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Inventor(s) ASAHARA; Norimi et al.

BATTERY ELECTRIC VEHICLE AND CONTROL DEVICE

Abstract

A battery electric vehicle includes an electric motor, a driving operation member, a storage device configured to store a database, and a processing circuit. The database is configured to manage a plurality of vehicle models obtained by modeling a plurality of virtual vehicles having different acceleration characteristics in response to a driving operation of a driver. The processing circuit is configured to read out a target vehicle model corresponding to a target virtual vehicle selected by the driver from the database and to calculate a virtual acceleration of the target virtual vehicle using the target vehicle model. The processing circuit is configured to calculate an adjusted virtual acceleration by multiplying the virtual acceleration by a coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle and to control the electric motor such that an acceleration of the battery electric vehicle is the adjusted virtual acceleration.

Inventors: **ASAHARA; Norimi (Numadu-shi, JP), FUJII; Kazuki (Hadano-shi, JP), KANEKO; Satoshi (Gotemba-shi, JP)**

Applicant: **TOYOTA JIDOSHA KABUSHIKI KAISHA** (Toyota-shi, JP)

Family ID: **1000008448801**

Assignee: **TOYOTA JIDOSHA KABUSHIKI KAISHA (Toyota-shi, JP)**

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-024657 filed on Feb. 21, 2024. The disclosure of the above-identified application, including the specification, drawings, and claims, is incorporated by reference herein in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a battery electric vehicle having an electric motor as a drive source and a control device.

2. Description of Related Art

[0003] An electric motor controls a voltage or magnetic field to be applied to enable control such that a desired motor torque is output. There is a technique of controlling an electric motor of a battery electric vehicle as appropriate by using the above to reproduce various driving feelings in the battery electric vehicle. For example, Japanese Patent No. 6787507 (JP 6787507 B) discloses a technique of reproducing, in the battery electric vehicle, a driving feeling due to a manual shift operation of a manual transmission vehicle in a pseudo manner.

SUMMARY

[0004] As one of factors that characterize the driving feeling of each vehicle, there is a sense of acceleration of the vehicle in response to a driving operation. The sense of acceleration of the vehicle is an important point when a driver feels fun in driving the vehicle. In particular, the preference for the sense of acceleration of the vehicle is different for each driver. Further, the driver may want to enjoy various senses of acceleration of the vehicle according to the mood.

[0005] In the present disclosure, a technique is studied in which a virtual acceleration when a virtual vehicle is driven by using a vehicle model is calculated and an electric motor is controlled to realize the calculated virtual acceleration in a battery electric vehicle. The vehicle model can be provided to each of a plurality of virtual vehicles. Therefore, with the technique, it is possible to reproduce the sense of acceleration of the virtual vehicles in one battery electric vehicle in a pseudo manner.

[0006] However, an acceleration that can be realized by the battery electric vehicle is naturally limited in relation to an output characteristic of a motor torque of the electric motor of the battery electric vehicle. For this reason, in a case of the virtual vehicle having an acceleration characteristic exceeding an acceleration capability of the battery electric vehicle, a situation occurs in which the acceleration characteristic cannot be realized as it is in the battery electric vehicle. As a result, there is a problem that the sense of acceleration of such a virtual vehicle cannot be reproduced in the battery electric vehicle. On the other hand, an increase in the acceleration capability of the battery electric vehicle to realize the acceleration characteristic of such a virtual vehicle causes the cost of the battery electric vehicle to be unnecessarily increased.

[0007] The present disclosure provides a battery electric vehicle and a control device that reproduce a sense of acceleration of a virtual vehicle having an acceleration characteristic exceeding an acceleration capability of the battery electric vehicle.

