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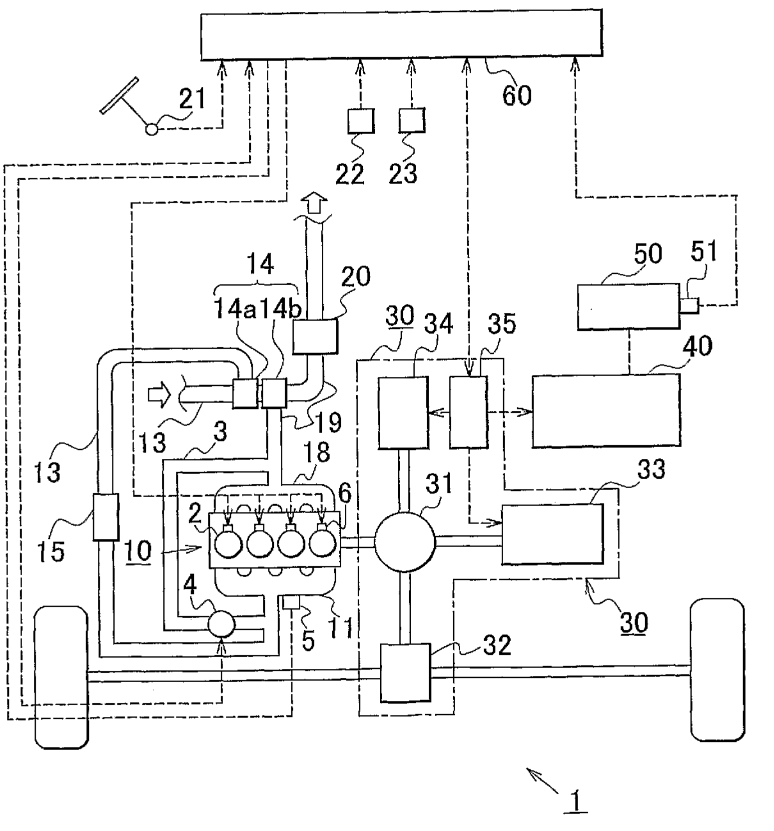
(54) Title: CONTROL APPARATUS AND CONTROL METHOD FOR HYBRID SYSTEM

FIG. 1



(57) Abstract: A control apparatus for a hybrid system with an EGR device (3, 4) performs fuel cut control to stop fuel injection in the engine, determines whether an EGR rate of gas sucked into the engine is equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the engine, and continues fuel cut control and generates a required output only by an electric motor (33) during a period from a time point at which a condition for switching fuel injection control from fuel cut control to normal fuel injection control is fulfilled to a time point at which it is determined that the EGR rate has become equal to or lower than the critical EGR rate, when the condition for switching the fuel injection control to normal fuel injection control is fulfilled during the performance of fuel cut control.

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CONTROL APPARATUS AND CONTROL METHOD FOR HYBRID SYSTEM

FIELD OF THE INVENTION

[0001] The invention relates to a control apparatus and a control method for a hybrid system.

BACKGROUND OF THE INVENTION

[0002] There is known a hybrid system that is equipped with an internal combustion engine and an electric motor as power sources to generate a required output by the internal combustion engine and/or the electric motor in accordance with an operating condition. In the hybrid system, there is known an art for improving fuel consumption by performing fuel cut control to stop the supply of fuel to the internal combustion engine during deceleration or during the stop of a vehicle and thus stopping the internal combustion engine.

[0003] Further, as an art for reducing the amount of exhaust gas emitted from an internal combustion engine and improving fuel consumption, there is known an EGR device that returns part of exhaust gas from the internal combustion engine to an intake system as EGR gas.

[0004] In a hybrid system equipped with an EGR device, when fuel cut control is performed during the introduction of EGR gas into an intake system by the EGR device, this EGR gas remains in the intake system and an exhaust system during fuel cut control. In some cases, this residual EGR gas is discharged to the outside of a vehicle without being sufficiently purified by an exhaust gas purification catalyst at the time of switching from fuel cut control. As a countermeasure against this phenomenon, Japanese Patent Application Publication No. 2002-256919 (JP-A-2002-256919) discloses an art for purifying residual EGR gas by engaging a clutch between an electric motor and an internal combustion engine during deceleration to carry out motoring and fully opening a throttle valve to send the residual EGR gas to an exhaust gas purification catalyst.

[0005] In a hybrid system equipped with an EGR device, when fuel cut control is performed during the introduction of EGR gas into an intake system by the EGR device, this EGR gas remains in the intake system during fuel cut control. This residual EGR gas is sucked into cylinders at the time of switching from fuel cut control. In the case where the amount of EGR gas at this time is excessively large, unstable combustion such as misfiring or the like may be caused in starting an internal combustion engine at the time of switching from fuel cut control.

DISCLOSURE OF THE INVENTION

[0006] The invention provides an art for stabilizing combustion in starting an internal combustion engine while generating a required output at the time of switching fuel injection control from fuel cut control to normal fuel injection control in a hybrid system equipped with an EGR device.

[0007] A first aspect of the invention relates to a control apparatus for a hybrid system equipped with an EGR device that causes part of exhaust gas from an internal combustion engine to flow into an intake system of the internal combustion engine as EGR gas, means for performing fuel cut control to stop fuel injection in the internal combustion engine, and determination means for determining whether an EGR rate of gas sucked into the internal combustion engine is equal to or lower than a predetermined critical EGR rate where misfiring does not occur in the internal combustion engine. This control apparatus for the hybrid system is equipped with control means for controlling the internal combustion engine so as to continue the fuel cut control without switching fuel injection control to normal fuel injection control and controlling an electric motor so as to generate a required output only by the electric motor during a period from a time point at which a condition for switching the fuel injection control from the fuel cut control to the normal fuel injection control is fulfilled to a time point at which the determination means determines that the EGR rate has become equal to or lower than the critical EGR rate, when the condition for switching the fuel injection control to the normal fuel injection control is fulfilled during performance of the fuel cut control.

[0008] "The critical EGR rate" is determined in advance on the basis of an upper limit of an EGR rate that does not cause misfiring in the internal combustion engine. The upper limit of the EGR rate that does not cause misfiring in the internal combustion engine differs depending on the operating condition of the internal combustion engine. Accordingly, "the critical EGR rate" may also be set as a variable value corresponding to the operating condition of the internal combustion engine at the time of fulfillment of the condition for switching fuel injection control to normal fuel injection control. In general, the combustion resistance against EGR gas is low when the operating condition of the internal combustion engine is low load, and is high when the operating condition of the internal combustion engine is high load. Therefore, the critical EGR rate may be set as a concentration that decreases as the operating condition of the internal combustion engine at the time of fulfillment of the condition for switching fuel injection control to normal fuel injection control shifts to the low load side. Alternatively, a constant value capable of suppressing the occurrence of misfiring may be set as "the critical EGR rate" regardless of the operating condition of the internal combustion engine at the time of fulfillment of the condition for switching fuel injection control to normal fuel injection control.

[0009] Further, any means capable of determining whether the EGR rate of gas sucked into the internal combustion engine is equal to or lower than the critical EGR rate may be adopted as "the determination means". For example, it is possible to install a gas concentration sensor in an intake manifold or an intake passage, and make the determination on the basis of a comparison between an output of the gas concentration sensor and the critical EGR rate. Further, it is also appropriate to estimate the EGR rate of gas sucked into the internal combustion engine through model calculation on the basis of data such as a control state of the EGR device (amount of EGR gas, opening degree of an EGR valve, temperature of EGR gas, or the like) immediately before the start of fuel cut control, a control state of the internal combustion engine (rotational speed, load, fuel injection amount, concentration of inactive components in exhaust gas, temperature of exhaust gas, throttle opening degree, or the like), a time from a time point at which fuel cut control starts to a time point at which the condition for switching fuel injection control to normal fuel injection control is fulfilled, and the like, and make the determination on the basis of a comparison between the estimated EGR rate and the critical EGR rate. Further, it is also possible to find out in advance a relationship in correspondence among these physical quantities, an elapsed time from fulfillment of the condition for switching fuel injection control to normal fuel injection control, and the EGR rate of gas sucked into the internal combustion engine, and make the determination on the basis of a measured value of the elapsed time from fulfillment of the condition for switching fuel injection control to normal fuel injection control. When the operating condition of the internal combustion engine immediately before the start of fuel cut control does not allow the introduction of EGR gas by the EGR device, it is considered that there is no EGR gas remaining in the intake system. It is therefore appropriate to determine that the EGR rate has become equal to or lower than the critical EGR rate as soon as the condition for switching fuel injection control to normal fuel injection control is fulfilled.

[0010] Further, "normal fuel injection control" is intended to distribute the required output to the internal combustion engine and the electric motor according to a predetermined distribution ratio, and inject and supply a predetermined amount of fuel that is so determined as to enable the generation of the required output distributed to the internal combustion engine. Further, fuel cut control is performed, for example, on an operating condition that makes the required output 0, such as a deceleration state, a vehicle stop state, or the like. Accordingly, "the condition for switching fuel injection control to normal fuel injection control" is fulfilled when the operating condition of the internal combustion engine changes from one of those operating conditions for performing fuel cut control to a different operating condition. For example, "the condition for switching fuel injection control to normal fuel injection control" is fulfilled in re-accelerating the vehicle from a state of deceleration, starting running from an idling stop state, or the like.

