

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
7 December 2006 (07.12.2006)

PCT

(10) International Publication Number
WO 2006/129853 A1

(51) International Patent Classification:

B60K 6/04 (2006.01)

(21) International Application Number:

PCT/JP2006/311355

(22) International Filing Date: 31 May 2006 (31.05.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2005-161613 1 June 2005 (01.06.2005) JP

(71) Applicant (for all designated States except US): TOYOTA JIDOSHA KABUSHIKI KAISHA [JP/JP]; 1, Toyota-cho, Toyota-shi, Aichi, 4718571 (JP).

(72) Inventor; and

(75) Inventor/Applicant (for US only): TOMO, Kentaro [JP/JP]; c/o TOYOTA JIDOSHA KABUSHIKI KAISHA, 1, Toyota-cho, Toyota-shi, Aichi, 4718571 (JP).

(74) Agent: ITEC INTERNATIONAL PATENT FIRM; Uchisaiwaicho Dai Bldg., 3-3, Uchisaiwai-cho, 1-chome, Chiyoda-ku, Tokyo 1000011 (JP).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

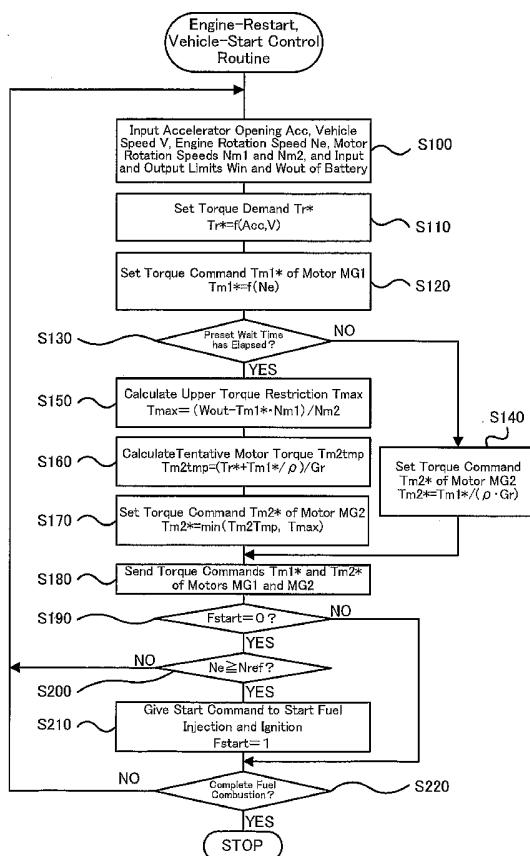
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

[Continued on next page]

(54) Title: HYBRID VEHICLE AND CONTROL METHOD OF HYBRID VEHICLE



(57) Abstract: When the driver heavily depresses an accelerator pedal (83) to start a hybrid vehicle in an engine stop condition, the control of the invention waits until elapse of a preset wait time and then starts outputting a torque equivalent to a preset torque demand to a ring gear shaft (32a) or a driveshaft. The preset wait time is determined not to make the driver feel uncomfortable with a poor response. This arrangement desirably shortens a time period when the vehicle acceleration is restricted due to insufficient power output until the engine starts to output sufficient power and make significant contribution to the vehicle acceleration. The control of the invention thus desirably prevents the driver from feeling the unexpectedly slow acceleration.

WO 2006/129853 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Description

Hybrid Vehicle and Control Method of Hybrid Vehicle

Technical Field

5 [0001] The present invention relates to a hybrid vehicle and its control method. More specifically the invention pertains to a hybrid vehicle equipped with an internal combustion engine capable of outputting driving power and at least one motor capable of outputting driving power, as well as a control method
10 of such a hybrid vehicle.

Background Art

15 [0002] One proposed hybrid vehicle has an engine and a generator motor connected to an output shaft linked to an axle via a planetary gear, and a driving motor connected to the axle (see, for example, Japanese Patent Laid-Open Gazette No. H10-325345). In this prior art structure, the driving motor is used to start the hybrid vehicle under an engine stop condition and, when the vehicle speed reaches 10 km/h, the engine starts to output the
20 power for driving.

Disclosure of the Invention

25 [0003] When the driver requires sudden acceleration for a jackrabbit start, the prior art hybrid vehicle may undesirably make the driver feel the unexpectedly slow acceleration immediately after a start and worsen the driver's drive feeling.

The motor generally outputs a large torque at a low rotation speed but decreases its maximum torque output with an increase in rotation speed. In response to the driver's requirement for sudden acceleration, the driving motor outputs a large torque 5 to make a jackrabbit start of the hybrid vehicle. The driving motor, however, decreases its maximum torque output with an increase in vehicle speed. The sum of the output torque from the driving motor and the output torque from the engine is thus required to satisfy a torque demand for driving the hybrid 10 vehicle. A start of the engine, however, takes some time, so that a start of torque output from the engine may be behind a decrease in torque output from the driving motor. In such cases, the driver feels the unexpectedly slow acceleration. The driver may similarly feel the unexpectedly slow acceleration 15 at the time of restarting the engine and accelerating the hybrid vehicle driven in the motor drive mode.

[0004] In a hybrid vehicle equipped with an internal combustion engine that is capable of outputting driving power and with at least one motor that is capable of outputting driving power and 20 in a control method of the hybrid vehicle, the object of the invention is thus to ensure smooth output of a driving force for vehicle start or acceleration under an operation stop condition of the internal combustion engine. In a hybrid vehicle equipped with an internal combustion engine that is 25 capable of outputting driving power and with at least one motor that is capable of outputting driving power and in a control

method of the hybrid vehicle, the object of the invention is to prevent the driver from feeling unexpectedly slow acceleration at a time of vehicle start or acceleration under an operation stop condition of the internal combustion engine.

5 [0005] In order to attain at least part of the above and the other related objects, the hybrid vehicle of the invention and the control method of the hybrid vehicle have the configurations discussed below.

[0006] The present invention is directed to a hybrid vehicle 10 equipped with an internal combustion engine capable of outputting driving power and with at least one motor capable of outputting driving power. The hybrid vehicle includes: an auto stop restart module that automatically stops the internal combustion engine upon satisfaction of a preset engine stop 15 condition and automatically restarts the internal combustion engine upon satisfaction of a preset engine start condition; a driving force demand setting module that sets a driving force demand required for driving the hybrid vehicle; and a control module that controls the internal combustion engine and the 20 motor so as to ensure output of a driving force based on the driving power demand set by the driving force demand setting module while imposing restriction on operation of the motor in response to setting of a driving force demand for vehicle start or acceleration by the driving force demand setting module upon 25 satisfaction of the preset engine start condition during an auto stop of the internal combustion engine, the control module

removing the restriction on the operation of the motor upon satisfaction of a predetermined restriction cancellation condition.

[0007] In response to setting of a driving force demand for 5 vehicle start or acceleration upon satisfaction of the preset engine start condition during an auto stop of the internal combustion engine, the hybrid vehicle of the invention controls the internal combustion engine and the motor to impose restriction on operation of the motor until satisfaction of the 10 predetermined restriction cancellation condition while ensuring output of a driving force equivalent to the driving power demand. The restriction on the operation of the motor results in a smooth variation in total driving force from a motor-only output mode to an engine-motor output mode with a 15 start of the internal combustion engine. This arrangement effectively ensures smooth output of the driving force and desirably prevents the driver from feeling the unexpectedly slow acceleration. The terminology 'in response to setting of a driving force demand for vehicle start or acceleration upon 20 satisfaction of the preset engine start condition during an auto stop of the internal combustion engine' includes 'at a time of starting the hybrid vehicle with a restart of the internal combustion engine in a vehicle stop state under the auto stop condition of the internal combustion engine' and 'at a time of 25 accelerating the hybrid vehicle with a restart of the internal combustion engine in a drive mode with output power from the

motor under the auto stop condition of the internal combustion engine'.

[0008] In one preferable application of the hybrid vehicle of the invention, the restriction imposed on the operation of the motor may prohibit power output from the motor or may hold a level of power output from the motor. In this application, a certain wait time elapses before output of a required power from the internal combustion engine. This arrangement more effectively ensures smooth output of the driving force after satisfaction of the predetermined restriction cancellation condition and prevents the driver from feeling the unexpectedly slow acceleration.

[0009] In another preferable application of the hybrid vehicle of the invention, the predetermined restriction cancellation condition may be elapse of a preset wait time since setting of the driving force demand for vehicle start or acceleration. The preset wait time may be a time period that does not make a general driver feel uncomfortable with a response to vary an acceleration after the driver's accelerator operation. This arrangement effectively prevents the driver from feeling uncomfortable at the time of vehicle start or at the time of vehicle acceleration due to the restricted operation of the motor.

[0010] In still another preferable application of the hybrid vehicle of the invention, the preset engine start condition may include a condition that the driving force demand set by the

driving force demand setting module is not less than a predetermined level. This arrangement enables a quicker start of the internal combustion engine, compared with an auto start of the internal combustion engine that starts the internal

5 combustion engine when the vehicle speed reaches a preset speed level. This arrangement more effectively ensures smooth output of the driving force at the time of vehicle start or at the time of vehicle acceleration and prevents the driver from feeling the unexpectedly slow acceleration.

10 [0011] In further still another preferable application, the hybrid vehicle of the invention may include an electric power-mechanical power input output mechanism connected with an output shaft of the internal combustion engine and an axle, and the mechanism may output at least part of the power of the

15 internal combustion engine to the axle through input and output of electric power and mechanical power. In this application, the electric power-mechanical power input output mechanism may include: a three shaft-type power input output unit linked to three shafts, the output shaft of the internal combustion engine, the axle, and a rotating shaft, and the unit may automatically input and output power from and to a residual one shaft based on powers input from and output to any two shafts among the three shafts; and a generator that inputs and outputs power from and to the rotating shaft. Moreover, the electric power-mechanical

20 power input output mechanism may include a pair-rotor motor that has a first rotor connected to the output shaft of the internal

25

combustion engine and a second rotor connected to the axle and is driven to rotate through relative rotation of the first rotor to the second rotor. In this application, the motor may input and output power from and to an axle that receives output of 5 power from the internal combustion engine. Further, the motor may input and output power from and to another axle different from an axle that receives output of power from the internal combustion engine. Moreover, the motor may be either one or both of a first motor inputting and outputting power from and to one 10 axle that receives output of power from the internal combustion engine and a second motor inputting and outputting power from and to another axle different from the one axle.

[0012] The present invention is also directed to a control method of a hybrid vehicle equipped with an internal combustion 15 engine capable of outputting driving power and at least one motor capable of outputting driving power, and automatically stopping the internal combustion engine upon satisfaction of a preset engine stop condition and automatically restarting the internal combustion engine upon satisfaction of a preset engine 20 start condition. The control method includes the steps of: controlling the internal combustion engine and the motor so as to ensure output of a driving force based on the driving power demand set by the driving force demand setting module while imposing restriction on operation of the motor in response to 25 setting of a driving force demand for vehicle start or acceleration by the driving force demand setting module upon

satisfaction of the preset engine start condition during an auto stop of the internal combustion engine; and removing the restriction on the operation of the motor upon satisfaction of a predetermined restriction cancellation condition.

5 [0013] In response to a drive request upon satisfaction of the preset engine start condition during an auto stop of the internal combustion engine, the control method of the invention controls the internal combustion engine and the motor to impose restriction on operation of the motor until satisfaction of the 10 predetermined restriction cancellation condition, while ensuring output of a driving force equivalent to a driving power demand required for driving the hybrid vehicle. The restriction on the operation of the motor results in a smooth variation in total driving force from a motor-only output mode 15 to an engine-motor output mode with a start of the internal combustion engine. This arrangement effectively ensures smooth output of the driving force at the time of vehicle start or at the time of vehicle acceleration and desirably prevents the driver from feeling the unexpectedly slow acceleration.