[0008] A battery electric vehicle according to a first aspect of the present disclosure includes an electric motor as a drive source, a driving operation member used for driving of the battery electric vehicle, a storage device configured to store a database, and a processing circuit. The database is configured to manage a plurality of vehicle models obtained by modeling a plurality of virtual vehicles having different acceleration characteristics in response to a driving operation of a driver. The processing circuit is configured to read out a target vehicle model corresponding to a target virtual vehicle from the database. The target virtual vehicle is selected by the driver from the virtual vehicles. The processing circuit is configured to calculate a virtual acceleration of the target virtual vehicle in response to an operation of the driving operation member using the target vehicle model based on an operation state of the driving operation member and a traveling state of the battery electric vehicle. The processing circuit is configured to execute adjustment processing of calculating an adjusted virtual acceleration by multiplying the virtual acceleration by a coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle. The processing circuit is configured to control the electric motor such that an acceleration of the battery electric vehicle is the adjusted virtual acceleration.

[0009] In the battery electric vehicle according to the first aspect of the present disclosure, in the adjustment processing, the processing circuit may be configured to set the coefficient to a value obtained by dividing a realizable maximum acceleration of the battery electric vehicle by a maximum acceleration in the acceleration characteristic of the target virtual vehicle when the acceleration characteristic of the target virtual vehicle exceeds an acceleration capability of the battery electric vehicle.

[0010] In the battery electric vehicle according to the first aspect of the present disclosure, in the adjustment processing, the processing circuit may be configured to set the coefficient to 1 when the acceleration characteristic of the target virtual vehicle does not exceed an acceleration capability of the battery electric vehicle.

[0011] In the battery electric vehicle according to the first aspect of the present disclosure, in the adjustment processing, the processing circuit may be configured to set the coefficient to 1 while the virtual acceleration is realizable by the battery electric vehicle, regardless of the acceleration characteristic of the target virtual vehicle.

[0012] In the battery electric vehicle according to the first aspect of the present disclosure, the driving operation member may include an accelerator pedal. In the adjustment processing, the processing circuit may be configured to change a value of the coefficient based on an accelerator operation amount of the accelerator pedal and a vehicle speed of the battery electric vehicle when the acceleration characteristic of the target virtual vehicle exceeds an acceleration capability of the battery electric vehicle.

[0013] In the battery electric vehicle according to the first aspect of the present disclosure, the processing circuit may be configured to calculate a target drive force of the battery electric vehicle to set the acceleration of the battery electric vehicle to the adjusted virtual acceleration. The processing circuit may be configured to change a motor torque output by the electric motor to provide the target drive force to the battery electric vehicle.

[0014] In the battery electric vehicle according to the first aspect of the present disclosure, each of the vehicle models may have one or a plurality of parameters related to the acceleration characteristic. The processing circuit may be further configured to set the one or the plurality of parameters of the target vehicle model according to the target virtual vehicle.

[0015] A control device according to a second aspect of the present disclosure is a control device for a battery electric vehicle. The battery electric vehicle includes an electric motor as a drive source and a driving operation member used for driving of the battery electric vehicle. The control device includes a storage device configured to store a database and a processing circuit. The database is configured to manage a plurality of vehicle models obtained by modeling a plurality of virtual vehicles having different acceleration characteristics in response to a driving operation of a driver. The processing circuit is configured to read out a target vehicle model corresponding to a target virtual vehicle from the database. The target virtual vehicle is selected by the driver from the virtual vehicles. The processing circuit is configured to calculate a virtual acceleration of the target virtual vehicle in response to an operation of the driving operation member using the target vehicle model based on an operation state of the driving operation member and a traveling state of the battery electric vehicle. The processing circuit is configured to execute adjustment processing of calculating an adjusted virtual acceleration by multiplying the virtual acceleration by a coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle. The processing circuit is configured to control the electric motor such that an acceleration of the battery electric vehicle is the adjusted virtual acceleration.

[0016] In the battery electric vehicle according to the second aspect of the present disclosure, in the adjustment processing, the processing circuit may be configured to set the coefficient to a value obtained by dividing a realizable maximum acceleration of the battery electric vehicle by a maximum acceleration in the acceleration characteristic of the target virtual vehicle when the acceleration characteristic of the target virtual vehicle exceeds an acceleration capability of the battery electric vehicle.