[0011] According to the invention, during a period from a time point at which the condition for switching fuel injection control from fuel cut control to normal fuel injection control is fulfilled to a time point at which it is determined that the EGR rate of gas sucked into the internal combustion engine becomes equal to or lower than the critical EGR rate, switching of fuel injection control to normal fuel injection control is delayed, and fuel cut control is continued. That is, when the EGR rate of gas sucked into the internal combustion engine is high enough to cause misfiring, fuel injection is not carried out. Accordingly, unstable combustion such as misfiring or the like can be restrained from occurring as a result of an excessively high EGR rate of sucked gas.

[0012] Due to the delay of the switching of fuel injection control to normal fuel injection control during the aforementioned period, the output assumed to be generated by the internal combustion engine under an operating condition for performing normal fuel injection control cannot be generated by the internal combustion engine. In this respect, according to the invention, the electric motor is so controlled by the control means as to generate the entire required output including this output to be intrinsically generated by the internal combustion engine. Thus, during the period in which switching of fuel injection control to normal fuel injection control is delayed, the output generated by the hybrid system can be restrained from failing to reach the required output as well. Accordingly, the occurrence of unstable combustion can be restrained at the time of switching fuel injection control from fuel cut control to normal fuel injection control, and the occurrence of problems such as an insufficient feeling of acceleration, torque fluctuation, a deterioration in driveability, and the like can be restrained as well.

[0013] In the invention, the control means may control the electric motor so as to carry out cranking of the internal combustion engine during a period in which the switching of fuel injection control to normal fuel injection control is delayed. As a matter of course, this cranking is carried out during the performance of fuel cut control. Thus, the scavenging of EGR gas remaining in the intake system can be promoted. Accordingly, the time required until the EGR rate of gas sucked into the internal combustion engine becomes equal to or lower than the critical EGR rate, namely, the delay time until fuel injection control is switched to normal fuel injection control can be reduced.

[0014] In the invention, when it is determined that the EGR rate of gas sucked into the internal combustion engine has become equal to or lower than the critical EGR rate, fuel injection control of the internal combustion engine can be switched to normal fuel injection control, and control of the electric motor can also be switched to normal control.

[0015] It should be noted herein that "switching of control of the electric motor to normal control" means, as described above, the distributing of the required output to the internal combustion engine and the electric motor according to the predetermined ratio and the performing of predetermined control, which is so determined as to enable the generation of the required output distributed to the electric motor, as to the electric motor.

[0016] A second aspect of the invention relates to a hybrid vehicle equipped with a hybrid system that is equipped with an internal combustion engine and an electric motor as power sources to generate/output a required output by the internal combustion engine and/or the electric motor and an EGR device that causes part of exhaust gas from the internal combustion engine to flow into an intake system of the internal combustion engine as EGR gas. This hybrid vehicle is equipped with a controller that performs fuel cut control to stop fuel injection in the internal combustion engine, determines whether an EGR rate of gas sucked into the internal combustion engine is equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the internal combustion engine, and controls the internal combustion engine so as to continue the fuel cut control without switching fuel injection control to normal fuel injection control and controlling the electric motor so as to generate a required output only by the electric motor during a period from a time point at which a condition for switching the fuel injection control from the fuel cut control to the normal fuel injection control is fulfilled to a time point at which the controller determines that the EGR rate has become equal to or lower than the critical EGR rate, when the condition for switching the fuel injection control to the normal fuel injection control is fulfilled during performance of the fuel cut control.

[0017] A third aspect of the invention relates to a control method for a hybrid system that is equipped with an internal combustion engine and an electric motor as power sources to generate/output a required output by the internal combustion engine and/or the electric motor. This control method is equipped with a step of determining whether to perform fuel cut control to stop fuel injection in the internal combustion engine or not, a step of determining whether a condition for switching fuel injection control from the fuel cut control to normal fuel injection control has been fulfilled, a step of determining whether an EGR rate of gas sucked into the internal combustion engine is equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the internal combustion engine, and a step of continuing the fuel cut control and generating the required output only by the electric motor during a period from a time point at which a condition for switching the fuel injection control from the fuel cut control to normal fuel injection control is fulfilled to a time point at which it is determined that the EGR rate has become equal to or lower than the predetermined critical EGR rate.

[0018] A fourth aspect of the invention relates to a control apparatus for a hybrid system that is equipped with an internal combustion engine and an electric motor as power sources to generate/output a required output by the internal combustion engine and/or the electric motor. This control apparatus is equipped with an EGR device that causes part of exhaust gas from the internal combustion engine to flow into an intake system of the internal combustion engine as EGR gas, a determination device that calculates an EGR rate of gas sucked into the internal combustion engine, and a controller that makes a determination on an operating state of the hybrid system and continues fuel cut control and controls the electric motor so as to generate the required output only by the electric motor during a period from a time point at which it is determined that a condition for switching fuel injection control from the fuel cut control to normal fuel injection control has been fulfilled, based on the determined operating state, to a time point at which the calculated EGR rate becomes equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the internal combustion engine.

[0019] The invention makes it possible to stabilize combustion in starting an internal combustion engine while generating a required output at the time of switching fuel injection control from fuel cut control to normal fuel injection control in a hybrid system equipped with an EGR device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of an exemplary embodiment with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 is a view showing the schematic configuration of a hybrid system according to this embodiment of the invention;

FIG. 2 is a view showing a relationship between an EGR rate of intake gas and torque fluctuation according to each operating state of an internal combustion engine;

FIG. 3 is a view showing a target value of the EGR rate that is determined for each operating condition of the internal combustion engine;

FIGS. 4A to 4C are views showing examples of how vehicle speed, required output, and the EGR rate of gas in an intake manifold change respectively with time when the control that delays switching of fuel injection control of the internal combustion engine according to this embodiment of the invention to normal control is applied, in the case where re-acceleration is carried out upon a shift of the internal combustion engine from a high load operating state to a deceleration state;

FIG. 5 is a flowchart showing a control routine that is executed when the control that delays switching of the fuel injection control of the internal combustion engine according to this embodiment of the invention to normal control is applied, in the case where re-acceleration is carried out upon a shift of the internal combustion engine from a high load operating state to a deceleration state;

FIGS. 6A to 6C are views showing examples of how vehicle speed, required output, and the EGR rate of gas in the intake manifold change respectively with time when the control that delays switching of the fuel injection control of the internal combustion engine according to this embodiment of the invention to normal control is applied, in the case where re-acceleration is carried out from an idling stop state;

FIG. 7 is a flowchart showing a control routine that is executed when the control that delays switching of the fuel injection control of the internal combustion engine according to this embodiment of the invention to normal control, in the case where re-acceleration is carried out from an idling stop state; and

FIG. 8 is a view showing an example of how the EGR rate of gas in the intake manifold changes with time when the internal combustion engine shifts from a normal control state to fuel cut control.

DETAILED DESCRIPTION OF EMBODIMENT

[0021] Hereinafter, a best mode of implementing the invention will be illustratively described in detail with reference to the drawings. The dimensions, materials, shapes, relative arrangements and the like of components described in this embodiment of the invention are not intended to limit the technical scope of the invention thereto unless specified otherwise.

[0022] FIG. 1 is a conceptual view showing the schematic configuration of a hybrid system according to this embodiment of the invention. Referring to FIG. 1, a hybrid system 1 is equipped with an internal combustion engine 10, a transaxle 30, an inverter 40, and a battery 50. An ECU 60 as a computer for performing the control of the hybrid system 1 is provided in parallel with the hybrid system 1.

[0023] The internal combustion engine 10 generates a driving force of a hybrid vehicle using the combustion energy of fuel as a source. The transaxle 30 is composed of a transmission and an axle that are integrated with each other. The transaxle 30 accommodates therein a power division mechanism (e.g., a planetary gear mechanism) 31, a reducer 32, an electric motor 33, a generator 34, and a power control unit 35 for performing the control of the electric motor 33 and the generator 34. Further, lubricating oil is stored in the transaxle 30 to lubricate the electric motor 33, the generator 34, the power division mechanism 31, the reducer 32, and the like.

[0024] The generator 34 generates an electric power by an output generated by the internal combustion engine 10. The electric motor 33 generates a driving force of the hybrid vehicle by an electric power supplied from the battery 50, which is charged with an electric power for driving the electric motor 33, or the generator 34. The output generated by the internal combustion engine 10 and the output generated by the electric motor 33 are transmitted to wheels via the power division mechanism 31 and the reducer 32.

[0025] The power division mechanism 31 realizes the transmission of a power between the internal combustion engine 10 and the generator 34, the transmission of a power between the internal combustion engine 10 and the reducer 32, and the transmission of a power between the electric motor 33 and the reducer 32. Further, the inverter 40 converts a direct current of the battery 50 and alternating currents of the electric motor 33 and the generator 34.

[0026] Next, the schematic configuration of the internal combustion engine 10 and an intake system and an exhaust system thereof will be described. An intake manifold 11 is connected to the internal combustion engine 10, and branch pipes of the intake manifold 11 communicate with combustion chambers of cylinders 2 respectively. The intake manifold 11 is connected to an intake passage 13, and the intake passage 13 is provided with a compressor 14a of a turbocharger 14 that is operated using the energy of exhaust gas as a drive source. Further, an intercooler 15 for cooling gas flowing through the intake passage 13 is provided in the intake passage 13 at a position downstream of the compressor 14a. The intake air that has flowed into the compressor 14a is compressed through rotation of a compressor wheel (not shown) fitted inside the compressor 14a. The intake air that has become high in temperature through compression is cooled by the intercooler 15 and then flows into the intake manifold 11. The intake air that has flowed into the intake manifold 11 is then distributed to the respective cylinders 2 via intake ports. The intake air distributed to each of the cylinders 2 then burns together with fuel injected from a corresponding one of fuel injection valves 6 provided in the cylinders 2 respectively. The intake manifold 11 is provided with a gas concentration sensor 5 for measuring a concentration of carbon dioxide in intake air.

