic flux from the rotor of the generator GE toward the stator. This suppresses an increase in the generator temperature THge. As described above, in the generator GE, the magnetic flux by the permanent magnets is smaller than the magnetic flux by the electromagnets formed by the excitation current Icr. When the generator GE is placed in a power generation amount non-control state, damages to the generator GE are minimized. When the electric motor MT is non-driven state, a decrease in the storage capacity of the high voltage battery **52** is suppressed. When the abnormal state determination unit **94***d* determines that an abnormal state has occurred, the vehicle **10** performs limp home by engine traveling using a traveling power source as the engine **12**.

[0046] The battery voltage determination unit **94***c* determines whether or not the battery voltage Vbat is less than a predetermined voltage determination value Vbat_jdg. The predetermined voltage determination value Vbat_jdg is, for example, a determination value determined experimentally or designedly in advance, in which the limp home by the engine travel is temporarily enabled even when the battery system is stopped. That is, when the battery voltage Vbat is equal to or greater than the predetermined voltage determination value Vbat_jdg, the low voltage battery **56** is capable of supplying power to the auxiliary device **58**.

[0047] The traveling state determination unit **94***f* determines whether or not the vehicle **10** is in the traveling state, that is, whether or not the vehicle speed V is zero.

[0048] In some cases, the generator GE is in a power generation amount non-control state and the vehicle **10** is in a traveling state due to the occurrence of an abnormal state. In this case, the rotation control availability determination unit **94***g* determines whether or not the engine rotational speed Ne can be increased so that the counter electromotive force Vemf generated in the generator GE becomes equal to or higher than the battery voltage Vbat. For example, the counter electromotive force Vemf may not be increased above the battery-voltage Vbat. Further, even if the counter electromotive force Vemf can be increased to be equal to or higher than the battery voltage Vbat, the vehicle acceleration Acc, which is an acceleration toward the traveling direction of the vehicle **10** due to an increase in the engine rotational speed Ne, may be out of a predetermined allowance range. In all of these cases, it is determined that the engine rotational speed Ne cannot be increased. The predetermined allowance range is a range in which the vehicle acceleration Acc is equal to or less than the acceleration determination value Acc_jdg. The acceleration determination value Acc_jdg is a predetermined determination value determined experimentally or designedly in advance, in which the driver's sense of discomfort is within an allowable range. The range of the acceleration determination value Acc_jdg or less corresponds to "within a predetermined allowance range" in the present disclosure.

[0049] FIG. **2** is an explanatory diagram of the high voltage battery **52**, the inverter **50**, the generator GE, DC/DC converter **54**, and the battery system ECU **94** shown in FIG.

1. In FIG. 2, the drive circuit of the electric motor MT in the configuration of the inverter 50 is omitted.

[0050] The inverter 50 includes a rotor coil control circuit 50a and a stator coil control circuit 50b.

[0051] The rotor coil control circuit 50a is a circuit that controls the excitation current Icr of the rotor coil Cr. As described above, for example, the rotor coil control circuit 50a controls the magnitude of the excitation current Ier of the rotor coil Cr by PWM control. As shown in FIG. 2, for example, in the rotor coil control circuit 50a, two pairs of switching elements connected in series are provided between the positive electrode line and the negative electrode line of the power line pair 60. The switching device is, for example, an insulated-gate bipolar transistor (IGBT), a power MOSFET, or the like. Diodes are connected in parallel to each of the switching elements. Each set of connecting points of the pair of switching elements connected in series is connected to one terminal and the other terminal of the rotor-coil Cr in the generator GE.

[0052] The stator coil control circuit 50b is a circuit that controls the excitation current Ics of the stator coil Cs. As shown in FIG. 2, for example, in the stator coil control circuit 50b, three pairs of switching elements connected in series are provided between the positive electrode line and the negative electrode line of the power line pair 60. Diodes are connected in parallel to each of the switching elements. The connection points of the pair of switching elements connected in series are connected to the respective connection terminals of the U-phase, the V-phase, and the W-phase of the stator-coil Cs in the generator GE.