[0017] In the battery electric vehicle according to the second aspect of the present disclosure, in the adjustment processing, the processing circuit may be configured to set the coefficient to 1 when the acceleration characteristic of the target virtual vehicle does not exceed an acceleration capability of the battery electric vehicle.

[0018] According to the present disclosure, the adjusted virtual acceleration is calculated by multiplying the virtual acceleration of the target virtual vehicle by the coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle. The electric motor is controlled such that the acceleration of the battery electric vehicle is the adjusted virtual acceleration. Accordingly, even when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle, it is possible to realize the acceleration characteristic capable of reproducing the sense of acceleration of the target virtual vehicle within the range of the acceleration capability of the battery electric vehicle. In this manner, according to the present disclosure, it is possible to reproduce the sense of acceleration of the virtual vehicle having the acceleration characteristic that exceeds the acceleration capability of the battery electric vehicle.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Features, advantages, and technical and industrial significance of exemplary embodiments of the present disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0020] FIG. **1** is a diagram showing a configuration of a battery electric vehicle according to an embodiment;

[0021] FIG. **2** is a tree diagram showing an example of a selection input that is received by an HMI regarding a control mode of the battery electric vehicle according to an embodiment;

[0022] FIG. **3** is a diagram showing an example of a functional configuration of a control device that functions as a motor control device;

[0023] FIG. **4** is a graph showing an example of an acceleration characteristic of the battery electric vehicle realized when the control mode is an on-demand mode;

[0024] FIG. **5** is a graph showing an example of the acceleration characteristic of the battery electric vehicle that is normally realized when the acceleration characteristic of a target virtual vehicle exceeds an acceleration capability of the battery electric vehicle;

[0025] FIG. **6** is a diagram showing an example of a functional configuration of an on-demand mode drive force calculation unit shown in FIG. **3**;

[0026] FIG. **7** is a graph showing an example of the acceleration characteristic of the battery electric vehicle realized by the motor control device according to an embodiment;
[0027] FIG. **8** is a flowchart showing a processing flow of processing executed by the on-demand mode drive force calculation unit;
[0028] FIG. **9** is a flowchart showing an example of processing related to setting of a coefficient;
[0029] FIG. **10** is a diagram showing an example of a configuration of a vehicle model;
[0030] FIG. **11** is a flowchart showing an example of processing related to setting of a coefficient in a first modification example;
[0031] FIG. **12** is a diagram showing an example of a coefficient setter in a second modification example; and
[0032] FIG. **13** is a diagram showing an example of a functional configuration of a control device that functions as a sound control device.

DETAILED DESCRIPTION OF EMBODIMENTS

[0033] Hereinafter, embodiments of the present disclosure will be described with reference to drawings. In each figure, the same reference numeral is assigned to the same or corresponding part and a description thereof is simplified or omitted.

1 Configuration of Power System of Battery Electric Vehicle

[0034] FIG. **1** is a diagram schematically showing a configuration of a battery electric vehicle **100** according to an embodiment of the present disclosure. First, a configuration of a power system of the battery electric vehicle **100** will be described with reference to FIG. **1**.

[0035] The battery electric vehicle **100** includes an electric motor (M) **2** as a drive source for traveling. The electric motor **2** is, for example, a three-phase alternating current motor. An output shaft **3** of the electric motor **2** is connected to a first end of a propeller shaft **5** via a gear mechanism **4**. The second end of the propeller shaft **5** is connected to a drive shaft **7** in front of a vehicle via a differential gear **6**.

[0036] The battery electric vehicle **100** includes drive tire-wheel assemblies **8** as front tire-wheel assemblies and dependent tire-wheel assemblies **12** as rear tire-wheel assemblies. The drive tire-wheel assemblies **8** are provided at both ends of the drive shaft **7**, respectively.

[0037] The battery electric vehicle **100** includes a battery (BATT) **14** and an inverter (INV) **16**. The battery **14** stores electric energy that drives the electric motor **2**. That is, the battery electric vehicle **100** is a battery electric vehicle (BEV) that travels with the electric energy stored in the battery **14**. The inverter **16** is, for example, a voltage type inverter. The inverter **16** controls a motor torque output by the electric motor **2** by PWM control.