[0027] Further, an exhaust manifold 18 is connected to the internal combustion engine 10, and branch pipes of the exhaust manifold 18 are connected to the combustion chambers of the cylinders 2 respectively via exhaust ports (not shown). The exhaust manifold 18 is connected to an exhaust passage 19, and the exhaust passage 19 is provided with a turbine 14b of the turbocharger 14. Further, an exhaust gas purification catalyst 20 is provided in the exhaust passage 19 at a position downstream of the turbine 14b, and the exhaust passage 19 is connected downstream of the exhaust gas purification catalyst 20 to a muffler (not shown). Burned gas in the respective cylinders 2 is discharged to the exhaust manifold 18 via the exhaust ports. This exhaust gas flows through the exhaust passage 19 and into the turbine 14b and rotates a turbine wheel (not shown) rotatably supported in the turbine 14b. A rotational torque of the turbine wheel (not shown) is transmitted to the compressor wheel (not shown) in the compressor 14a. The exhaust gas that has flowed out from the turbine 14b is purified of noxious substances (e.g., NOx, HC, CO, and the like) by the exhaust gas purification catalyst 20 and is then discharged to the atmosphere through the muffler.

[0028] That section of the exhaust passage 19 which is located upstream of the turbine 14b and that section of the intake passage 13 which is located downstream of the compressor 14a are connected to each other by an EGR passage 3. Part of exhaust gas flowing through the exhaust passage 19 flows into the intake passage 13 via the EGR passage 3 as EGR gas. The EGR passage 3 extends across an EGR valve 4 for adjusting the amount of EGR gas flowing through the EGR passage 3.

[0029] The hybrid system 1 is provided with various sensors such as a crank position sensor 23 for outputting a signal corresponding to a rotational angle of a crankshaft, an accelerator position sensor 21 for outputting a signal corresponding to a depression amount of an accelerator pedal (accelerator opening degree), a vehicle speed sensor 22 for outputting a signal corresponding to a running speed of the vehicle, an SOC sensor 51 for acquiring a charge state (SOC) of the battery 50, and the like in addition to the aforementioned gas concentration sensor 5. The signals from the respective sensors are input to the ECU 60. The ECU 60 calculates an EGR rate of intake gas present in the intake manifold 11, on the basis of a signal input from the gas concentration sensor 5.

[0030] Further, in addition to the aforementioned fuel injection valves 6 and the aforementioned EGR valve 4, various components are connected to the ECU 60, and the operations of these respective components are controlled in accordance with signals input from the aforementioned various sensors. For example, the ECU 60 calculates a required output to be generated by the hybrid system 1 on the basis of signals input from the accelerator position sensor 21 and the crank position sensor 23, determines a distribution ratio of the required output to the internal combustion engine 10 and the electric motor 33 on the basis of an operating condition and a signal input from the SOC sensor 51, and controls the amount of fuel injected into the internal combustion engine 10 and the supply of an electric power to the electric motor 33 so as to enable generation of an output corresponding to the distribution.

[0031] By opening the EGR valve 4, EGR gas is caused to flow into the intake passage 13. By thus introducing EGR gas into the intake system of the internal combustion engine 10, the amounts of cooling loss and pumping loss are reduced and hence an improvement in fuel consumption can be made. Further, the amounts of noxious substances contained in exhaust gas, such as NOx and the like, are reduced and hence an improvement in exhaust emission performance can be made. In some cases, however, when the EGR rate of intake gas becomes excessively high, combustion is destabilized to the extent of causing a problem such as misfiring, torque fluctuation or the like. In general, when the operating condition of the internal combustion engine 10 is low load/low rotation, the amount of fresh air and the amount of fuel injection are small and hence unstable combustion is likely to occur in response to the introduction of EGR gas. On the other hand, when the operating condition of the internal combustion engine 10 is high load/high rotation, stable combustion is carried out and hence unstable combustion is unlikely to occur despite the introduction of a large amount of EGR gas. FIG. 2 shows respective relationships between the EGR rate of intake air and torque fluctuation in the case where the operating condition of the internal combustion engine 10 is low load/low rotation and in the case where the operating condition of the internal combustion engine 10 is high load/high rotation. As shown in FIG. 2, even at an EGR rate that is unlikely to cause torque fluctuation when the operating condition of the internal combustion engine 10 is high load/high rotation, large torque fluctuation may be caused when the operating condition of the internal combustion engine 10 is low load/low rotation.

[0032] Thus, in consideration of the fact that the upper limit of the EGR rate (critical EGR rate) of intake air that does not destabilize combustion differs depending on the operating condition of the internal combustion engine 10, EGR control is performed in the hybrid system according to this embodiment of the invention such that the EGR rate of intake gas increases as the operating condition of the internal combustion engine 10 shifts to the high load/high rotation side. FIG. 3 shows a relationship between the operating condition of the internal combustion engine 10 and the EGR rate. As shown in FIG. 3, the EGR rate is increased with increases in the rotational speed and/or the load of the internal combustion engine 10. Further, in a predetermined low load/low rotation range indicated by diagonal lines in FIG. 3, the introduction of EGR gas is stopped.

[0033] In the hybrid system according to this embodiment of the invention, fuel cut control is performed to stop the injection of fuel by the fuel injection valves 6 on a predetermined operating condition that makes the required output for the internal combustion engine 10 zero. The predetermined operating condition means a deceleration state, a vehicle stop state, or the like. By performing fuel cut control, the consumption of surplus fuel can be suppressed and hence an improvement in fuel consumption can be made. During fuel cut control, the EGR valve 4 is closed and the introduction of EGR gas is stopped as well.

[0034] Now, when fuel cut control is started during the operation of the internal combustion engine 10 on an operating condition allowing the introduction of EGR gas, EGR gas remains in an intake system region composed of that section of the EGR passage 3 which is located downstream of the EGR valve 4, that section of the intake passage 13 which is located downstream of a connecting point of the EGR passage 3, and the intake manifold 11 during fuel cut control. Part of the EGR gas remaining in the intake system region is sucked into the cylinders 2 and scavenged by the time when the internal combustion engine 10 stops rotating completely after the start of fuel cut control.

In some cases, however, this EGR gas is not sufficiently scavenged from the inside of the intake system region, for example, on a certain operating condition of the internal combustion engine 10 immediately before the start of fuel cut control. In such cases, the internal combustion engine 10 is stopped with the EGR gas remaining in the intake system region. In this state, when a condition for switching fuel injection control from fuel cut control to normal fuel injection control (normal control) (switching condition) is fulfilled as to the internal combustion engine 10, the EGR gas remaining in the intake system region is first sucked into the cylinders 2.

[0035] In particular, when fuel cut control is started from an operating condition belonging to a high load/high rotation range where a large amount of EGR gas is introduced, a large amount of EGR gas may remain in the intake system region upon fulfillment of the condition for switching fuel injection control to normal control. In such cases, when switching of fuel injection control to normal control is made immediately after fulfillment of the condition for switching fuel injection control to normal control, residual gas with a high EGR rate in the intake system region is sucked into the cylinders 2 of the internal combustion engine 10, and fuel is supplied to the internal combustion engine 10 by the fuel injection valves 6. Therefore, the EGR rate of gas sucked into the cylinders may become excessively high beyond the critical EGR rate corresponding to the operating condition of the internal combustion engine 10 upon fulfillment of the switching condition and cause unstable combustion such as misfiring or the like.

[0036] Thus, in the hybrid system 1 according to this embodiment of the invention, when the condition for switching fuel injection control from fuel cut control to normal control is fulfilled during the performance of fuel cut control, an EGR rate of gas in the intake manifold 11 is calculated on the basis of an output of the gas concentration sensor 5. When the calculated EGR rate is higher than the critical EGR rate corresponding to the operating condition of the internal combustion engine 10 upon fulfillment of the switching condition, fuel cut control is continued without switching the fuel injection control of the internal combustion engine 10 from fuel cut control to normal control.

Then, when the EGR rate of gas in the intake manifold 11, which is calculated on the basis of the output of the gas concentration sensor 5, becomes equal to or lower than the aforementioned critical EGR rate, fuel cut control is terminated to switch fuel injection control to normal control. Furthermore, the electric motor 33 is so controlled as to output an output assumed to be intrinsically generated by the internal combustion engine 10 during a delay period from a time point at which the condition for switching fuel injection control from this fuel cut control to normal control is fulfilled to a time point at which fuel injection control is actually switched to normal control. Moreover, the electric motor 33 is so controlled as to carry out the cranking of the internal combustion engine 10 during this delay period.