20

Brief Description of the Drawings

Fig. 1 schematically illustrates the configuration of a hybrid vehicle in one embodiment of the invention;

25 Fig. 2 is a flowchart showing an engine-restart, vehicle-start control routine executed by a hybrid electronic control unit mounted on the hybrid vehicle of the embodiment;

Fig. 3 is a flowchart showing a drive control routine executed by the hybrid electronic control unit;

Fig. 4 shows one example of a torque demand setting map;

Fig. 5 shows a relation between torque command T_{m1}^* of 5 a motor MG1 and rotation speed N_e of an engine at a start of the engine;

Fig. 6 is an alignment chart showing torque-rotation speed dynamics of respective rotational elements of a power distribution integration mechanism at a start of the engine;

10 Fig. 7 shows an efficient operation curve of the engine to set a target rotation speed N_e^* and a target torque T_e^* ;

Fig. 8 is an alignment chart showing torque-rotation speed dynamics of the respective rotational elements of the power distribution integration mechanism;

15 Fig. 9 shows comparison between time variations of vehicle acceleration in the embodiment and in a comparative example;

Fig. 10 is a flowchart showing an engine-restart, vehicle-acceleration control routine;

20 Fig. 11 schematically shows the structure of another hybrid vehicle in one modified example; and

Fig. 12 schematically shows the structure of still another hybrid vehicle in another modified example.

25 **Best Modes of Carrying Out the Invention**

[0014] One mode of carrying out the invention is discussed below

as a preferred embodiment. Fig. 1 schematically illustrates the construction of a hybrid vehicle 20 with a power output apparatus mounted thereon in one embodiment of the invention. As illustrated, the hybrid vehicle 20 of the embodiment includes

5 an engine 22, a three shaft-type power distribution integration mechanism 30 that is linked with a crankshaft 26 functioning as an output shaft of the engine 22 via a damper 28, a motor MG1 that is linked with the power distribution integration mechanism 30 and is capable of generating electric power, a

10 reduction gear 35 that is attached to a ring gear shaft 32a functioning as a drive shaft connected with the power distribution integration mechanism 30, another motor MG2 that is linked with the reduction gear 35, and a hybrid electronic control unit 70 that controls the whole power output apparatus.

15 [0015] The engine 22 is an internal combustion engine that uses a hydrocarbon fuel, such as gasoline or light oil, to output power. An engine electronic control unit (hereafter referred to as engine ECU) 24 receives signals from diverse sensors that detect operating conditions of the engine 22, and takes charge

20 of operation control of the engine 22, for example, fuel injection control, ignition control, and intake air flow regulation. The engine ECU 24 communicates with the hybrid electronic control unit 70 to control operations of the engine 22 in response to control signals transmitted from the hybrid

25 electronic control unit 70 while outputting data relating to the operating conditions of the engine 22 to the hybrid

electronic control unit 70 according to the requirements.

[0016] The power distribution and integration mechanism 30 has a sun gear 31 that is an external gear, a ring gear 32 that is an internal gear and is arranged concentrically with the sun gear 31, multiple pinion gears 33 that engage with the sun gear 31 and with the ring gear 32, and a carrier 34 that holds the multiple pinion gears 33 in such a manner as to allow free revolution thereof and free rotation thereof on the respective axes. Namely the power distribution and integration mechanism 10 30 is constructed as a planetary gear mechanism that allows for differential motions of the sun gear 31, the ring gear 32, and the carrier 34 as rotational elements. The carrier 34, the sun gear 31, and the ring gear 32 in the power distribution and integration mechanism 30 are respectively coupled with the 15 crankshaft 26 of the engine 22, the motor MG1, and the reduction gear 35 via ring gear shaft 32a. While the motor MG1 functions as a generator, the power output from the engine 22 and input through the carrier 34 is distributed into the sun gear 31 and the ring gear 32 according to the gear ratio. While the motor 20 MG1 functions as a motor, on the other hand, the power output from the engine 22 and input through the carrier 34 is combined with the power output from the motor MG1 and input through the sun gear 31 and the composite power is output to the ring gear 32. The power output to the ring gear 32 is thus finally 25 transmitted to the driving wheels 63a and 63b via the gear mechanism 60, and the differential gear 62 from ring gear shaft

32a.

[0017] Both the motors MG1 and MG2 are known synchronous motor generators that are driven as a generator and as a motor. The motors MG1 and MG2 transmit electric power to and from a battery 50 via inverters 41 and 42. Power lines 54 that connect the inverters 41 and 42 with the battery 50 are constructed as a positive electrode bus line and a negative electrode bus line shared by the inverters 41 and 42. This arrangement enables the electric power generated by one of the motors MG1 and MG2 5 to be consumed by the other motor. The battery 50 is charged with a surplus of the electric power generated by the motor MG1 or MG2 and is discharged to supplement an insufficiency of the electric power. When the power balance is attained between the motors MG1 and MG2, the battery 50 is neither charged nor 10 discharged. Operations of both the motors MG1 and MG2 are controlled by a motor electronic control unit (hereafter referred to as motor ECU) 40. The motor ECU 40 receives diverse signals required for controlling the operations of the motors MG1 and MG2, for example, signals from rotational position 15 detection sensors 43 and 44 that detect the rotational positions of rotors in the motors MG1 and MG2 and phase currents applied to the motors MG1 and MG2 and measured by current sensors (not shown). The motor ECU 40 outputs switching control signals to the inverters 41 and 42. The motor ECU 40 communicates with 20 the hybrid electronic control unit 70 to control operations of the motors MG1 and MG2 in response to control signals 25

transmitted from the hybrid electronic control unit 70 while outputting data relating to the operating conditions of the motors MG1 and MG2 to the hybrid electronic control unit 70 according to the requirements.

5 [0018] The battery 50 is under control of a battery electronic control unit (hereafter referred to as battery ECU) 52. The battery ECU 52 receives diverse signals required for control of the battery 50, for example, an inter-terminal voltage measured by a voltage sensor (not shown) disposed between terminals of the battery 50, a charge-discharge current measured by a current sensor (not shown) attached to the power line 54 connected with the output terminal of the battery 50, and a battery temperature T_b measured by a temperature sensor 51 attached to the battery 50. The battery ECU 52 outputs data relating to the state of the battery 50 to the hybrid electronic control unit 70 via communication according to the requirements.

10 The battery ECU 52 calculates a state of charge (SOC) of the battery 50, based on the accumulated charge-discharge current measured by the current sensor, for control of the battery 50.

15 [0019] The hybrid electronic control unit 70 is constructed as a microprocessor including a CPU 72, a ROM 74 that stores processing programs, a RAM 76 that temporarily stores data, and a non-illustrated input-output port, and a non-illustrated communication port. The hybrid electronic control unit 70 receives various inputs via the input port: an ignition signal from an ignition switch 80, a gearshift position SP from a

gearshift position sensor 82 that detects the current position of a gearshift lever 81, an accelerator opening Acc from an accelerator pedal position sensor 84 that measures a step-on amount of an accelerator pedal 83, a brake pedal position BP 5 from a brake pedal position sensor 86 that measures a step-on amount of a brake pedal 85, and a vehicle speed V from a vehicle speed sensor 88. The hybrid electronic control unit 70 communicates with the engine ECU 24, the motor ECU 40, and the battery ECU 52 via the communication port to transmit diverse 10 control signals and data to and from the engine ECU 24, the motor ECU 40, and the battery ECU 52, as mentioned previously.

[0020] The hybrid vehicle 20 of the embodiment thus constructed calculates a torque demand to be output to the ring gear shaft 32a functioning as the drive shaft, based on observed values 15 of a vehicle speed V and an accelerator opening Acc, which corresponds to a driver's step-on amount of an accelerator pedal 83. The engine 22 and the motors MG1 and MG2 are subjected to operation control to output a required level of power corresponding to the calculated torque demand to the ring gear 20 shaft 32a. The operation control of the engine 22 and the motors MG1 and MG2 selectively effectuates one of a torque conversion drive mode, a charge-discharge drive mode, and a motor drive mode. The torque conversion drive mode controls the operations of the engine 22 to output a quantity of power equivalent to 25 the required level of power, while driving and controlling the motors MG1 and MG2 to cause all the power output from the engine

22 to be subjected to torque conversion by means of the power distribution integration mechanism 30 and the motors MG1 and MG2 and output to the ring gear shaft 32a. The charge-discharge drive mode controls the operations of the engine 22 to output

5 a quantity of power equivalent to the sum of the required level of power and a quantity of electric power consumed by charging the battery 50 or supplied by discharging the battery 50, while driving and controlling the motors MG1 and MG2 to cause all or part of the power output from the engine 22 equivalent to the

10 required level of power to be subjected to torque conversion by means of the power distribution integration mechanism 30 and the motors MG1 and MG2 and output to the ring gear shaft 32a, simultaneously with charge or discharge of the battery 50. The motor drive mode stops the operations of the engine 22 and drives

15 and controls the motor MG2 to output a quantity of power equivalent to the required level of power to the ring gear shaft 32a. The torque conversion drive mode is equivalent to the charge-discharge drive mode without charge or discharge of the battery 50. There is accordingly no necessity to specifically

20 discriminate the torque conversion drive mode from the charge-discharge drive mode. The hybrid vehicle 20 of the embodiment stops the operation of the engine 22 and runs in the motor drive mode under the condition of a relatively small power demand for the vehicle, for example, during a low-speed drive

25 or during a vehicle stop. The hybrid vehicle of the embodiment drives the engine 22 and runs in the charge-discharge drive mode

under the condition of a large power demand or a large torque demand for the vehicle, for example, during a high-speed drive or on the occasion of an abrupt acceleration from the low speed.

The hybrid vehicle 20 of the embodiment drives the engine 22

5 and runs in the charge-discharge drive mode under the requirement of warming up the engine 22 or a catalyst packed in a catalyst converter for treatment of the emission from the engine 22 or under the requirement of charging the battery 50 having a low state of charge (SOC).

10 [0021] The description regards the operations of the hybrid vehicle 20 of the embodiment constructed as described above, especially a series of control operations to restart the engine 22 and start the hybrid vehicle 20 in response to the driver's heavy depression of the accelerator pedal 83 during a vehicle

15 stop with the operation stop of the engine 22. Fig. 2 is a flowchart showing an engine-restart, vehicle-start control routine executed by the hybrid electronic control unit 70. This engine restart control is triggered by the driver's depression of the accelerator pedal 83 and continues until complete fuel

20 combustion in the engine 22. Fig. 3 is a flowchart showing a drive control routine executed by the hybrid electronic control unit 70. The drive control is performed during a drive of the hybrid vehicle 20 in the charge-discharge drive mode after complete fuel combustion in the engine 22. The drive control

25 is repeated at preset time intervals, for example, at every several msec, after complete fuel combustion in the engine 22.

[0022] The engine-restart, vehicle-start control routine of Fig. 2 is triggered by the driver's heavy depression of the accelerator pedal 83 during a vehicle stop with the operation stop of the engine 22. In the engine-restart, vehicle-start control routine of Fig. 2, the CPU 72 of the hybrid electronic control unit 70 first inputs various data required for control, that is, the accelerator opening Acc from the accelerator pedal position sensor 84, the vehicle speed V from the vehicle speed sensor 88, rotation speeds Nm1 and Nm2 of the motors MG1 and MG2, a rotation speed Ne of the engine 22, and an input limit Win and an output limit Wout of the battery 50 (step S100). The rotation speed Ne of the engine 22 is computed from a detection signal of a crank position sensor (not shown) attached to the crankshaft 26 of the engine 22 and is received from the engine ECU 24 by communication. The rotation speeds Nm1 and Nm2 of the motors MG1 and MG2 are computed from the rotational positions of the respective rotors in the motors MG1 and MG2 detected by the rotational position detection sensors 43 and 44 and are received from the motor ECU 40 by communication. The input limit Win and the output limit Wout of the battery 50 are set based on the battery temperature Tb of the battery 50 measured by the temperature sensor 51 and the state of charge SOC of the battery 50 and are received from the battery ECU 52 by communication.