[0053] The relay 62 is provided between the high voltage battery 52 and the power line pair 60. That is, the high voltage battery 52 is connected to the power line pair 60 via the relay 62. The power line pair 60 includes a pair of positive and negative electrode lines.

[0054] The relay 62 is, for example, a mechanical relay in which a closed state (connected state) in which the relay 62 is closed and an open state (shut-off state) in which the relay 62 is open are switched by the battery system ECU 94. The relay 62 is provided between the positive electrode of the high voltage battery 52 and the positive electrode line of the power line pair 60, and between the negative electrode of the high voltage battery 52 and the negative electrode line of the power line pair 60. The relay 62 is an opening/closing device that disconnects and connects the high voltage battery 52 and the power line pair 60.

[0055] A smoothing capacitor C1 is provided between the power line pair 60 in the vicinity of the inverters 50.

[0056] For example, when all the switching elements of the rotor coil control circuit 50a and the stator coil control circuit 50b in the inverter 50 are turned off by the battery system ECU 94, the excitation current Ier becomes zero and the generator GE is brought into the power generation amount non-control state. When the engine 12 is in operation, the rotor of the generator GE is rotated in accordance with the engine rotational speed Ne. As a result, a rotating magnetic field in which the magnetic flux generated by the permanent magnets rotates is generated, and a counter electromotive force Vemf is induced in the stator coil Cs of the generator GE. The counter electromotive force Vemf induced by the generator GE is converted into a DC voltage by the diode provided in the inverter 50 and the smoothing capacitor C1 provided between the power line pair 60. The higher the generator rotational speed Nge, that is, the higher the engine rotational speed Ne, the higher the counter electromotive force Vemf.

[0057] For example, the generator rotational speed Nge required to generate the counter electromotive force Vemf can be calculated by applying the required counter electromotive force Vemf to a map in which the relation between the generator rotational speed Nge and the counter electromotive force Vemf is experimentally or designedly determined in advance based on the rotating magnetic field by the permanent magnets. Based on the generator rotational speed Nge and the predetermined rotational ratio a, an engine rotational speed Ne required to generate the required counter electromotive force Vemf is calculated.

[0058] Return to FIG. 1. When the abnormal state determination unit 94d determines that an abnormal state has occurred and the battery voltage determination unit 94c determines that the battery voltage Vbat is less than the predetermined voltage determination value Vbat_jdg, the relay control unit 94b controls the relay 62 to the open state, and the converter control unit 94c controls DC/DC converter 54 to the stopped state.

[0059] When the abnormal state determination unit 94d determines that the abnormal state has occurred, the battery voltage determination unit 94e determines that the battery voltage Vbat is equal to or higher than the predetermined voltage determination value Vbat_jdg, and the traveling state determination unit 94f determines that the vehicle 10 is not in the traveling state, the engine control unit 92a increases the engine rotational speed Ne so that the counter electromotive force Vemf generated in the generator GE becomes equal to or higher than the battery voltage Vbat, and the converter control unit 94c controls DC/DC converter 54 to an operating state so as to supply electric power from the high voltage battery 52 to the low voltage battery 56.

[0060] In some cases, the abnormal state determination unit 94d determines that an abnormal state has occurred, the battery voltage determination unit 94e determines that the battery voltage Vbat is equal to or higher than the predetermined voltage determination value Vbat_jdg, and the traveling state determination unit 94f determines that the vehicle 10 is in the traveling state. In this case, (a) when the engine rotational speed Ne can be increased and the rotation control availability determination unit 94g determines, the engine control unit 92a increases the engine rotational speed Ne as much as possible, and (b) when the rotation control availability determination unit 94g determines that it is impossible to increase the engine rotational speed Ne, the engine control unit 92a controls the engine rotational speed Ne based on the required drive torque Trdem. “Increase the engine rotational speed Ne as much as possible” means that the rotation control availability determination unit 94g can increase the engine rotational speed Ne as much as possible.