[0037] By performing this control, the EGR rate of gas sucked into the cylinders 2 of the internal combustion engine 10 is equal to or lower than the critical EGR rate when the fuel injection control of the internal combustion engine 10 is switched from fuel cut control to normal control. Therefore, the occurrence of unstable combustion such as misfiring or the like can be restrained at the time of switching of fuel injection control to normal control, and the occurrence of problems such as torque fluctuation, a deterioration in driveability, and the like can be restrained. In addition, during the aforementioned delay period, the electric motor 33 compensates for an output that cannot be generated by the internal combustion engine 10 due to the delay of the switching of fuel injection control of the internal combustion engine 10 to normal control although the output by the internal combustion engine 10 is intrinsically assumed in response to the switching of fuel injection control of the internal combustion engine 10 from fuel cut control to normal control. Therefore, the required output during the delay period can be generated in just proportion, and the occurrence of a deterioration in driveability such as an insufficient feeling of acceleration or the like can be restrained. Further, during the aforementioned delay period, the electric motor 33 is so controlled as to further carry out the cranking of the internal combustion engine 10. Therefore, the scavenging of gas remaining in the intake system region can be completed earlier. Accordingly, the delay period can be reduced, and the fuel injection control of the internal combustion engine 10 can be switched to normal control earlier.

[0038] FIGS. 4A to 4C are time charts showing examples of how the vehicle speed, the required output, and the EGR rate of gas in the intake manifold 11 change with time respectively when the above-described control according to this embodiment of the invention is applied in carrying out re-acceleration upon a shift of the internal combustion engine 10 from a high load operation state to a deceleration state. FIG. 4A represents the vehicle speed of the vehicle mounted with the hybrid system 1 according to this embodiment of the invention as a power source. FIG. 4B represents the required output for the hybrid system 1. FIG. 4C represents the EGR rate of gas in the intake manifold 11 that is calculated by the ECU 60 on the basis of the signal from the gas concentration sensor 5.

[0039] In the example shown in FIG. 4, before a time t_1, a required output for the hybrid system 1 is entirely distributed to the internal combustion engine 10, and the ECU 60 controls the hybrid system 1 such that the internal combustion engine 10 generates the entire required output. At this time, the internal combustion engine 10 is operated with high load, and a large amount of EGR gas is introduced into the intake system as described above.

[0040] When a condition for deceleration is fulfilled in response to a request by a driver at the time t_1, the required output for the hybrid system 1 becomes equal to 0, and the required output for the internal combustion engine 10 becomes equal to 0 as well. As a result, fuel cut control is performed in the internal combustion engine 10. Further, the target value of the EGR rate becomes equal to 0 at the same time, and the EGR valve 4 is closed as a result.

[0041] During fuel cut control after the time t_1, the internal combustion engine 10 continues to rotate through inertia but gradually decreases in rotational speed. Owing to this inertial rotation after the start of fuel cut control, gas in the intake system region is scavenged, and the EGR valve 4 is closed to stop the introduction of new EGR gas as well. Therefore, the EGR rate of gas in the intake manifold 11 gradually decreases.

[0042] At a time t_2, a request for re-acceleration is made. The condition for switching fuel injection control from fuel cut control to normal control is thereby fulfilled. At this time, an EGR rate of gas in the intake manifold 11 is calculated on the basis of a signal from the gas concentration sensor 5, and the calculated EGR rate and a critical EGR rate Rc are compared with each other. In the example shown in FIG. 4, the EGR rate of gas in the intake manifold 11 is higher than the critical EGR rate Rc at the time t_2. Therefore, fuel cut control is continued without switching the fuel injection control of the internal combustion engine 10 to normal control, the entire required output for the hybrid system 1 at this time is distributed to the electric motor 33, and the electric motor 33 is so controlled as to generate the required output. Furthermore, the electric motor 33 is so controlled as to carry out the cranking of the internal combustion engine 10, and the scavenging of gas in the intake system region is thereby promoted. Therefore, after the time t_2, the speed at which the EGR rate of gas in the intake manifold 11 decreases increases. The cranking of the internal combustion engine 10 at this time is carried out together with fuel cut control. This cranking is not accompanied by fuel injection.

[0043] When the EGR rate calculated on the basis of the signal from the gas concentration sensor 5 becomes equal to or lower than the critical EGR rate Rc at a time t_3, the fuel injection control of the internal combustion engine 10 is switched from fuel cut control to normal control. That is, the entire required output for the hybrid system 1 is distributed to the internal combustion engine 10 and the electric motor 33 according to a distribution ratio determined in advance in accordance with an operating condition, and fuel injection control in the internal combustion engine 10 and electric power supply control in the electric motor 33 are so performed as to enable generation of the output thus distributed to each of the internal combustion engine 10 and the electric motor 33.

[0044] FIG. 5 is a flowchart showing a routine for performing the above-described control according to this embodiment of the invention. This routine is executed during fuel cut control of the internal combustion engine 10.

[0045] In step S101, the ECU 60 determines whether a condition for switching the fuel injection control of the internal combustion engine 10 to normal control has been fulfilled. For example, this condition is fulfilled when there is a request for acceleration. When a positive determination is made in step S101, the ECU 60 proceeds to step S102. When a negative determination is made in step S101, the ECU 60 temporarily terminates the execution of this routine.

[0046] In step S102, the ECU 60 calculates an EGR rate R of gas in the intake manifold 11 on the basis of a signal from the gas concentration sensor 5, and determines whether the calculated EGR rate R is higher than the critical EGR rate Rc. When a positive determination is made in step S102 ($R > Rc$), the ECU 60 proceeds to step S103. When a negative determination is made in step S102 ($R \leq Rc$), the ECU 60 proceeds to step S104.

[0047] In step S103, the ECU 60 continues fuel cut control for the internal combustion engine 10, and performs electric power supply control for the electric motor 33 so as to generate the required output distributed to the internal combustion engine 10 by the electric motor 33. Further, the ECU 60 starts the cranking of the internal combustion engine 10 by the electric motor 33.

[0048] In step S104, the ECU 60 switches fuel injection control to normal control. That is, the ECU 60 carries out fuel injection so as to generate the required output distributed to the internal combustion engine 10 by the internal combustion engine 10, and performs electric power supply control so as to generate the required output distributed to the electric motor 33 by the electric motor 33.

[0049] In the aforementioned example, the control performed in the case where the EGR rate of gas in the intake manifold 11 is higher than the critical EGR rate Rc at the time t_2 corresponding to the request for re-acceleration has been described. However, in the case where there is a request for re-acceleration when residual gas in the intake system region is sufficiently scavenged through inertial rotation of the internal combustion engine 10 in a deceleration state, the EGR rate of gas in the intake manifold 11 at that time may be equal to or lower than the critical EGR rate. In such cases, the fuel injection control of the internal combustion engine 10 may be immediately switched to normal control without performing the control of delaying the switching of the fuel injection control of the internal combustion engine 10 according to this embodiment of the invention to normal control. Further, it is not indispensable to carry out the fuel cut cranking of the internal combustion engine 10 by the electric motor 33 during the delay period until the the fuel injection control of the internal combustion engine 10 is switched to normal control.

[0050] FIG. 6 is composed of time charts showing examples of how the vehicle speed, the required output, and the EGR rate of gas in the intake manifold 11 change with time when the above-described control according to this embodiment of the invention is applied in carrying out acceleration from a vehicle stop state accompanied by the stop of the internal combustion engine 10. FIG. 6A represents the vehicle speed of the vehicle mounted with the hybrid system 1 according to this embodiment of the invention as a power source. FIG. 6B represents the required output for the hybrid system 1. FIG. 6C represents the EGR rate of gas in the intake manifold 11 that is calculated by the ECU 60 on the basis of the signal from the gas concentration sensor 5.

[0051] Before the time t_1, the vehicle is stopped. At this time, fuel cut control is performed for the internal combustion engine 10, the internal combustion engine 10 is stopped, and idling stop control is performed. In the example shown in FIGS. 6A to 6C, it is assumed that high-concentration EGR gas remains in the intake system region in this idling stop state. For example, such a situation is assumable when the control of introducing a large amount of EGR gas is performed immediately before the start of the idling stop state.

[0052] A request for re-acceleration is made at the time t_1. The condition for switching fuel injection control from fuel cut control to normal control is thereby fulfilled. At this time, an EGR rate of gas in the intake manifold 11 is calculated on the basis of a signal from the gas concentration sensor 5, and the calculated EGR rate and the critical EGR rate are compared with each other. In the example shown in FIG. 6, the EGR rate of gas in the intake manifold 11 is higher than the critical EGR rate Rc at the time t_1. Therefore, fuel cut control is continued without switching the fuel injection control of the internal combustion engine 10 to normal control, the entire required output for the hybrid system 1 at this time is distributed to the electric motor 33, and the electric motor 33 is so controlled as to generate the required output. Furthermore, the electric motor 33 is so controlled as to carry out the cranking of the internal combustion engine 10, and the scavenging of gas in the intake system region is thereby promoted. Therefore, after the time t_1, the EGR rate of gas in the intake manifold 11 gradually decreases. The cranking of the internal combustion engine 10 at this time is carried out together with fuel cut control and is not accompanied by fuel injection.

[0053] When the EGR rate calculated on the basis of the signal from the gas concentration sensor 5 becomes equal to or lower than the critical EGR rate Rc at the time t_2, the fuel injection control of the internal combustion engine 10 is switched from fuel cut control to normal control. That is, the entire required output for the hybrid system 1 is distributed to the internal combustion engine 10 and the electric motor 33 according to the distribution ratio determined in advance in accordance with the operating condition, and fuel injection control in the internal combustion engine 10 and electric power supply control in the electric motor 33 are so performed as to enable generation of the output thus distributed to each of the internal combustion engine 10 and the electric motor 33.