[0023] After the data input, the CPU 72 sets a torque demand Tr^* to be output to the ring gear shaft 32a or a driveshaft linked

with the drive wheels 63a and 63b as a required torque for the hybrid vehicle 20, based on the input accelerator opening Acc and the input vehicle speed V (step S110). A concrete procedure of setting the torque demand Tr^* in this embodiment stores in 5 advance variations in torque demand Tr^* against the accelerator opening Acc and the vehicle speed V as a torque demand setting map in the ROM 74 and reads the torque demand Tr^* corresponding to the given accelerator opening Acc and the given vehicle speed V from this torque demand setting map. One example of the torque 10 demand setting map is shown in Fig. 4.

[0024] The CPU 72 subsequently sets a torque command $Tm1^*$ of the motor MG1 according to the input rotation speed Ne of the engine 22 (step S120). Fig. 5 shows a relation between the torque command $Tm1^*$ of the motor MG1 and the rotation speed Ne 15 of the engine 22 as one example. Immediately after a start of the engine-restart, vehicle-start control routine at a time $t1$, the rating process sets a relatively large torque to the torque command $Tm1^*$ of the motor MG1 and quickly increases the rotation speed Ne of the engine 22. After a time $t2$ when the rotation 20 speed Ne of the engine 22 has passed through a resonant rotation speed area, the torque command $Tm1^*$ is set to a motoring torque required for stable motoring of the engine 22 to or over a threshold rotation speed $Nref$. Such setting reduces electric power consumption and a reactive force applied on the ring gear 25 shaft 32a or the driveshaft. At a time $t3$ when the rotation speed Ne of the engine 22 reaches the threshold rotation speed

Nref, the rating process sets the torque command $Tm1^*$ equal to 0. At a time $t5$, the complete fuel combustion in the engine 22 is identified, and the torque command $Tm1^*$ is set to a power generation torque required for power generation. The current 5 state in the processing flow is immediately after the start instruction of the engine 22, so that a relatively large torque is set to the torque command $Tm1^*$. Fig. 6 is an alignment chart showing torque-rotation speed dynamics of the respective rotational elements included in the power distribution 10 integration mechanism 30 at this moment. The left axis 'S' represents the rotation speed of the sun gear 31 that is equivalent to the rotation speed $Nm1$ of the motor MG1. The middle axis 'C' represents the rotation speed of the carrier 15 34 that is equivalent to the rotation speed Ne of the engine 22. The right axis 'R' represents the rotation speed Nr of the ring gear 32 that is equivalent to the product of the rotation speed $Nm2$ of the motor MG2 and a gear ratio Gr of the reduction gear 35.

[0025] After setting the torque command $Tm1^*$ of the motor MG1, 20 the CPU 72 specifies whether a preset wait time has elapsed since the start of this control routine (step S130). Until elapse of the preset wait time, the CPU 72 calculates a cancellation torque, which cancels out a torque applied to the ring gear shaft 32a or the driveshaft by the torque output of the motor MG1, 25 according to Equation (1) given below and set the calculated cancellation torque to a torque command $Tm2^*$ of the motor MG2

(step S140) :

$$Tm2^* = Tm1^* / (\rho \cdot Gr) \quad (1)$$

5 The wait time represents a time period elapsing between the driver's depression of the accelerator pedal 83 and an actual start of the hybrid vehicle 20 with torque application and is determined not to make the driver feel uncomfortable with a poor response. The wait time is set equal to, for example, 0.2 to
10 0.3 seconds. The CPU 72 then sends the torque commands $Tm1^*$ and $Tm2^*$ of the motors MG1 and MG2 to the motor ECU 40 (step S180) and identifies the value of a start flag $Fstart$ (step S190). The start flag $Fstart$ is set to 1 on a start of fuel injection and ignition of the engine 22. Upon identification of the start
15 flag $Fstart$ equal to 0, the rotation speed Ne of the engine 22 is compared with a preset threshold rotation speed $Nref$ (step S200). When the rotation speed Ne of the engine 22 is lower than the preset threshold rotation speed $Nref$ (step S200: No), the processing flow returns to step S100. The threshold
20 rotation speed $Nref$ represents a starting rotation speed for a start of fuel injection and ignition of the engine 22 and is set equal to, for example, 1000 rpm or 1200 rpm. When receiving the torque commands $Tm1^*$ and $Tm2^*$ of the motors MG1 and MG2, the motor ECU 40 drives and controls the motor MG1 to output
25 a torque equivalent to the torque command $Tm1^*$, while driving and controlling the motor MG2 to output a torque equivalent to

the torque command T_{m2}^* . The engine-restart, vehicle-start control routine repeats the above series of processing, until elapse of the preset wait time since the start of this routine (step S130). The motor MG2 accordingly outputs only the 5 cancellation torque that cancels out the torque applied to the ring gear shaft 32a or the driveshaft by the torque output of the motor MG1, but does not output a torque equivalent to the torque demand T_r^* corresponding to the driver's depression amount of the accelerator pedal 83. The motor MG2 is thus under 10 operation control until elapse of the preset wait time. This involves prohibition of the power output to the ring gear shaft 32a or the driveshaft.

[0026] When the preset wait time has elapsed since the start of this engine-restart, vehicle-start control routine, the CPU 15 72 calculates an upper torque restriction T_{max} as a maximum torque output from the motor MG2 according to Equation (2) given below (step S150) :

$$T_{max} = (W_{out} - T_{m1}^* \cdot N_{m1}) / N_{m2} \quad (2)$$

The upper torque restriction T_{max} is given by dividing a difference between the output limit W_{out} of the battery 50 and power consumption (power generation) of the motor MG1, which is the product of the torque command T_{m1}^* and the current rotation speed N_{m1} of the motor MG1, by the current rotation speed N_{m2} of the motor MG2. The CPU 72 then calculates a 25

tentative motor torque T_{m2tmp} to be output from the motor MG2 from the torque demand Tr^* , the torque command T_{m1*} of the motor MG1, the gear ratio ρ of the power distribution integration mechanism 30, and the gear ratio Gr of the transmission 60 5 according to Equation (3) given below (step S160) :

$$T_{m2tmp} = (Tr^* + T_{m1*} / \rho) / Gr \quad (3)$$

The CPU 72 sets the smaller between the calculated upper torque 10 restriction T_{max} and the calculated tentative motor torque T_{m2tmp} to the torque command T_{m2*} of the motor MG2 (step S170). The CPU 72 then sends the torque commands T_{m1*} and T_{m2*} of the motors MG1 and MG2 to the motor ECU 40 (step S180) and compares the rotation speed Ne of the engine 22 with the preset threshold 15 rotation speed N_{ref} (step S200). When the rotation speed Ne of the engine 22 is lower than the threshold rotation speed N_{ref} (step S200: No), the processing flow returns to step S100. The torque command T_{m2*} of the motor MG2 set in this manner cancels out the motoring torque for motoring the engine 22 and is output 20 as the torque demand Tr^* to the ring gear shaft 32a or the driveshaft under restriction in the output limit of the battery 50. Equation (3) given above is readily introduced from the alignment chart of Fig. 6.

[0027] When the rotation speed Ne of the engine 22 reaches or 25 exceeds the preset threshold rotation speed N_{ref} during output of the torque equivalent to the torque demand Tr^* to the ring

gear shaft 32a with motoring the engine 22, the CPU 72 gives a start command to the engine ECU 24 to start fuel injection and ignition of the engine 22 and sets the start flag Fstart equal to 1 (step S210). The CPU 72 then detects complete or 5 incomplete fuel combustion of the engine 22 (step S220). In the event of incomplete fuel combustion, the processing flow goes back to step S100. Setting the start flag Fstart equal to 1 at step S210 gives a negative answer at step S190. The processing flow accordingly skips the specification of whether 10 the rotation speed Ne of the engine 22 reaches or exceeds the preset threshold rotation speed Nref at step S200 and immediately goes to step S220 for detection of complete or fuel combustion of the engine 22. In response to detection of complete fuel combustion of the engine 22, the processing flow 15 terminates the engine-restart, vehicle-start control routine of Fig. 2 and subsequently starts and repeatedly executes the drive control routine of Fig. 3.

[0028] Like step S100 in the engine-restart, vehicle-start control routine of Fig. 2, the CPU 72 of the hybrid electronic 20 control unit 70 first inputs various data required for control, that is, the accelerator opening Acc from the accelerator pedal position sensor 84, the vehicle speed V from the vehicle speed sensor 88, the rotation speeds Nm1 and Nm2 of the motors MG1 and MG2, the rotation speed Ne of the engine 22, and the input 25 limit Win and the output limit Wout of the battery 50 at step S300 in the drive control routine of Fig. 3. The CPU 72

subsequently refers to the torque demand setting map of Fig. 4 to set the torque demand Tr^* , which is to be output to the ring gear shaft 32a or the driveshaft, and sets a vehicle power demand P^* required for the hybrid vehicle 20, based on the input 5 accelerator opening Acc and the input vehicle speed V (step S310). The vehicle power demand P^* is calculated as the sum of the product of the torque demand Tr^* and a rotation speed Nr of the ring gear shaft 32a or the driveshaft, a charge-discharge power demand Pb^* to be charged into or 10 discharged from the battery 50, and a potential loss. The rotation speed Nr of the ring gear shaft 32a is obtained by multiplying the vehicle speed V by a preset conversion factor k .

[0029] The vehicle power demand P^* is compared with a previous 15 engine power demand Pe^* (previous Pe^*), which has been set in a previous cycle of this drive control routine as a power required for the engine 22 (step S320). When the previous engine power demand Pe^* is less than the vehicle power demand P^* (step S320: Yes), the CPU 72 adds a preset rate value Prt 20 to the previous engine power demand Pe^* and sets the smaller between the result of the addition and the vehicle power demand P^* to a new engine power demand Pe^* (step S330). When the previous engine power demand Pe^* is not less than the vehicle power demand P^* (step S320: No), on the other hand, the CPU 72 25 subtracts the preset rate value Prt from the previous engine power demand Pe^* and sets the greater between the result of the

subtraction and the vehicle power demand P^* to a new engine power demand Pe^* (step S340). The rate value Prt is set equal to or slightly lower than an upper limit for a smooth change of the power output from the engine 22 during the interval of the 5 repeated execution of this drive control routine. Updating the engine power demand Pe^* in this manner ensures a smooth change of the power output from the engine 22. The current state in the processing flow is immediately after the restart and complete fuel combustion of the engine 22 in response to the 10 driver's heavy depression of the accelerator pedal 83. The vehicle power demand P^* is greater than the previous engine power demand Pe^* (initial value =0). At this moment, the sum of the previous engine power demand Pe^* and the preset rate value Prt is set to the new engine power demand Pe^* . During the 15 repeated execution of the drive control routine, the engine power demand Pe^* is sequentially updated to gradually approach the vehicle power demand P^* .

[0030] After updating the engine power demand Pe^* , the CPU 72 sets a target rotation speed Ne^* and a target torque Te^* of the 20 engine 22 corresponding to the new engine power demand Pe^* (step S350). The target rotation speed Ne^* and the target torque Te^* of the engine 22 are determined according to an efficient operation curve of ensuring efficient operations of the engine 22 and a curve of the engine power demand Pe^* . Fig. 7 shows 25 an efficient operation curve of the engine 22 to set the target rotation speed Ne^* and the target torque Te^* . As clearly shown

in Fig. 7, the target rotation speed N_{e^*} and the target torque T_{e^*} are given as an intersection of the efficient operation curve and a curve of constant engine power demand P_{e^*} ($= N_{e^*} \times T_{e^*}$).