[0061] FIG. 3 is an example of a flowchart illustrating a main part of the control operation of the electronic control device 90 illustrated in FIG. 1. At the beginning of the flow chart of FIG. 3, the generator GE is in a power generation control condition.

[0062] First, in S10 corresponding to the function of the abnormal state determination unit 94d (hereinafter, the “steps” are omitted), it is determined whether or not an abnormal state in which the generator GE needs to be in the power generation amount non-control state has occurred. When the determination of S10 is YES, in S20 corresponding to the functions of the electric motor control unit **92**c and the generator control unit **94**a, the electric motor MT is set to the non-driven state and the generator GE is set to the power generation amount non-control state. After S**20** is executed, it is determined whether or not the battery voltage Vbat is less than the predetermined voltage determination value Vbat_jdg in S**30** corresponding to the function of the battery voltage determination unit **94**c. When the determination of S**30** is YES, the relay **62** is controlled to be in the open state and DC/DC converter **54** is controlled to be in the stopped state in S**40** corresponding to the functions of the relay control unit **94**b and the converter control unit **94**c. After S**40** is executed, in S**50** corresponding to the functions of the engine control unit **92**a and the shift control unit **92**b, the limp home by the engine travel is temporarily executed until immediately before the auxiliary device battery exhaustion occurs. "Auxiliary device battery exhaustion" is a state in which the auxiliary device **58** cannot operate normally because the auxiliary device **58** is no longer supplied with power necessary for normal operation. After S**50** is executed, the flow chart ends.

[0063] When the determination of S30 is NO, it is determined whether or not the vehicle **10** is in the traveling state in S**60** corresponding to the function of the traveling state determination unit **94**f. When the determination of S**60** is NO, in S**70** corresponding to the functions of the engine control unit **92**a and the converter control unit **94**c, DC/DC converter **54** is controlled to be in an operating condition so that the low voltage battery **56** is supplied with electric power from the high voltage battery **52** and the engine rotational speed Ne is increased so that the counter electromotive force Vemf generated in the generator GE becomes equal to or higher than the battery voltage Vbat. When the determination of S**60** is YES, in S**80** corresponding to the function of the rotation control availability determination unit **94**g, it is determined whether the engine rotational speed Ne can be increased so that the counter electromotive force Vemf generated by the generator GE becomes equal to or higher than the battery voltage Vbat within the range in which the vehicle acceleration Acc is equal to or lower than the acceleration determination value Acc_jdg. When the determination of S**80** is YES, the vehicle acceleration Acc can be controlled within the acceleration determination value Acc_jdg or less. When the determination of S**80** is NO, the vehicle acceleration Acc cannot be controlled within the acceleration determination value Acc_jdg or less. When the determination of S**80** is YES, the engine rotational speed Ne is increased in S**90** corresponding to the function of the engine control unit **92**a. When the determination of S10 is NO and the determination of S**80** is NO, the engine rotational speed

[0064] Ne is controlled based on the required drive torque Trdem in S**100** corresponding to the function of the engine control unit **92**a. After S**70** is executed, after S**90** is executed, and after S**100** is executed, both returns.

[0065] According to the present embodiment, when the generator GE is placed in the power generation amount non-control state due to the occurrence of the abnormal state, the "increase control" is executed and electric power is supplied from the high voltage battery **52** to the low voltage battery **56** through DC/DC converters **54**. The increase control is a control for increasing the engine rotational speed Ne so that the counter electromotive force Vemf generated in the generator GE becomes equal to or higher than the battery-voltage Vbat. Even if the generator GE is in the power generation amount non-control state, the increase control is executed so that the counter electromotive force Vemf generated in the generator GE becomes equal to or higher than the battery voltage Vbat, so that electric power is continuously supplied from the high voltage battery **52** to the low voltage battery **56** by DC/DC converter **54**. As a result, a decrease in the amount of electricity stored in the high voltage battery **52** is suppressed, and the occurrence of auxiliary device battery exhaustion is suppressed, so that a decrease in the travelable distance of the vehicle **10** is suppressed.