[0054] FIG. 7 is a flowchart showing a routine for performing the above-described control according to this embodiment of the invention. This routine is executed in an idling stop state.

[0055] In step S201, the ECU 60 determines whether a condition for switching the fuel injection control of the internal combustion engine 10 to normal control has been fulfilled. For example, this condition is fulfilled when there is a request for acceleration. When a positive determination is made in step S201, the ECU 60 proceeds to step S202. When a negative determination is made in step S201, the ECU 60 temporarily terminates the execution of this routine.

[0056] In step S202, the ECU 60 calculates the EGR rate R of gas in the intake manifold 11 on the basis of a signal from the gas concentration sensor 5, and determines whether the calculated EGR rate R is higher than the critical EGR rate Rc. When a positive determination is made in step S202 ($R > Rc$), the ECU 60 proceeds to step S203.

When a negative determination is made in step S202 ($R \leq Rc$), the ECU 60 proceeds to step S204.

[0057] In step S203, the ECU 60 continues fuel cut control for the internal combustion engine 10, and performs electric power supply control for the electric motor 33 so as to generate the required output distributed to the internal combustion engine 10 by the electric motor 33. Further, the ECU 60 starts the cranking of the internal combustion engine 10 by the electric motor 33.

[0058] In step S204, the ECU 60 switches the fuel injection of the internal combustion engine 10 to normal control. That is, the ECU 60 carries out fuel injection so as to generate the required output distributed to the internal combustion engine 10 by the internal combustion engine 10, and performs electric power supply control so as to generate the required output distributed to the electric motor 33 by the electric motor 33.

[0059] In the foregoing embodiment of the invention, the EGR passage 3, the EGR valve 4, and the ECU 60 for controlling the EGR valve 4 can be regarded as the EGR device in the invention. Further, the ECU 60, which makes the determinations in step S102 and step S202, can be regarded as the determination means in the invention. Further, the ECU 60, which delays switching of the fuel injection control of the internal combustion engine 10 to normal control in step S103 in accordance with the determination result of step S102, and the ECU 60, which delays switching of the fuel injection control of the internal combustion engine 10 to normal control in step S203 in accordance with the determination result of step S202, can be regarded as the control means in the invention.

[0060] The foregoing embodiment of the invention can be subjected to various modifications within the scope of the invention. For example, it can be determined according to a method different from the foregoing embodiment of the invention whether the EGR rate of gas sucked into the internal combustion engine is equal to or lower than the critical EGR rate. For example, as shown in FIG. 8, the EGR rate of gas in the intake manifold 11 after a transition of the internal combustion engine 10 from a normal control state to a fuel cut control state can be calculated on the basis of an operating condition of the internal combustion engine 10 immediately before the start of fuel cut control (e.g., rotational speed, load, intake air amount, fuel injection amount, target EGR rate, concentration of carbon dioxide in exhaust gas, or the like) and an elapsed time from the start of fuel cut control. It is also appropriate to find out in advance how this operating condition immediately before the start of fuel cut control and this elapsed time from the start of fuel cut control are related to the EGR rate of gas in the intake manifold 11, and estimate the EGR rate of gas in the intake manifold 11 at the time of fulfillment of the condition for switching the fuel injection control of the internal combustion engine 10 from fuel cut control to normal control on the basis of the elapsed time from the start of fuel cut control at the time of fulfillment of the condition. Further, the EGR passage in the foregoing embodiment of the invention may be a passage for connecting that section of the exhaust passage 19 which is located downstream of the turbine 14b or the exhaust gas purification catalyst 20 and that section of the intake passage 13 which is located upstream of the compressor 14a to each other. Further, a certain constant calculated in advance may be used as the critical EGR rate, or this critical EGR rate may be a variable value corresponding to the operating condition at the time of fulfillment of the switching condition from fuel cut control to normal control.

CLAIMS:

1. A control apparatus for a hybrid system equipped with an internal combustion engine and an electric motor as power sources to generate/output a required output by the internal combustion engine and/or the electric motor, comprising:

an EGR device that causes part of exhaust gas from the internal combustion engine to flow into an intake system of the internal combustion engine as EGR gas;

means for performing fuel cut control to stop fuel injection in the internal combustion engine;

determination means for determining whether an EGR rate of gas sucked into the internal combustion engine is equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the internal combustion engine; and

control means for controlling the internal combustion engine so as to continue the fuel cut control without switching fuel injection control to normal fuel injection control and controlling the electric motor so as to generate the required output only by the electric motor during a period from a time point at which a condition for switching the fuel injection control from the fuel cut control to the normal fuel injection control is fulfilled to a time point at which the determination means determines that the EGR rate has become equal to or lower than the critical EGR rate, when the condition for switching the fuel injection control to the normal fuel injection control is fulfilled during performance of the fuel cut control.

2. The control apparatus according to claim 1, wherein the control means controls the electric motor so as to carry out cranking of the internal combustion engine during the period.

3. The control apparatus according to claim 1 or 2, wherein the control means controls the internal combustion engine so as to switch the fuel injection control from the fuel cut control to the normal fuel injection control and switches a control of the electric motor to

normal control when the determination means determines that the EGR rate has become equal to or lower than the critical EGR rate.

4. The control apparatus according to any one of claims 1 to 3, wherein the fuel cut control is performed in a deceleration state or a vehicle stop state.

5. The control apparatus according to claim 4, wherein the condition for switching the fuel injection control to the normal fuel injection control is a condition fulfilled at a time of re-acceleration from a deceleration state or a vehicle stop state.

6. The control apparatus according to any one of claims 1 to 5, further comprising a gas concentration sensor that measures a concentration of carbon dioxide in gas sucked into the internal combustion engine, wherein

the determination means calculates the EGR rate on a basis of the measured concentration of carbon dioxide.

7. A hybrid vehicle comprising:

a hybrid system that is equipped with an internal combustion engine and an electric motor as power sources to generate/output a required output by the internal combustion engine and/or the electric motor;

an EGR device that causes part of exhaust gas from the internal combustion engine to flow into an intake system of the internal combustion engine as EGR gas;

a controller performs fuel cut control to stop fuel injection in the internal combustion engine; determines whether an EGR rate of gas sucked into the internal combustion engine is equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the internal combustion engine; and controls the internal combustion engine so as to continue the fuel cut control without switching fuel injection control to normal fuel injection control and controlling the electric motor so as to generate the required output only by the electric motor during a period from a time point at which a condition for switching the fuel injection control from the fuel cut control to the normal fuel injection control is fulfilled to a time point at which the controller determines that the EGR rate has become equal to or lower than the critical EGR rate, when the condition for switching the fuel injection control to the normal fuel injection control is fulfilled during performance of the fuel cut control.

8. A control method for a hybrid system that is equipped with an internal combustion engine and an electric motor as power sources to generate/output a required output by the internal combustion engine and/or the electric motor, comprising:

determining whether to perform fuel cut control to stop fuel injection in the internal combustion engine or not;

determining whether a condition for switching fuel injection control from fuel cut control to normal fuel injection control has been fulfilled;

determining whether an EGR rate of gas sucked into the internal combustion engine is equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the internal combustion engine; and

continuing the fuel cut control and generating the required output only by the electric motor during a period from a time point at which a condition for switching the fuel injection control from the fuel cut control to normal fuel injection control is fulfilled to a time point at which it is determined that the EGR rate has become equal to or lower than the predetermined critical EGR rate.

9. A control apparatus for a hybrid system that is equipped with an internal combustion engine and an electric motor as power sources to generate/output a required output by the internal combustion engine and/or the electric motor, comprising:

an EGR device that causes part of exhaust gas from the internal combustion engine to flow into an intake system of the internal combustion engine as EGR gas;

a determination device that calculates an EGR rate of gas sucked into the internal combustion engine; and a controller that makes a determination on an operating state of the hybrid system and continues fuel cut control and controls the electric motor so as to generate the required output only by the electric motor during a period from a time point at which it is determined that a condition for switching fuel injection control from the fuel cut control to normal fuel injection control has been fulfilled, based on the determined operating state, to a time point at which the calculated EGR rate becomes equal to or lower than a predetermined critical EGR rate that does not cause misfiring in the internal combustion engine.