5 [0031] After setting the target rotation speed N_{e^*} and the target torque T_{e^*} of the engine 22, the CPU 72 calculates a target rotation speed N_{m1^*} of the motor MG1 from the target rotation speed N_{e^*} of the engine 22, the rotation speed N_r ($= N_{m2}/G_r$) of the ring gear shaft 32a, and the gear ratio ρ of the power 10 distribution integration mechanism 30 according to Equation (4) given below, while calculating the torque command T_{m1^*} of the motor MG1 from the calculated target rotation speed N_{m1^*} and the current rotation speed N_{m1} of the motor MG1 according to Equation (5) given below (step S360):

15

$$N_{m1^*} = N_{e^*} \cdot (1+\rho) / \rho - N_{m2} / (G_r \cdot \rho) \quad (4)$$

$$T_{m1^*} = \text{Previous } T_{m1^*} + k_1(N_{m1^*} - N_{m1}) + k_2 \int (N_{m1^*} - N_{m1}) dt \quad (5)$$

Equation (4) is a dynamic relational expression of the 20 rotational elements included in the power distribution integration mechanism 30. Fig. 8 is an alignment chart showing torque-rotation speed dynamics of the respective rotational elements included in the power distribution integration mechanism 30. Two upward thick arrows on the axis 'R' respectively show a torque that is transmitted to the ring gear shaft 32a when the torque T_{e^*} is output from the engine 22 that

is in steady operation at a specific drive point of the target rotation speed N_e^* and the target torque T_e^* , and a torque that is applied to the ring gear shaft 32a via the reduction gear 35 when a torque T_{m2}^* is output from the motor MG2. Equation 5 (4) is readily introduced from the alignment chart of Fig. 8 Equation (5) is a relational expression of feedback control to drive and rotate the motor MG1 at the target rotation speed N_{m1}^* . In Equation (5) given above, 'k1' in the second term and 'k2' in the third term on the right side respectively denote a gain 10 of the proportional and a gain of the integral term.

[0032] After calculation of the target rotation speed N_{m1}^* and the torque command T_{m1}^* of the motor MG1, the CPU 72 calculates a lower torque restriction T_{min} and the upper torque restriction T_{max} as minimum and maximum torques output from the motor MG2 15 according to Equations (6) and (7) given below (step S370) :

$$T_{min} = (W_{in} - T_{m1}^* \cdot N_{m1}) / N_{m2} \quad (6)$$

$$T_{max} = (W_{out} - T_{m1}^* \cdot N_{m1}) / N_{m2} \quad (7)$$

20 The lower torque restriction T_{min} and the upper torque restriction T_{max} are respectively given by dividing a difference between the input limit W_{in} of the battery 50 and power consumption (power generation) of the motor MG1, which is the product of the torque command T_{m1}^* and the current 25 rotation speed N_{m1} of the motor MG1, and a difference between the output limit W_{out} of the battery 50 and the power consumption

(power generation) of the motor MG1 by the current rotation speed N_{m2} of the motor MG2. The CPU 72 then calculates the tentative motor torque T_{m2tmp} to be output from the motor MG2 from the torque demand Tr^* , the torque command T_{m1^*} of the motor MG1, the gear ratio ρ of the power distribution integration mechanism 30, and the gear ratio Gr of the transmission 60 according to Equation (8) given below (step S380) :

$$T_{m2tmp} = (Tr^* + T_{m1^*} / \rho) / Gr \quad (8)$$

10

The CPU 72 limits the tentative motor torque T_{m2tmp} to the range between the calculated lower torque restriction T_{min} and upper torque restriction T_{max} to set the torque command T_{m2^*} of the motor MG2 (step S390). Setting the torque command T_{m2^*} of the motor MG2 in this manner restricts the torque demand Tr^* to be output to the ring gear shaft 32a or the driveshaft within the range between the input limit W_{in} and the output limit W_{out} of the battery 50. Equation (8) is readily introduced from the alignment chart of Fig. 8.

20 [0033] After setting the target rotation speed N_{e^*} and the target torque Te^* of the engine 22 and the torque commands T_{m1^*} and T_{m2^*} of the motors MG1 and MG2, the CPU 72 sends the target rotation speed N_{e^*} and the target torque Te^* of the engine 22 to the engine ECU 24 and the torque commands T_{m1^*} and T_{m2^*} of the motors MG1 and MG2 to the motor ECU 40 (step S400) and exits 25 from this drive control routine. The engine ECU 24 receives

the target rotation speed Ne^* and the target torque Te^* and performs fuel injection control and ignition control of the engine 22 to drive the engine 22 at a specified drive point of the target rotation speed Ne^* and the target torque Te^* . The 5 motor ECU 40 receives the torque commands $Tm1^*$ and $Tm2^*$ and performs switching control of the switching elements included in the respective inverters 41 and 42 to drive the motor MG1 with the torque command $Tm1^*$ and the motor MG2 with the torque command $Tm2^*$.

10 [0034] Fig. 9 shows comparison between time variations of vehicle acceleration in the embodiment and in a comparative example when the hybrid vehicle 20 starts in response to the driver's heavy depression of the accelerator pedal 83 during a stop with the operation stop of the engine 22. A solid line 15 curve represents a time variation of vehicle acceleration in the embodiment, and a one-dot chain line curve represents a time variation of vehicle acceleration in the comparative example. A broken line curve represents contribution of the power output from the engine 22 to the vehicle acceleration. The comparative 20 example controls the motor MG2 to output the torque demand Tr^* corresponding to the accelerator opening Acc immediately after the driver's heavy depression of the accelerator pedal 83 without waiting until elapse of the preset wait time. In the comparative example, the motor MG2 starts outputting the torque 25 demand Tr^* corresponding to the accelerator opening Acc at a time $t10$ when the driver steps on the accelerator pedal 83. The

immediate torque output from the motor MG2 immediately generates the vehicle acceleration. The insufficient power output restricts the increase in vehicle acceleration for a time period T2 until a time t_{14} when the contribution of the power output from the engine 22 abruptly increases. This relatively long time period T2 before the abrupt increase in contribution of the power output from the engine 22 undesirably causes the driver to feel the unexpectedly slow acceleration. In the embodiment, on the other hand, the motor MG2 starts outputting the torque demand Tr^* corresponding to the accelerator opening Acc at a time t_{11} after elapse of a preset wait time (for example, 0.3 seconds) since the driver's depression of the accelerator pedal 83. The insufficient power output restricts the increase in vehicle acceleration for a time period T1 until the time t_{14} when the contribution of the power output from the engine 22 abruptly increases. The time period T1 is shorter than the time period T2. The control of the embodiment thus prevents the driver from feeling the unexpectedly slow acceleration. As mentioned previously, the preset wait time elapsing the driver's depression of the accelerator pedal 83 and an actual output of the torque demand Tr^* from the motor MG2 is determined not to make the driver feel uncomfortable with a poor response. The wait time until generation of the vehicle acceleration accordingly does not make the driver feel strange.

[0035] As described above, in response to the driver's heavy depression of the accelerator pedal 83 during a vehicle stop

with the operation stop of the engine 22, the hybrid vehicle 20 of the embodiment waits until elapse of the preset wait time, which is determined not to make the driver feel uncomfortable with a poor response, and then starts output of the torque demand 5 Tr^* to the ring gear shaft 32a or the driveshaft. Such control desirably prevents the driver from feeling the unexpectedly slow acceleration, which is caused by the restricted vehicle acceleration until a start of the engine 22 to output sufficient power and make significant contribution to the vehicle 10 acceleration. This arrangement ensures smooth torque output on a restart of the engine 22 and improves the driver's drive feeling.

[0036] The hybrid vehicle 20 of the embodiment controls the motor MG2 not to start outputting torque to the ring gear shaft 15 32a or the driveshaft until elapse of the preset wait time since the driver's depression of the accelerator pedal 83. One possible modification may control the motor MG2 to output a limited level of torque to the ring gear shaft 32a or the driveshaft until elapse of the preset wait time since the 20 driver's depression of the accelerator pedal 83.

[0037] In the hybrid vehicle 20 of the embodiment, the wait time elapsing the driver's depression of the accelerator pedal 83 and an actual output of the torque demand Tr^* from the motor MG2 is determined not to make the driver feel uncomfortable with 25 a poor response. The wait time is set equal to 0.2 to 0.3 seconds in the embodiment. The wait time may be set to a shorter time

such as 0.1 second or to a longer time such as 0.4 to 0.5 seconds.

Setting the longer time to the wait time may cause the driver to feel slightly uncomfortable with a poor response.

[0038] The embodiment regards the engine-restart,

5 vehicle-start control to restart the engine 22 and start the hybrid vehicle 20 in response to the driver's heavy depression of the accelerator pedal 83 during a vehicle stop with an auto stop of the engine 22. This control technique is also applicable to accelerate the hybrid vehicle 20 in response to
10 the driver's heavy depression of the accelerator pedal 83 in the motor drive mode with an auto stop of the engine 22. In the motor drive mode, the hybrid vehicle 20 is driven with the output power of the motor MG2. In this application, an engine-restart, vehicle-acceleration control routine shown in
15 the flowchart of Fig. 10 is executed, instead of the engine-restart, vehicle-start control routine of Fig. 2. In the engine-restart, vehicle-acceleration control routine of Fig. 10, the CPU 72 of the hybrid electronic control unit 70 first holds the torque command T_{m2}^* of the motor MG2 as a holding
20 torque T_{hold} (step S100B) and executes the processing of steps S100 through S120 in the same manner as the engine-restart, vehicle-start control routine of Fig. 2. Until elapse of a preset wait time, which is determined not to make the driver feel uncomfortable with a poor response, the torque command T_{m2}^* of the motor MG2 is set to the sum of the holding torque T_{hold}
25 and the cancellation torque (step S140B). Here the

cancellation torque cancels out the output torque of the motor MG2 for motoring the engine 22 (torque calculated by the right side of Equation (1) given previously). This torque command $Tm2^*$ of the motor MG2 is sent with the torque command $Tm1^*$ of the motor MG1 to the motor ECU 40 (step S180). This modified control procedure holds the output torque to the ring gear shaft 32a or the driveshaft until elapse of the preset wait time, which is determined not to make the driver feel uncomfortable with a poor response. After the elapse of the preset wait time, the processing of and after step S150 is executed in the same manner as the engine-restart, vehicle-start control routine of Fig. 2. In response to detection of complete fuel combustion of the engine 22, the processing flow terminates this engine-restart, vehicle-acceleration control routine of Fig. 10 and repeatedly executes the drive control routine of Fig. 3. This application outputs the torque demand Tr^* to the ring gear shaft 32a or the driveshaft for acceleration of the hybrid vehicle 20 in the motor drive mode, after elapse of the preset wait time that is determined not to make the driver feel uncomfortable with a poor response. Such control desirably prevents the driver from feeling the unexpectedly slow acceleration, which is caused by the restricted vehicle acceleration until a start of the engine 22 to output sufficient power and make significant contribution to the vehicle acceleration. This arrangement ensures smooth torque output for acceleration of the hybrid vehicle 20, which is driven with the output power of the motor MG2 in the motor

drive mode with an auto stop of the engine 22, and improves the driver's drive feeling.

[0039] In this application, the hybrid vehicle 20 executes the engine-restart, vehicle-acceleration control routine of Fig.