[0066] According to the present embodiment, if in a vehicle stop state when the

[0067] generator GE is in the power generation amount non-control state due to the occurrence of the abnormal state, the increase control is executed when the power generation amount is in the stopped state. When in the vehicle stop state, the driver does not accelerate unintentionally even if the engine rotational speed Ne increases. As a result, the vehicle acceleration Acc in which the driver feels uncomfortable is prevented, and the lowering of the travelable range of the vehicle **10** is suppressed.

[0068] According to the present embodiment, when the vehicle **10** is in the traveling state when the generator GE is in the power generation amount non-control state due to the occurrence of the abnormal state, the increase control is executed when the vehicle acceleration Acc can be controlled within the acceleration determination value Acc_jdg or less. When the vehicle acceleration Acc can be controlled within the range of the acceleration determination value Acc_jdg or less, the vehicle acceleration Acc is limited within the range of the acceleration determination value Acc_jdg or less even if the engine rotational speed Ne increases in the traveling state. This suppresses the uncomfortable feeling felt by the driver, and suppresses a decrease in the travelable distance of the vehicle **10**.

[0069] According to the present embodiment, when the vehicle **10** is in the traveling state when the generator GE is in the power generation amount non-controlled state due to the occurrence of the abnormal state, and when the vehicle acceleration Acc is not controllable within the range of the acceleration determination value Acc_jdg or less, the engine rotational speed Ne is determined based on the required drive torque Trdem. When the vehicle acceleration Acc cannot be controlled within the acceleration determination value Acc_jdg or less, the engine rotational speed Ne is determined based on the required drive torque Trdem, so that unintentional acceleration by the driver is not performed. This prevents the driver from feeling uncomfortable due to the vehicle-acceleration Acc.

[0070] According to the present embodiment, the vehicle **10** includes an electric motor MT that is a traveling power source driven by electric power supplied from the high voltage battery **52**, and the electric motor MT is in a non-driven state when the generator GE is in a power generation amount non-control state due to generation of an abnormal state. Since the electric motor MT is set in the non-driven state, a decrease in the amount of electricity stored in the high voltage battery **52** is suppressed, so that the electric power is easily supplied from the high voltage battery **52** to the low voltage battery **56** and the auxiliary device **58** by DC/DC converters **54**, and the generation of the auxiliary device battery exhaustion is suppressed.

[0071] It should be noted that the above-described embodiments of the present disclosure are examples of the present disclosure, and the present disclosure can be implemented in various modifications and improvements based on the knowledge of a person skilled in the art without departing from the gist thereof.

[0072] In the above-described embodiment, when the generator GE is in a vehicle stop state in the power generation amount non-control state due to the occurrence of the abnormal state, the increase control is executed when the power generation amount non-control state, but the increase control may not be executed. For example, by executing the increase control in the traveling state of the vehicle **10**, a decrease in the amount of electricity stored in the high voltage battery **52** is suppressed, and the occurrence of auxiliary device battery exhaustion is suppressed, so that a decrease in the travelable distance of the vehicle **10** is suppressed.

[0073] In the above-described embodiment, when the vehicle **10** is in the traveling state when the generator GE is in the power generation amount non-control state due to the occurrence of the abnormal state, the increase control is executed when the vehicle acceleration Acc is controllable within the range of the acceleration determination value Acc_jdg or less. However, the increase control may not be executed. For example, by executing the increase control in the vehicle stop state, the decrease in the amount of electric power stored in the high voltage battery **52** is suppressed, and the occurrence of the auxiliary device battery exhaustion is suppressed, so that the decrease in the travelable distance of the vehicle **10** is suppressed.