FIG. 1

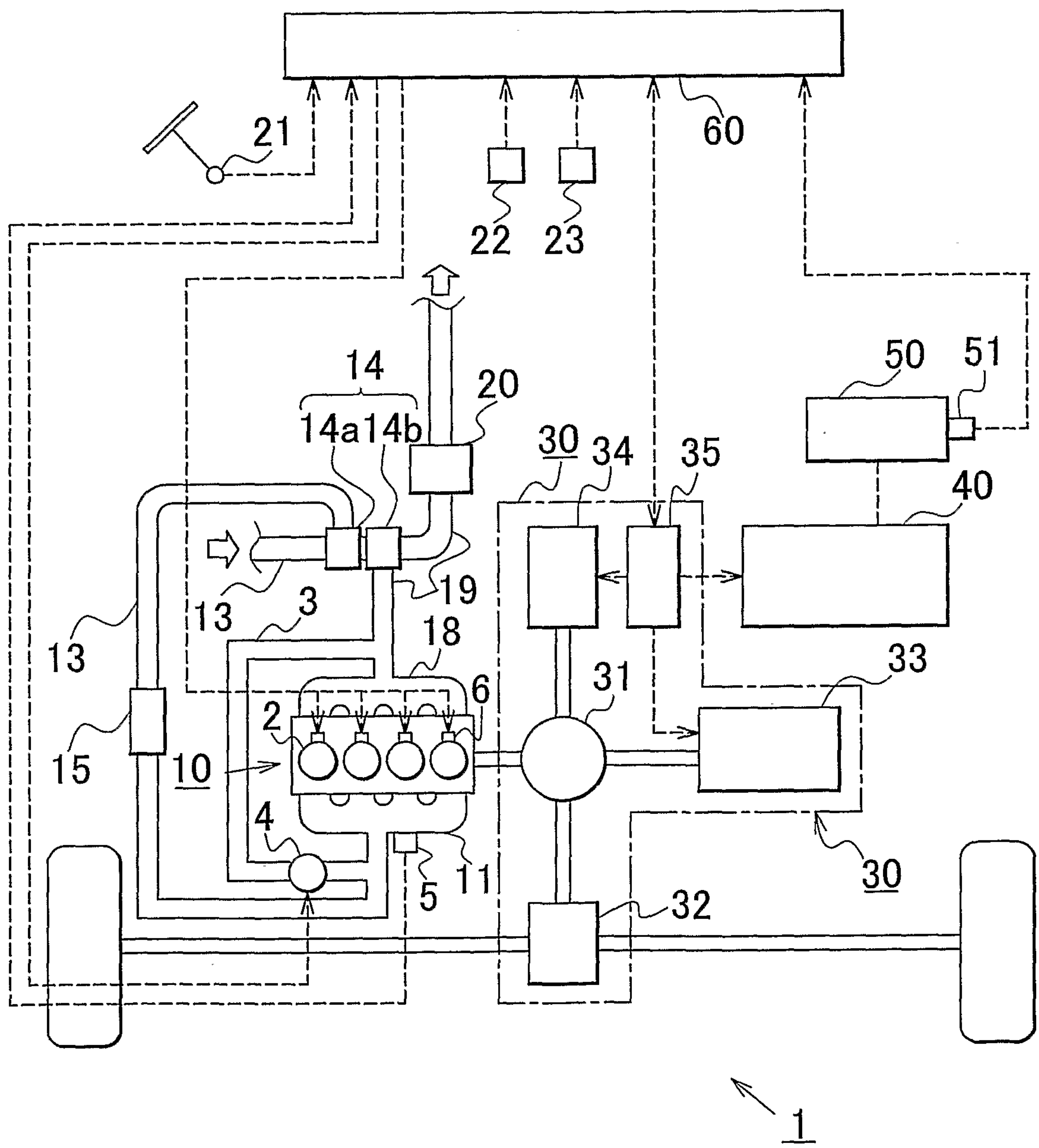
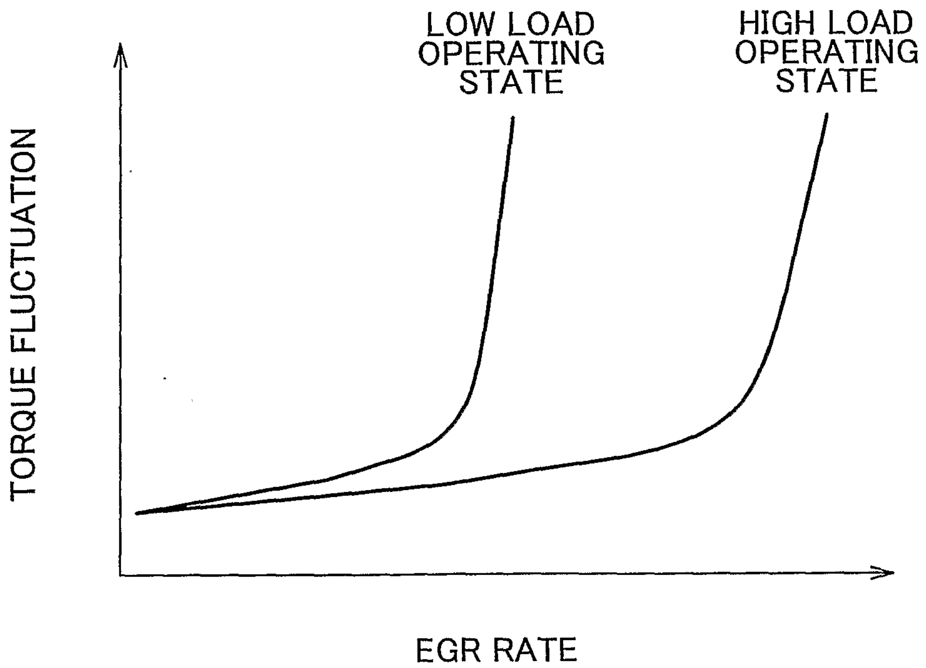

60
21
22
23
14
14a
14b
20
50
51
30
34
35
40
13
19
3
18
33
31
6
2
15
10
4
11
5
32
30
1