2 Configuration of Control System of Battery Electric Vehicle

[0038] Subsequently, a configuration of a control system of the battery electric vehicle **100** will be described with reference to FIG. **1**.

[0039] The battery electric vehicle **100** includes a vehicle speed sensor **30** for detecting a vehicle speed. At least one tire-wheel assembly speed sensor (not shown) provided in each of right and left front tire-wheel assemblies **8** and right and left rear tire-wheel assemblies **12** is used as the vehicle speed sensor **30**. The vehicle speed is one of traveling states of the battery electric vehicle **100**. The battery electric vehicle **100** may further include a sensor for detecting other traveling states of the battery electric vehicle **100** such as a yaw rate, a posture, and a surrounding environment.

[0040] The battery electric vehicle **100** includes an accelerator pedal stroke sensor **32**. The accelerator pedal stroke sensor **32** is provided in an accelerator pedal **22**, and outputs a signal indicating an operation state of the accelerator pedal **22**. The operation state of the accelerator pedal typically includes an accelerator operation amount and an accelerator operation speed. Further, the battery electric vehicle **100** includes a brake pedal stroke sensor **34**. The brake pedal stroke sensor **34** is provided in a brake pedal **24**, and outputs a signal indicating the operation state of the brake pedal **24**. The operation state of the brake pedal **24** typically includes a brake operation amount or a brake operation speed.

[0041] Each of the accelerator pedal **22** and the brake pedal **24** is one of driving operation members used for driving of the battery electric vehicle **100**. In addition, the battery electric vehicle **100** may include various types of driving operation members, such as a steering wheel for the driving related to steering.

[0042] The battery electric vehicle **100** includes a rotation speed sensor **40**. The rotation speed sensor **40** is provided in the electric motor **2**, and outputs a signal indicating a rotation speed of the electric motor **2**.

[0043] The battery electric vehicle **100** includes a battery management system (BMS) **10**. The battery management system **10** is a device that monitors a cell voltage, current, temperature, and the like of the battery **14**. The battery management system **10** has a function of estimating a state of charge (SOC) of the battery **14**.

[0044] The battery electric vehicle **100** includes a human machine interface (HMI) **20** as an interface with a driver and an in-vehicle speaker **21**. The HMI **20** presents various types of information to the driver by display or sound, and also receives various types of inputs from the driver. The HMI **20** is configured of a display (for example, multi-information display or meter display), a switch, a touch pad, a speaker phone, a touch screen, and the like. For example, the HMI **20** displays various types of information on the display, and receives the input from the driver regarding a display content by a switch operation. Further, for example, the HMI **20** displays various types of information on a touch screen, and receives the input from the driver regarding the display content by a touch operation on the touch screen. The in-vehicle speaker **21** is a sound generator that artificially generates a sound in a vehicle cabin. In particular, the in-vehicle speaker **21** can output a pseudo engine sound described below. The in-vehicle speaker **21** may be configured as a part of the HMI **20**.

[0045] The battery electric vehicle **100** includes a control device **101**. Various types of sensors or control target devices mounted on the battery electric vehicle **100** are connected to the control device **101** by an in-vehicle network, such as a controller area network (CAN). In addition to the vehicle speed sensor **30**, the accelerator pedal stroke sensor **32**, the brake pedal stroke sensor **34**, and the rotation speed sensor **40**, various sensors may be mounted on the battery electric vehicle **100** and connected to the control device **101** via the in-vehicle network.

[0046] The control device **101** generates control signals related to various types of control of the battery electric vehicle **100** based on the signals acquired from the respective sensors. The control device **101** is typically an electronic control unit (ECU). The control device **101** may be a combination of a plurality of ECUs. The control device **101** includes at least a processing circuit **102** and a storage device **103**.