5 10 in response to an acceleration request. The engine-restart, vehicle-acceleration control of this application holds the torque level output from the motor MG2 to the ring gear shaft 32a until elapse of the preset wait time, which is determined not to make the driver feel uncomfortable with a poor response.

10 The control of holding the output torque level is, however, not essential, and the requirement is restricted power output. One possible modification may set the torque command T_{m2*} of the motor MG2 to gradually increase the output torque to the ring gear shaft 32a, instead of holding the output torque level.

15 [0040] In the hybrid vehicle 20 of the embodiment described above, the power of the motor MG2 goes through the change speed by the reduction gear 35 and is output to the ring gear shaft 32a or the driveshaft. The technique of the invention is, however, not restricted to this configuration but may be adopted 20 in a hybrid vehicle 120 of a modified configuration shown in Fig. 11, where the power of the motor MG2 is transmitted to a different axle (an axle linked to wheels 64a and 64b) from the axle connecting with the ring gear shaft 32a (the axle linked to the drive wheels 63a and 63b).

25 [0041] In the hybrid vehicle 20 of the embodiment, the power of the engine 22 is output via the power distribution

integration mechanism 30 to the ring gear shaft 32a or the driveshaft connected to the drive wheels 63a and 63b. The technique of the invention is, however, not restricted to this configuration but may also be applicable to a hybrid vehicle 5 220 of another modified configuration shown in Fig. 12. The hybrid vehicle 220 of Fig. 12 has a pair-rotor motor 230 including an inner rotor 232 connected to the crankshaft 26 of the engine 22 and an outer rotor 234 connected to a driveshaft for output of the power to the drive wheels 63a and 63b. The 10 pair-rotor motor 230 transmits part of the output power of the engine 22 to the driveshaft, while converting the residual engine output power into electric power.

[0042] The embodiment and its modified examples discussed above are to be considered in all aspects as illustrative and not 15 restrictive. There may be many other modifications, changes, and alterations without departing from the scope or spirit of the main characteristics of the present invention.

Industrial Applicability

20 [0043] The technique of the invention is preferably applied to automobile manufacturing industries and other relevant industries.

Claims:

1. A hybrid vehicle with an internal combustion engine capable of outputting driving power and at least one motor 5 capable of outputting driving power, said hybrid vehicle comprising:

an auto stop restart module that automatically stops said internal combustion engine upon satisfaction of a preset engine stop condition and automatically restarts said internal 10 combustion engine upon satisfaction of a preset engine start condition;

a driving force demand setting module that sets a driving force demand required for driving said hybrid vehicle; and

15 a control module that controls said internal combustion engine and said motor so as to ensure output of a driving force based on said driving power demand set by said driving force demand setting module while imposing restriction on operation of said motor in response to setting of a driving force demand for vehicle start or acceleration by said driving force demand 20 setting module upon satisfaction of said preset engine start condition during an auto stop of said internal combustion engine, said control module removing said restriction on said operation of said motor upon satisfaction of a predetermined restriction cancellation condition.

said restriction imposed on said operation of said motor prohibits power output from said motor.

3. A hybrid vehicle in accordance with claim 1, wherein
5 said restriction imposed on said operation of said motor holds
a level of power output from said motor.

4. A hybrid vehicle in accordance with claim 1, wherein
said predetermined restriction cancellation condition is
10 elapse of a preset wait time since setting of said driving force
demand for vehicle start or acceleration.

5. A hybrid vehicle in accordance with claim 4, wherein
said preset wait time is a time period that does not make a
15 general driver feel uncomfortable with a response to vary an
acceleration after the driver's accelerator operation.

6. A hybrid vehicle in accordance with claim 1, wherein
said preset engine start condition includes a condition that
20 said driving force demand set by said driving force demand
setting module is not less than a predetermined level.

7. A hybrid vehicle in accordance with claim 1, said hybrid
vehicle further comprising:

25 an electric power-mechanical power input output
mechanism connected with an output shaft of said internal

combustion engine and an axle, said mechanism outputting at least part of the power of said internal combustion engine to said axle through input and output of electric power and mechanical power.

5

8. A hybrid vehicle in accordance with claim 7, wherein said electric power-mechanical power input output mechanism includes : a three shaft-type power input output unit linked to three shafts, said output shaft of said internal combustion engine, said axle, and a rotating shaft, said unit automatically inputting and outputting power from and to a residual one shaft based on powers input from and output to any two shafts among said three shafts ; and a generator that inputs and outputs power from and to said rotating shaft.

15

9. A hybrid vehicle in accordance with claim 7, wherein said electric power-mechanical power input output mechanism includes a pair-rotor motor that has a first rotor connected to said output shaft of said internal combustion engine and a second rotor connected to said axle, said mechanism being driven to rotate through relative rotation of said first rotor to said second rotor.

10. A hybrid vehicle in accordance with claim 1, wherein said motor inputs and outputs power from and to an axle that receives output of power from said internal combustion engine.

11. A hybrid vehicle in accordance with claim 1, wherein
said motor inputs and outputs power from and to another axle
different from an axle that receives output of power from said
5 internal combustion engine.

12. A hybrid vehicle in accordance with claim 1, wherein
said motor is either one or both of a first motor inputting and
outputting power from and to one axle that receives output of
10 power from said internal combustion engine and a second motor
inputting and outputting power from and to another axle
different from said one axle.

13. A control method of a hybrid vehicle, said hybrid
15 vehicle being equipped with an internal combustion engine
capable of outputting driving power and at least one motor
capable of outputting driving power, said hybrid vehicle
automatically stopping said internal combustion engine upon
satisfaction of a preset engine stop condition and
20 automatically restarting said internal combustion engine upon
satisfaction of a preset engine start condition, said method
comprising the steps of:

controlling said internal combustion engine and said
motor so as to ensure output of a driving force based on said
25 driving power demand set by said driving force demand setting
module while imposing restriction on operation of said motor

40

in response to setting of a driving force demand for vehicle start or acceleration by said driving force demand setting module upon satisfaction of said preset engine start condition during an auto stop of said internal combustion engine; and

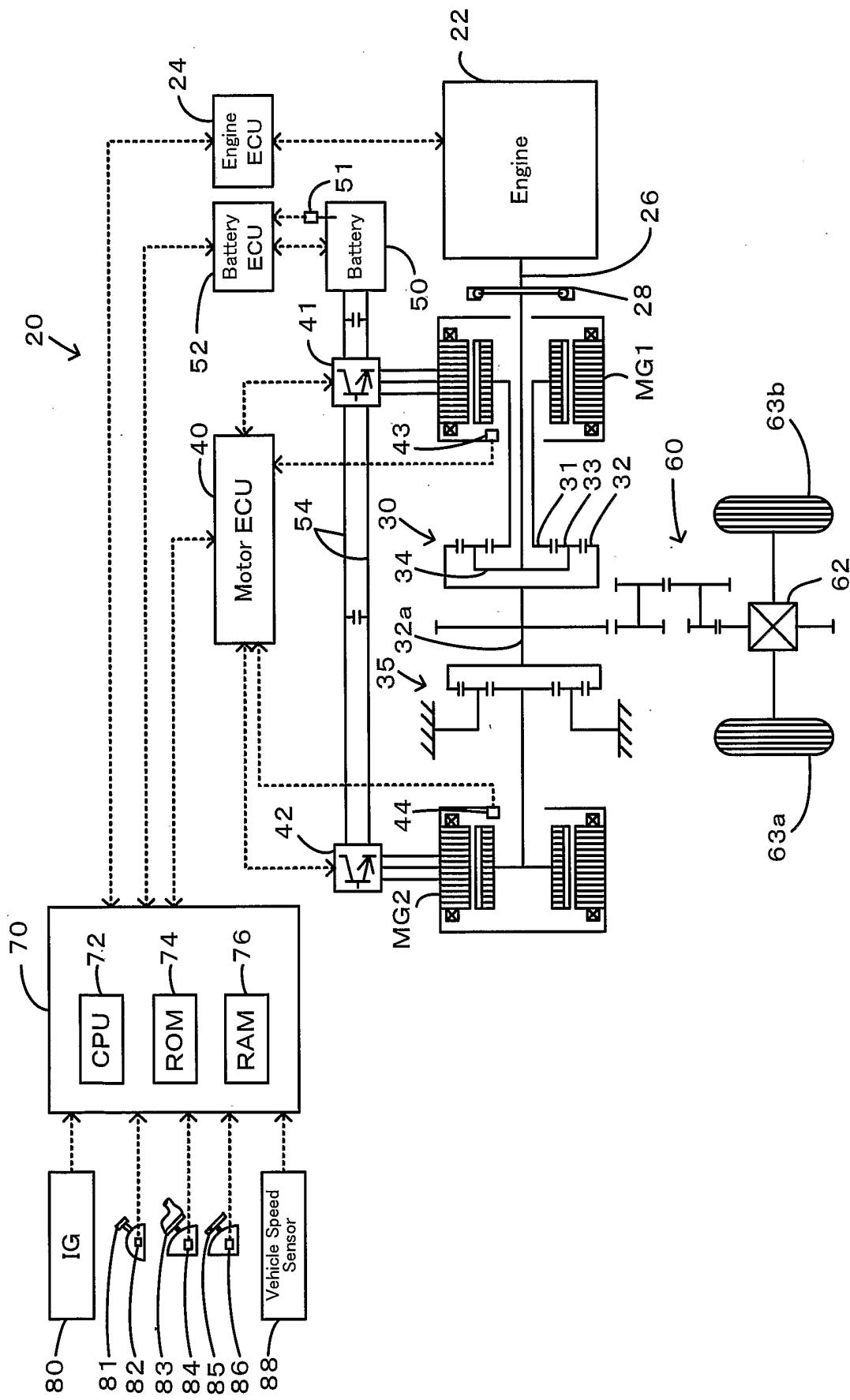
5 removing said restriction on said operation of said motor upon satisfaction of a predetermined restriction cancellation condition.