FIG. 2


LOW LOAD OPERATING STATE
HIGH LOAD OPERATING STATE
TORQUE FLUCTUATION
EGR RATE

F.I G. 3

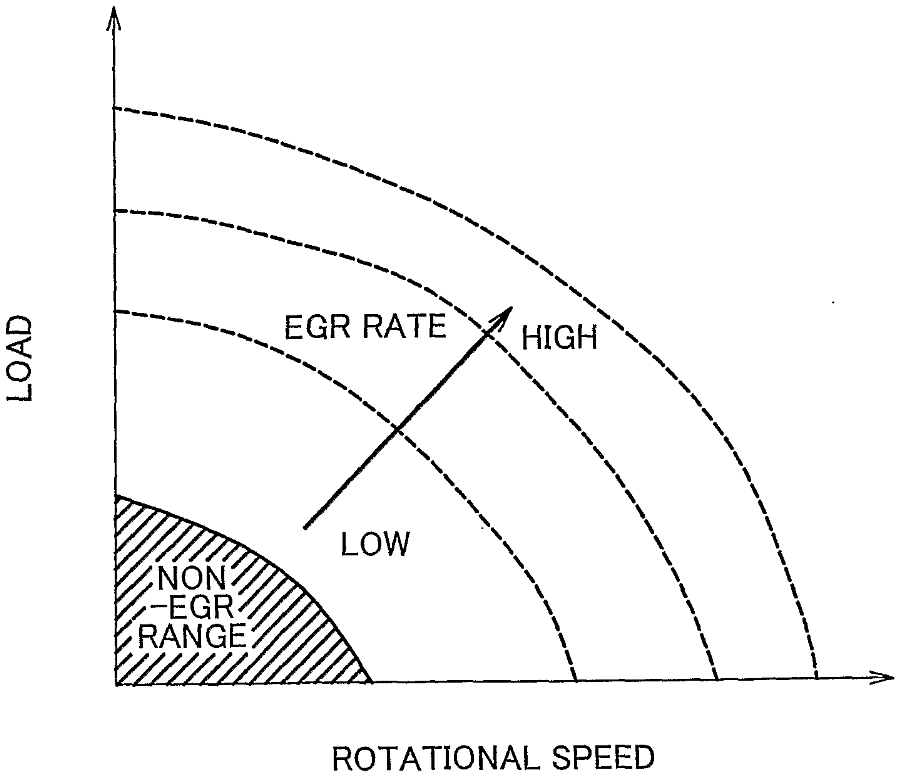


FIG. 4A

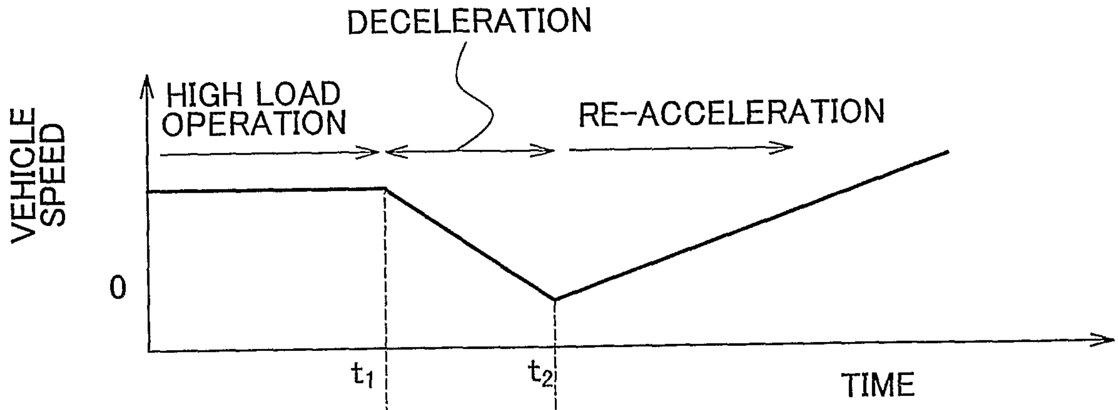


FIG. 4B

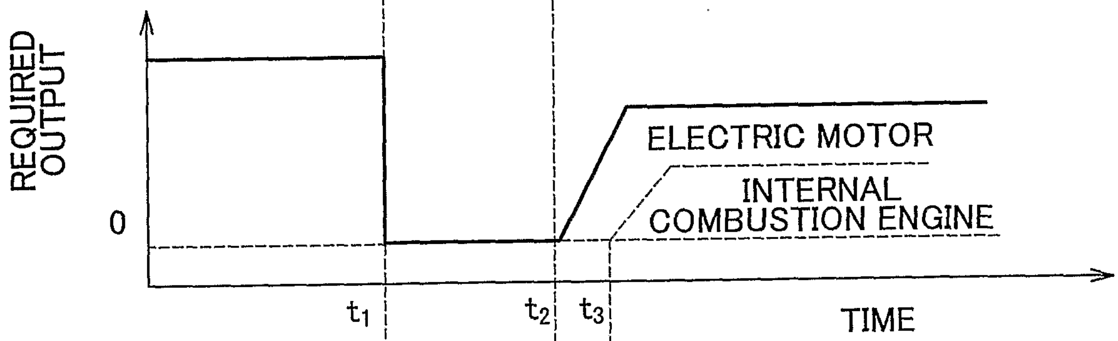


FIG. 4C

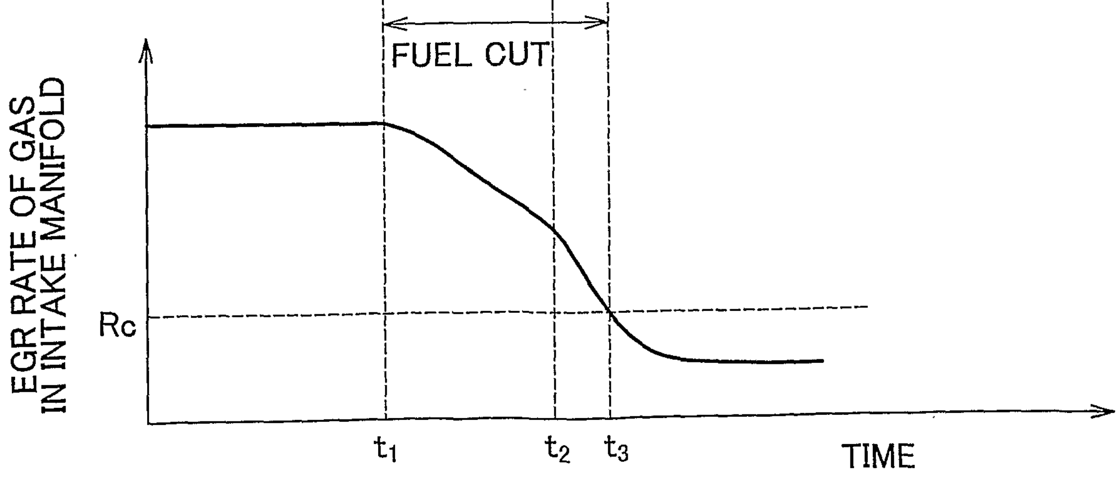


FIG. 5

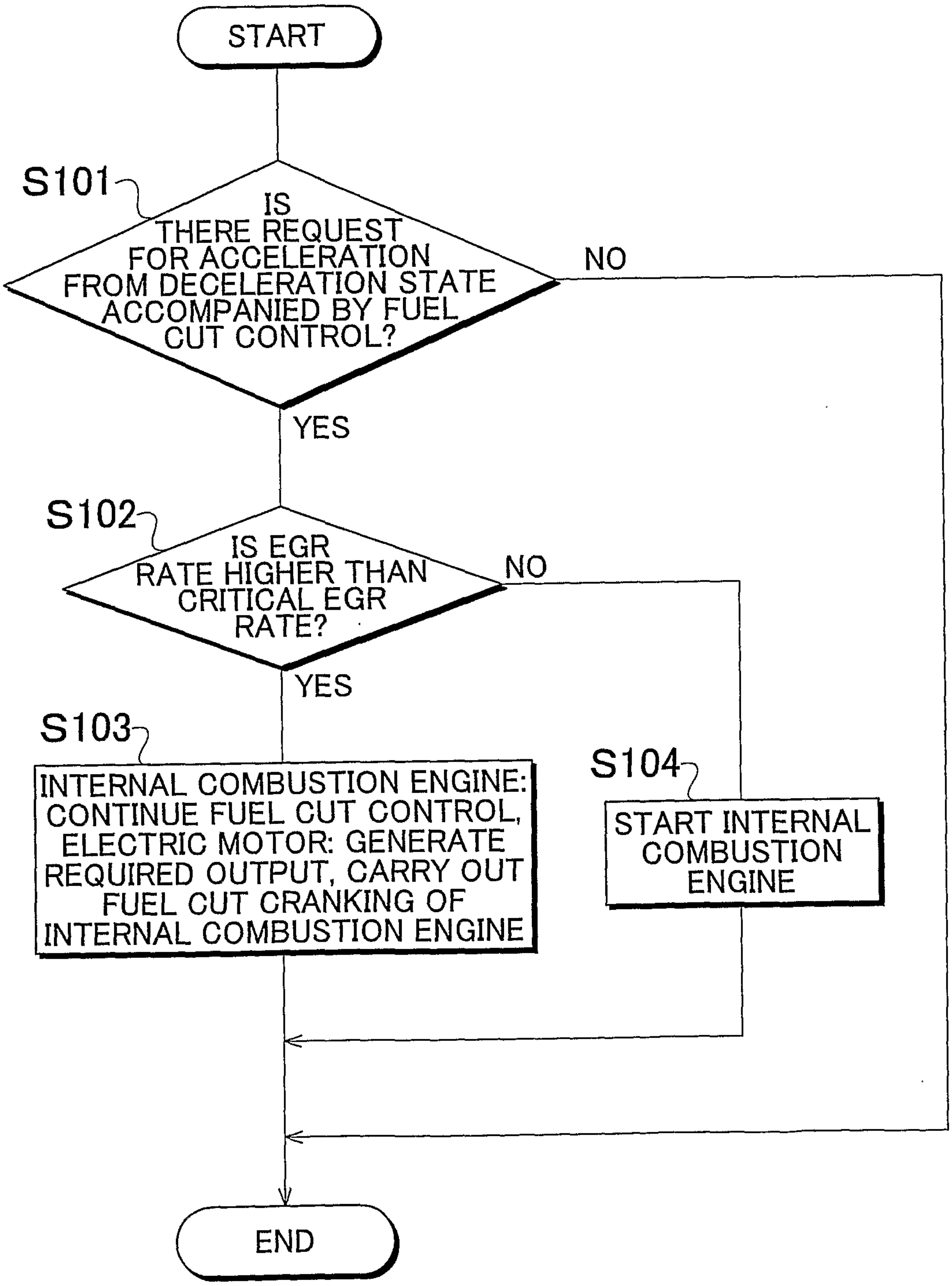

START
S101
IS THERE REQUEST FOR ACCELERATION FROM DECELERATION STATE ACCOMPANIED BY FUEL CUT CONTROL?
NO
YES
S102
IS EGR RATE HIGHER THAN CRITICAL EGR RATE?
NO
YES
S103
INTERNAL COMBUSTION ENGINE: CONTINUE FUEL CUT CONTROL, ELECTRIC MOTOR: GENERATE REQUIRED OUTPUT, CARRY OUT FUEL CUT CRANKING OF INTERNAL COMBUSTION ENGINE
S104
START INTERNAL COMBUSTION ENGINE
END