[0074] In the above-described embodiment, if the vehicle **10** is in the traveling state when the generator GE is in the power generation amount non-control state due to the occurrence of the abnormal state, the engine rotational speed Ne is determined based on the required drive torque Trdem when the vehicle acceleration Acc cannot be controlled within the range of the acceleration determination value Acc_jdg or less, but this may not be the case. For example, even when such control is not possible, the increase control may be executed. By executing the increase control, a decrease in the travelable distance of the vehicle **10** is suppressed.

[0075] In the above-described embodiment, when the generator GE is in the power generation amount non-control state due to the generation of the abnormal state, the electric motor MT is in the non-driven state, but for example, the electric motor MT may be in the driven state. Even when the electric motor MT is in the drive mode, when the increase control is executed as compared with when the increase control is not executed, a decrease in the travelable range of the vehicles **10** is suppressed.

[0076] In the above-described embodiment, the rotor of the generator GE is provided with a permanent magnet, but may be provided without the permanent magnet. For example, the rotor may not be provided with permanent magnets, and only the rotor coil Cr may be provided. In such an embodiment, the excitation current Icr may be adjusted to a predetermined constant value (>0) irrespective of the generator rotational speed Nge so that the magnetic flux from the rotor of the generator GE toward the stator becomes substantially the same as that of the permanent magnets in the above-described embodiment due to the occurrence of the abnormal state. The predetermined constant value is an empirically or designedly predetermined current value so that the generator GE is minimized from being damaged.

[0077] In the above-described embodiment, the belt transmission device **40** connects the engine **12**, the generator GE, and the air compressor AC to each other. However, for example, the belt transmission device **40** may be configured such that the engine **12** and the generator GE are connected to each other, but the air compressor AC is not connected to each other.

[0078] In the above-described embodiment, the "control device" in the present disclosure is divided into a drive-system ECU **92** and a battery system ECU **94**, but the present disclosure is not limited thereto. For example, the "control device" may have a configuration that is further divided for each function than in the above-described embodiment as necessary, or may have a configuration in which all the functions are integrated into one.

What is claimed is:

1. A control device for a vehicle including an engine, a generator coupled to the engine, a high voltage battery that is able to perform power transfer with the generator, a low voltage battery that supplies power to an auxiliary device driving the engine, the low voltage battery having a lower voltage than a voltage of the high voltage battery, and a DC/DC converter provided between the high voltage battery and the low voltage battery, wherein when the generator is set to a power generation amount non-control state due to an occurrence of an abnormal state, the control device executes an increase control that causes a rotational speed of the engine to increase such that a counter electromotive force generated in the generator becomes equal to or more than a voltage of the high voltage battery, and the control device supplies power from the high voltage battery to the low voltage battery via the DC/DC converter.

2. The control device according to claim **1**, wherein if the vehicle is in a vehicle stop state when the generator is set to the power generation amount non-control state due to an occurrence of the abnormal state, the control device executes the increase control.

3. The control device according to claim **1**, wherein if the vehicle is in a traveling state when the generator is set to the power generation amount non-control state due to an occurrence of the abnormal state, the control device executes the increase control when a vehicle acceleration is not able to be controlled within a predetermined allowance range.

4. The control device according to claim **3**, wherein if the vehicle is in the traveling state when the generator is set to the power generation amount non-control state due to an occurrence of the abnormal state, a rotational speed of the engine is determined based on a required drive torque when the vehicle acceleration is not able to be controlled within the predetermined allowance range.

5. A control device according to claim **1**, wherein:

the vehicle further includes an electric motor being a traveling power source driven by power supplied from the high voltage battery; and

when the generator is set to the power generation amount non-control state due to an occurrence of the abnormal state, the electric motor is set to a non-driven state.

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