10

15

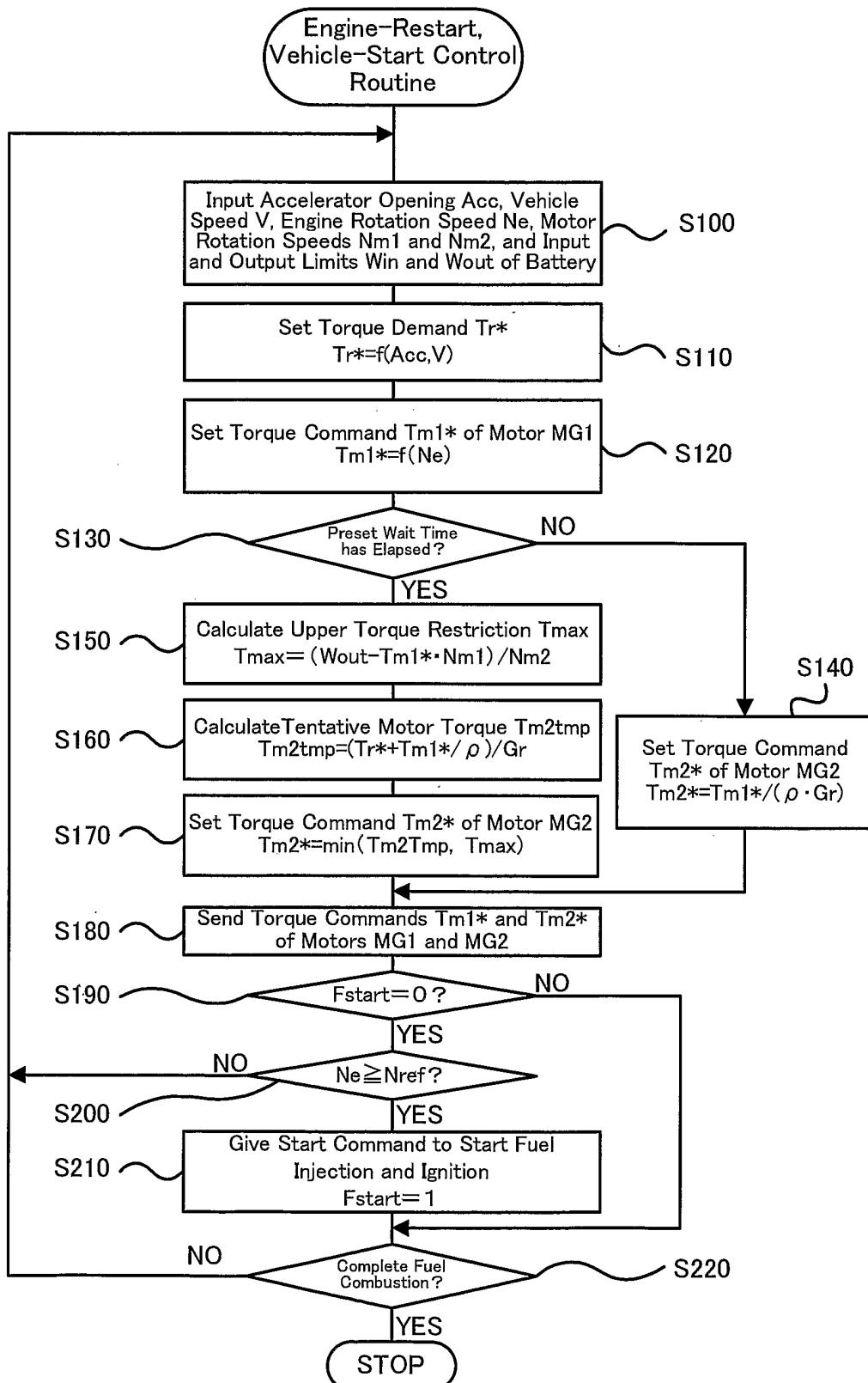
20

25

1/12
FIG.1

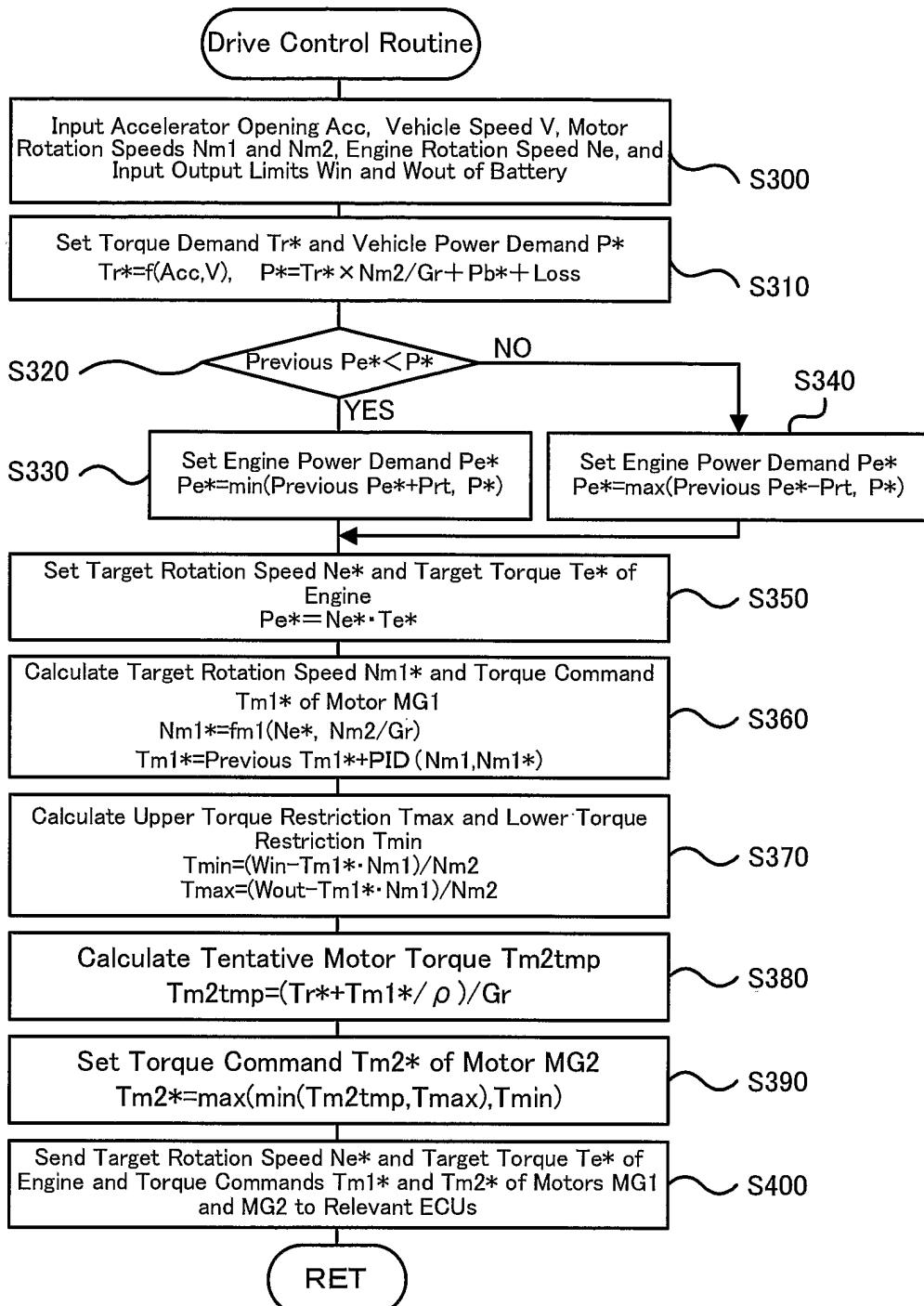
2/12

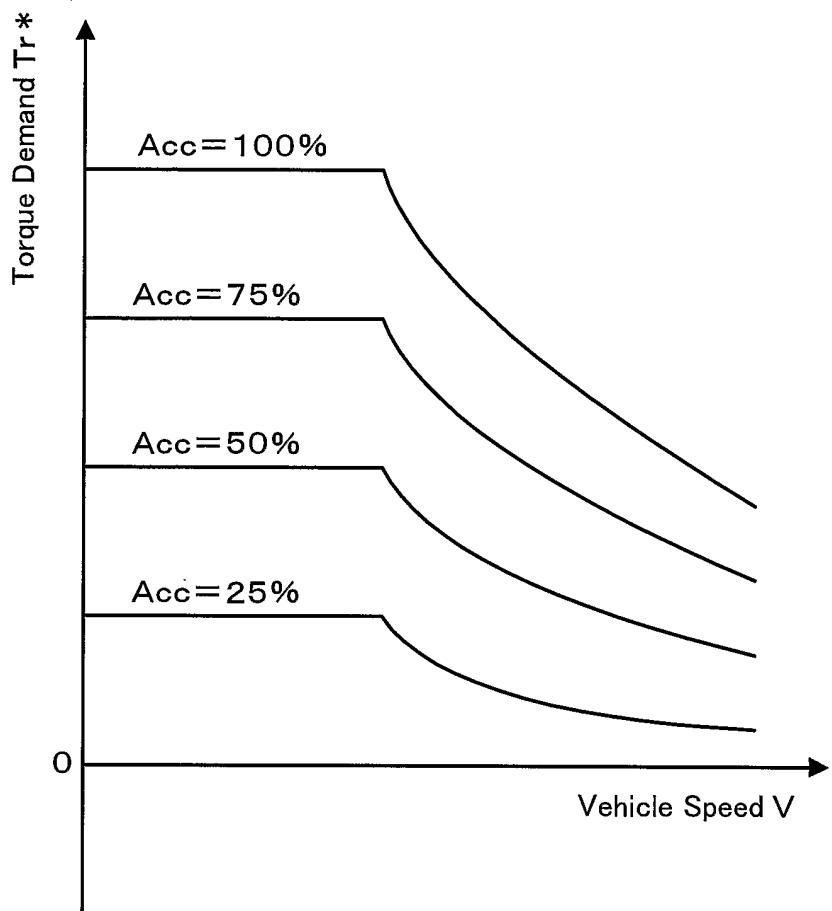
FIG.2

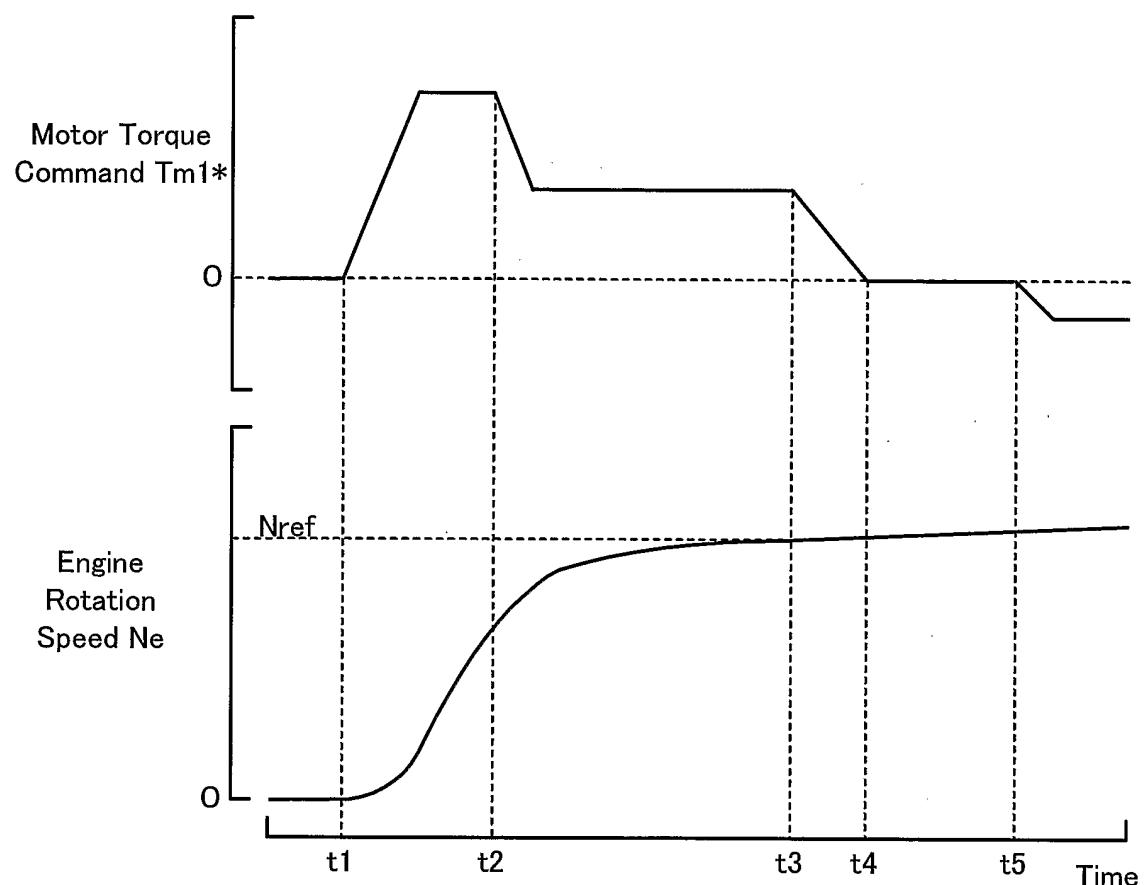


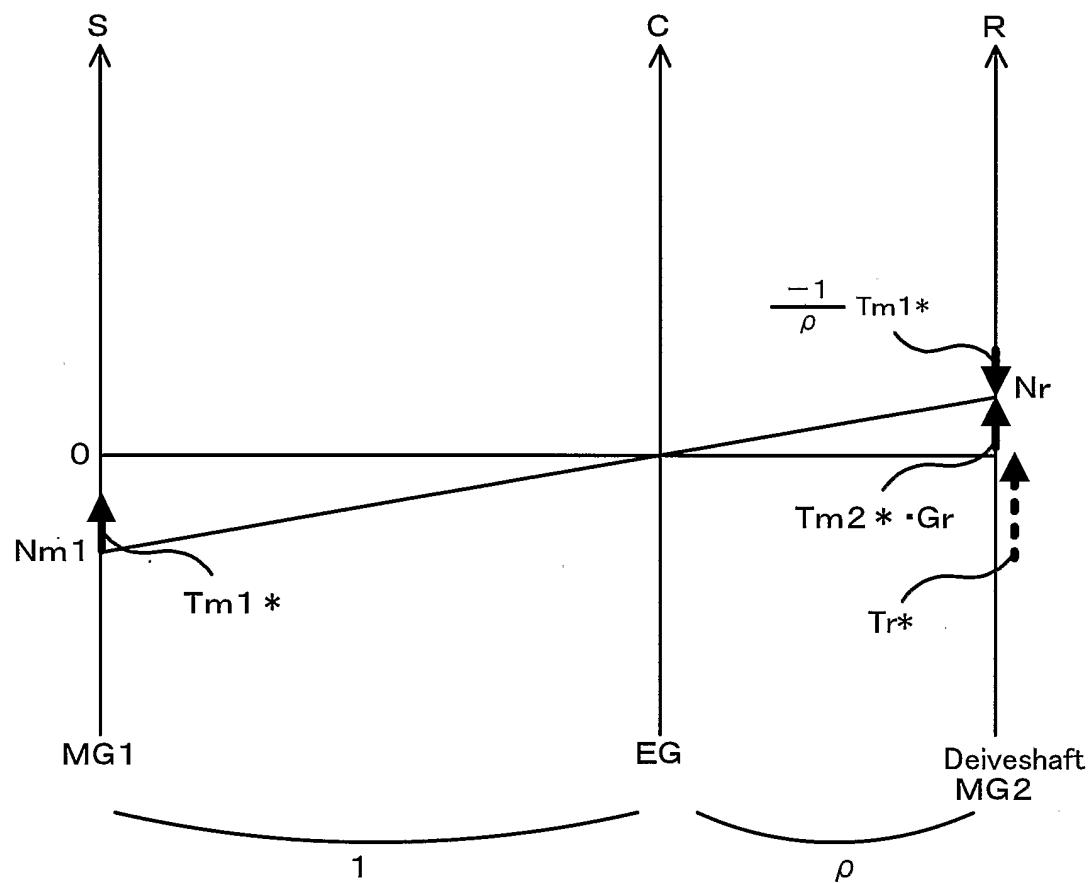
3/12

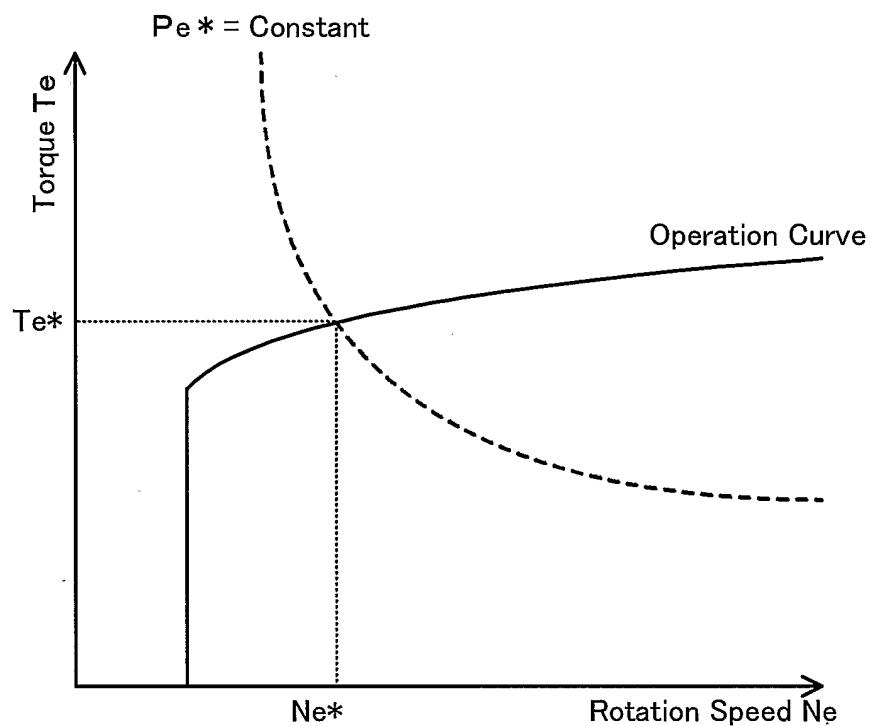
FIG.3

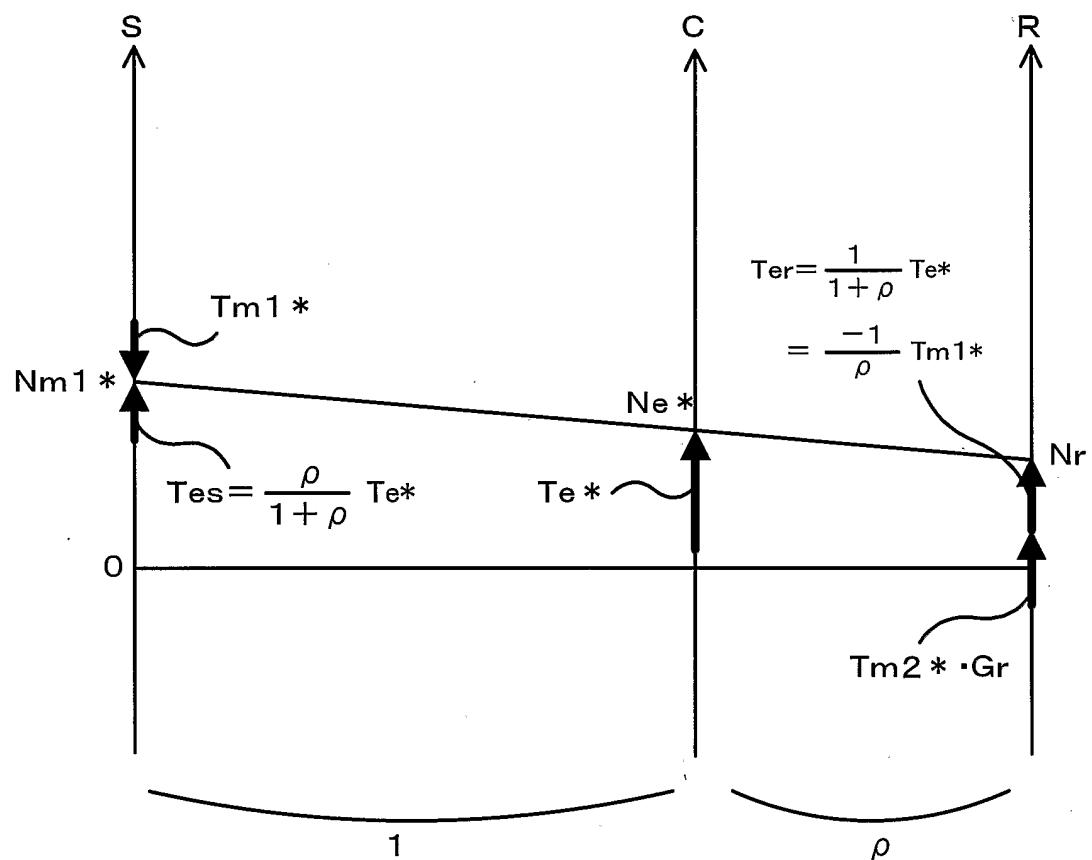


4/12
FIG.4

5/12
FIG.5

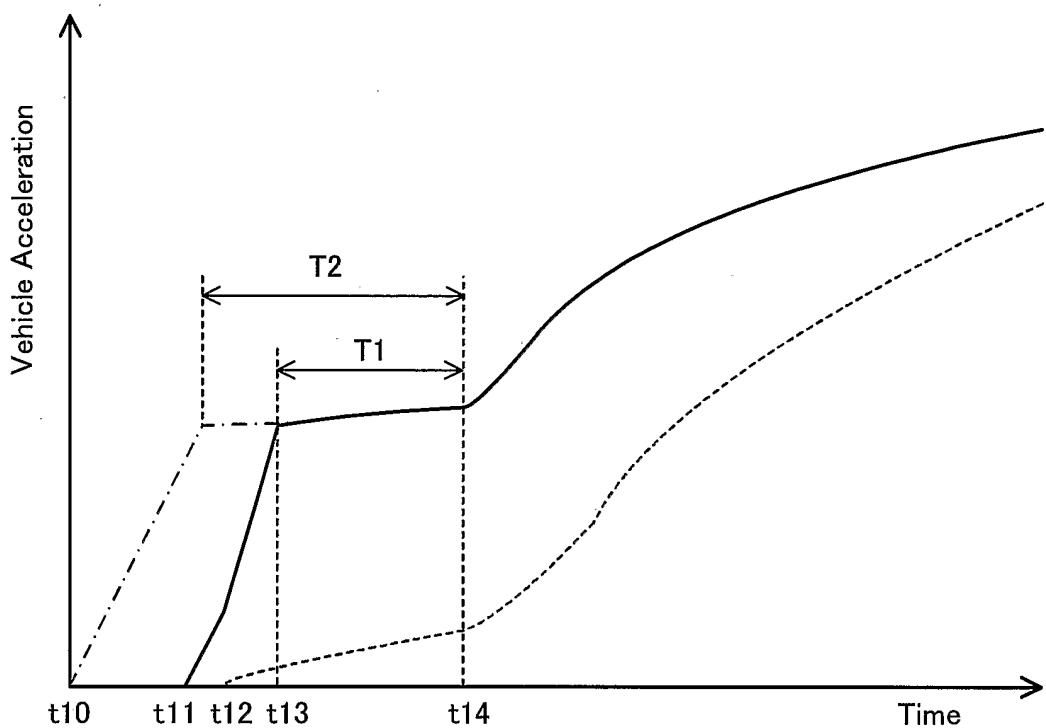
6/12
FIG.6

7/12
FIG.7

8/12
FIG.8

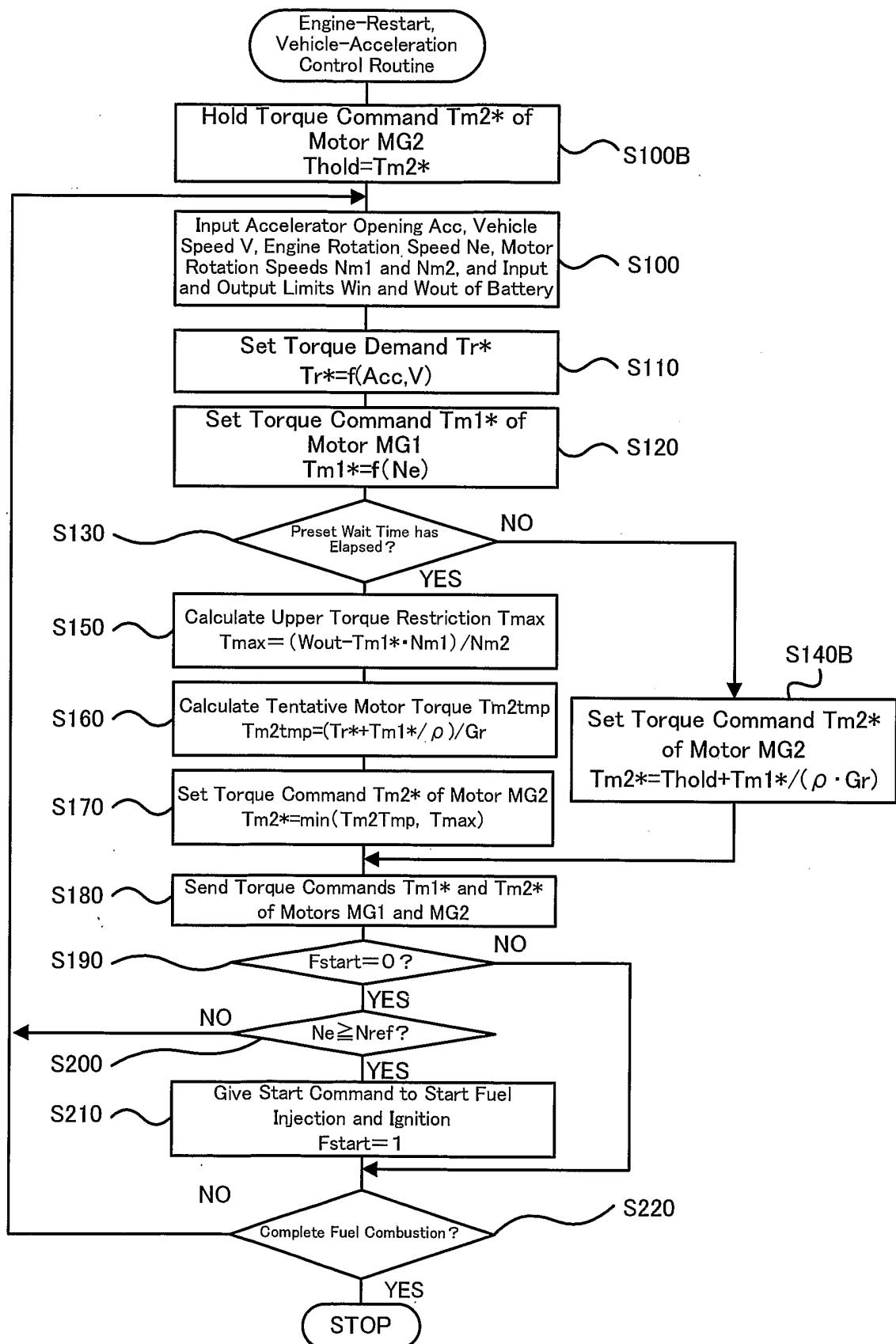
9/12

FIG.9

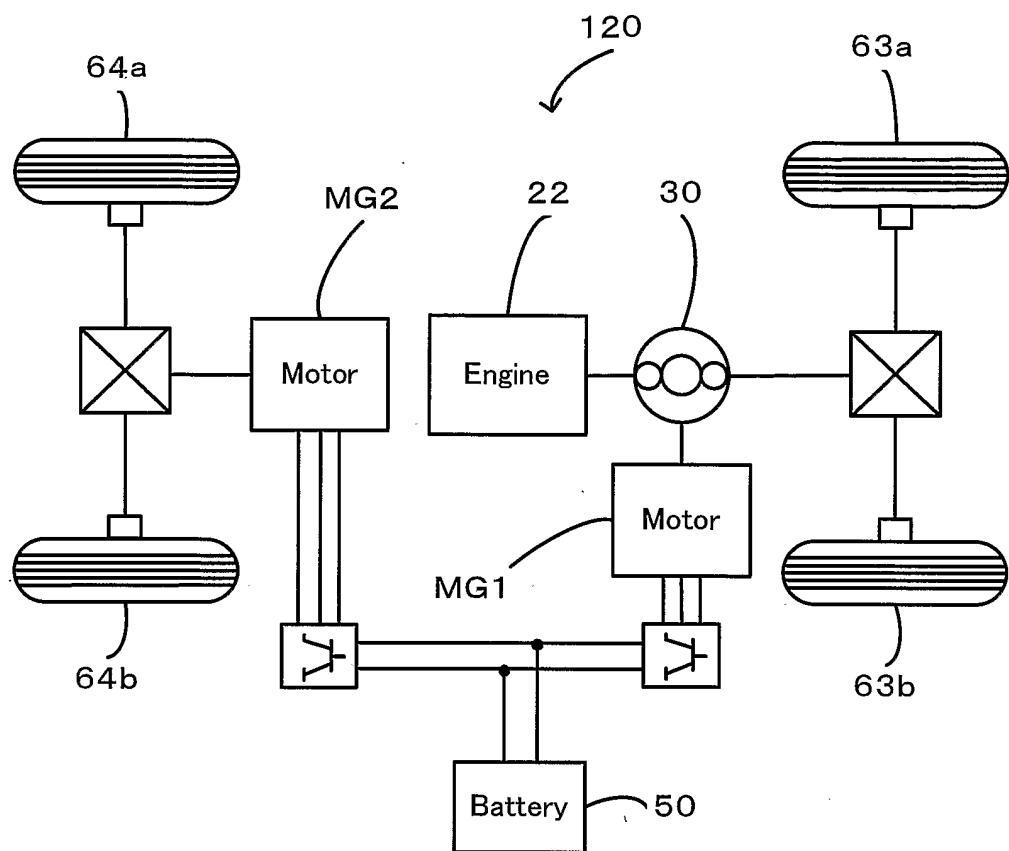


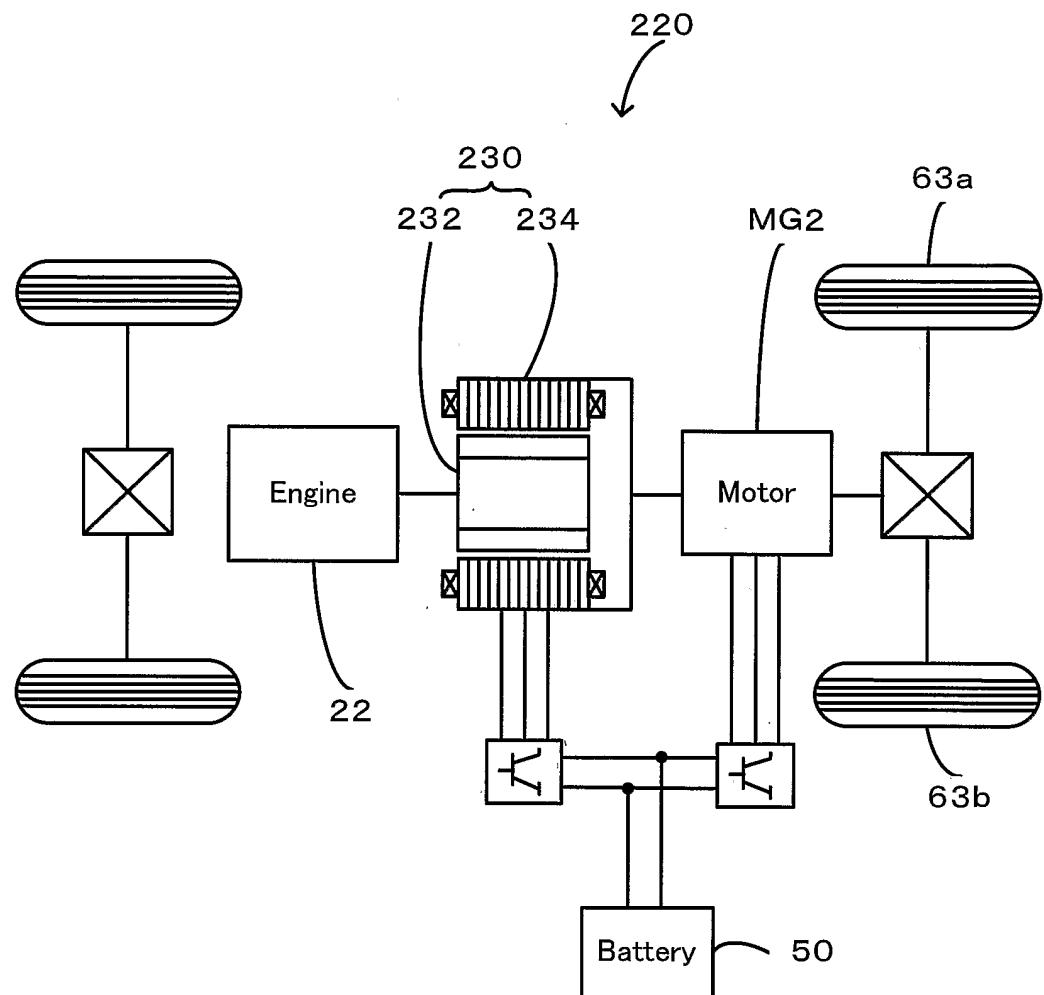
10/12

FIG.10



11/12
FIG.11



12/12
FIG.12

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2006/311355A. CLASSIFICATION OF SUBJECT MATTER
INV. B60K6/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60K

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

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

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|---|-----------------------|