FIG. 6A

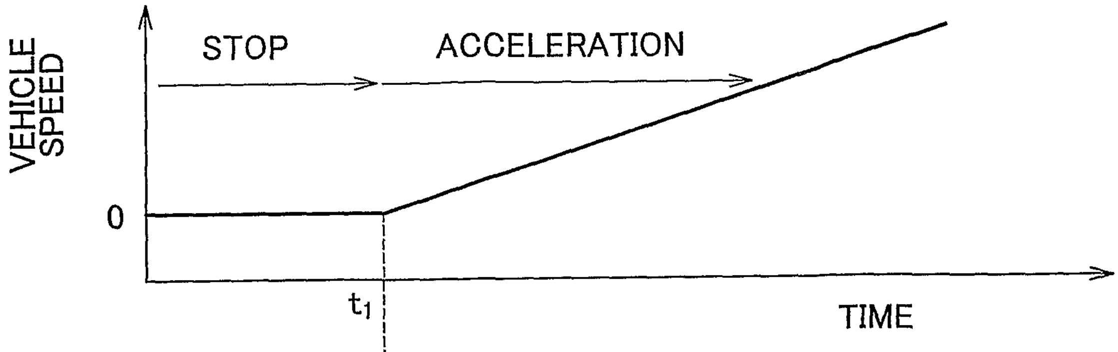


FIG. 6B

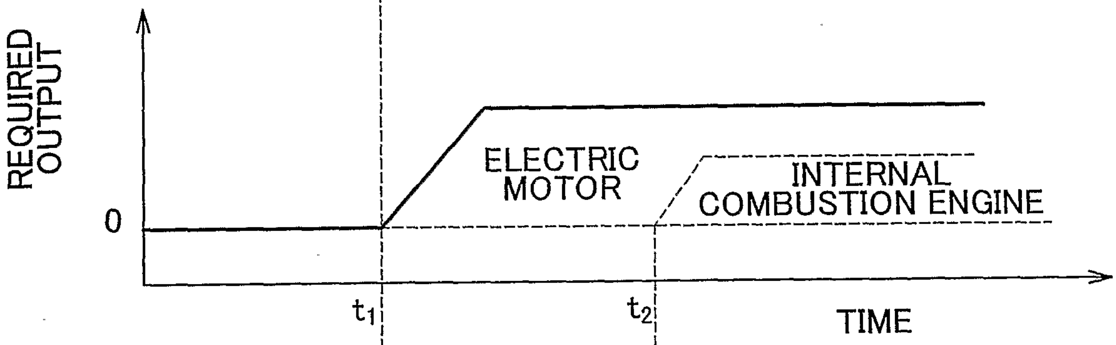


FIG. 6C

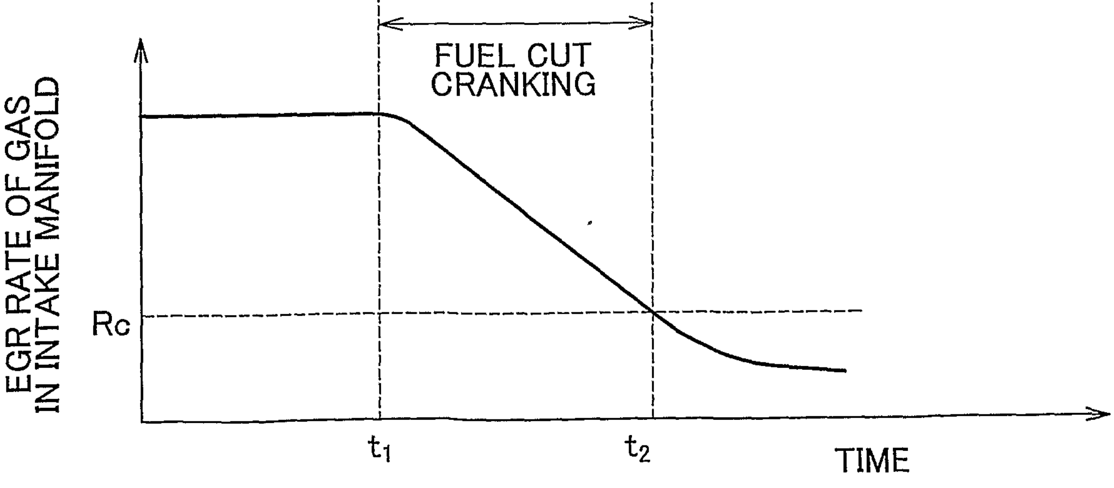


FIG. 7

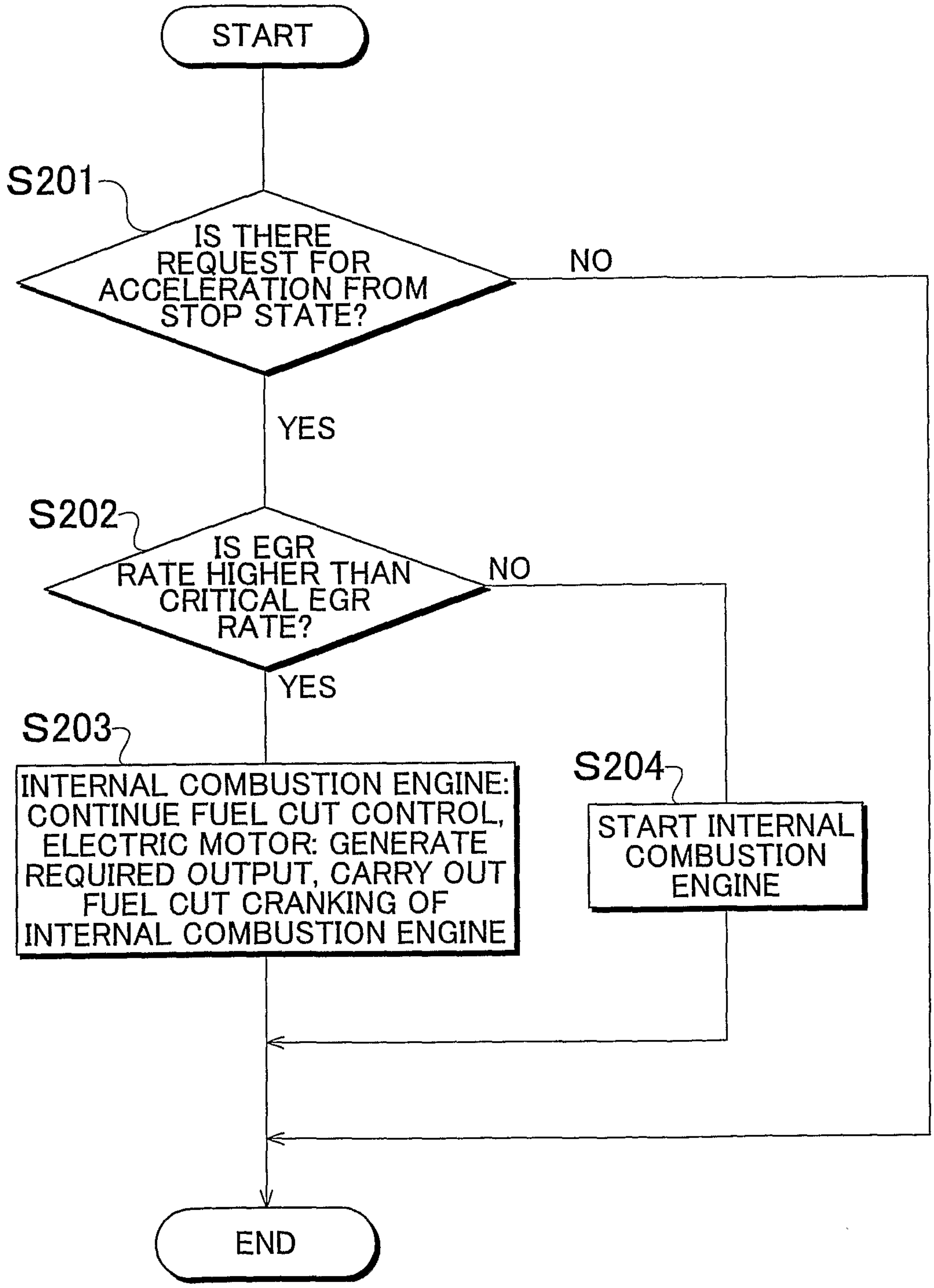
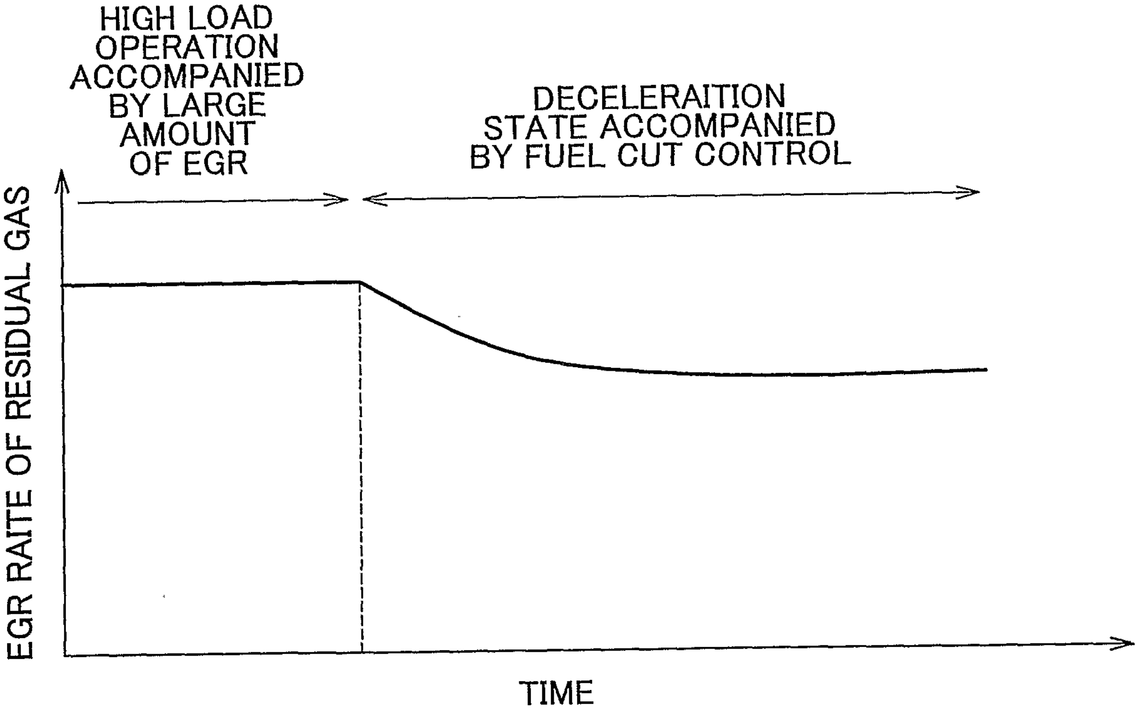

START
S201
IS THERE REQUEST FOR ACCELERATION FROM STOP STATE?
NO
YES
S202
IS EGR RATE HIGHER THAN CRITICAL EGR RATE?
NO
YES
S203
INTERNAL COMBUSTION ENGINE: CONTINUE FUEL CUT CONTROL, ELECTRIC MOTOR: GENERATE REQUIRED OUTPUT, CARRY OUT FUEL CUT CRANKING OF INTERNAL COMBUSTION ENGINE
S204
START INTERNAL COMBUSTION ENGINE
END

FIG. 8


HIGH LOAD OPERATION ACCOMPANIED BY LARGE AMOUNT OF EGR
DECELERAITION STATE ACCOMPANIED BY FUEL CUT CONTROL
EGR RAITE OF RESIDUAL GAS
TIME