| X | US 5 818 116 A (NAKAE ET AL) 6 October 1998 (1998-10-06) column 23, line 1 - line 5 column 24, line 30 - line 67 column 25, line 6 - line 8 column 26, line 10 - line 26 column 27, line 57 - line 61 column 30, line 14 - line 16 column 32, line 32 - line 45 column 37, line 14 - line 50 column 38, line 34 - line 39 figures 1,7,16,18,19,23,24,35 ----- | 1,3, 6-10,13 |
| X | US 6 380 640 B1 (KANAMORI AKIHIKO ET AL) 30 April 2002 (2002-04-30) column 28, line 23 - column 29, line 53 figures 1,4,8 ----- | 1,2,13 |
| | | -/- |



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

31 August 2006

Date of mailing of the international search report

06/09/2006

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Wilson, M

INTERNATIONAL SEARCH REPORT

| |
|---|
| International application No PCT/JP2006/311355 |
|---|

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|---|-----------------------|
| X | US 5 789 877 A (YAMADA ET AL) 4 August 1998 (1998-08-04) column 19, line 59 – line 65 figure 8 figure 18 ----- | 1,9,13 |
| A | US 2004/231627 A1 (KAITA KEIJI ET AL) 25 November 2004 (2004-11-25) paragraph [0037] figure 2 ----- | 12 |
| X | US 2001/022166 A1 (YAMAGUCHI KATSUHIKO ET AL) 20 September 2001 (2001-09-20) paragraph [0084] – paragraph [0088] paragraph [0093] – paragraph [0096] figure 4 ----- | 1,2,13 |
| A | US 2004/006419 A1 (KIMURA AKIHIRO) 8 January 2004 (2004-01-08) paragraph [0030] figure 2 ----- | 2 |

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2006/311355

| Patent document cited in search report | | Publication date | | Patent family member(s) | | Publication date |
|--|----|------------------|----------------|--------------------------------------|--|--|
| US 5818116 | A | 06-10-1998 | JP JP | 3610687 B2 9222064 A | | 19-01-2005 26-08-1997 |
| US 6380640 | B1 | 30-04-2002 | DE JP | 10049387 A1 2001112112 A | | 19-07-2001 20-04-2001 |
| US 5789877 | A | 04-08-1998 | JP JP KR | 3052804 B2 9042122 A 243487 B1 | | 19-06-2000 10-02-1997 01-02-2000 |
| US 2004231627 | A1 | 25-11-2004 | JP | 2004346811 A | | 09-12-2004 |
| US 2001022166 | A1 | 20-09-2001 | | NONE | | |
| US 2004006419 | A1 | 08-01-2004 | JP | 2004003453 A | | 08-01-2004 |