[0047] The processing circuit **102** executes various types of processing. The processing circuit **102** is configured of, for example, a general-purpose processor, a specific-purpose processor, a central processing unit (CPU), a graphics processing unit (GPU), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), an integrated circuit, a conventional circuit, and a combination of one or a plurality of these. A processor including a transistor and other circuits is an example of the processing circuit **102**. The processing circuit **102** may also be referred to as circuitry or processing circuitry. The circuitry is hardware programmed to realize the function described in the present disclosure, or hardware that executes the function.

[0048] The storage device **103** stores various types of information needed to execute the processing of the processing circuit **102**. The storage device **103** is configured of a recording medium, such as a random access memory (RAM), a read only memory (ROM), a solid state drive (SSD), or a hard disk drive (HDD). The storage device **103** stores a computer program **104** that can be executed by the processing circuit **102** and various types of data **105**. The computer program **104** is configured of a plurality of instructions that describes the processing to be executed by the processing circuit **102**. The computer program **104** may be recorded on a computer-readable recording medium. The processing circuit **102** that executes the computer program **104** and the storage device **103** cooperate with each other to realize the function of the control device **101**.

[0049] The control device **101** according to the present embodiment has, regarding control of the battery electric vehicle **100**, at least two control modes of a normal mode and an on-demand mode. The control of the battery electric vehicle **100**, which is executed by the control device **101**, is changed according to a selected control mode. Hereinafter, the control mode of the battery electric vehicle **100** will be described.

3 Control Mode of Battery Electric Vehicle

[0050] As described above, there are at least two modes of the normal mode and the on-demand mode in the control mode of the battery electric vehicle **100**. The normal mode is a control mode in which the battery electric vehicle **100** is driven as a normal BEV. When the normal mode is selected, the control device **101** performs the control of the battery electric vehicle **100** to operate as the normal BEV. On the other hand, the on-demand mode is a control mode in which a sense of acceleration of a virtual vehicle (hereinafter referred to as “target virtual vehicle”) selected by the driver from among a plurality of virtual vehicles is reproduced in the battery electric vehicle **100**. When the on-demand mode is selected, the control device **101** performs the control of the battery electric vehicle **100** such that the driver can obtain the sense of acceleration as if the driver drives the target virtual vehicle. Details of various types of control of the battery electric vehicle **100** in each of the normal mode and the on-demand mode will be described below.

[0051] In the on-demand mode, the virtual vehicles include various vehicles having different acceleration characteristics in response to a driving operation of the driver. Each virtual vehicle may be assumed to be a real vehicle, or may be assumed to be a vehicle that is not present in reality. The difference in the acceleration characteristic is generally due to a difference in a configuration of a powertrain from the drive source to the drive tire-wheel assemblies or a difference in a control method of the powertrain. Therefore, the virtual vehicles may be considered to include various vehicles in which at least some elements of the configuration or the control method related to the powertrain are different.

[0052] The driver operates the HMI **20** to select the control mode. The HMI **20** is configured to receive a selection input of the control mode from the driver. Further, the HMI **20** is configured to receive the selection input of the target virtual vehicle from the driver in the on-demand mode.

[0053] FIG. **2** is a tree diagram showing an example of the selection input received by the HMI **20**. For example, the HMI **20** receives the selection input from the driver as follows in accordance with the tree shown in FIG. **2**, via the display on the display or the touch screen.

[0054] First, the HMI **20** displays a setting menu screen on the display or the touch screen in response to the operation of the driver. An initial screen of the setting menu screen displays an option “control mode” and an option “target virtual vehicle”. The option “control mode” is to receive the selection input of the control mode from the driver. The option “target virtual vehicle” is to receive the selection input of the target virtual vehicle from the driver.

[0055] When the option “control mode” is selected, next, the setting menu screen displays the option “normal mode” and the option “on-demand mode”. When the option “normal mode” is selected, the HMI **20** determines that the control mode of the battery electric vehicle **100** is the normal mode. When the option “on-demand mode” is selected, the HMI **20** determines that the control mode of the battery electric vehicle **100** is the on-demand mode. In this manner, the HMI **20** receives the selection input of the control mode from the driver.

[0056] On the other hand, when the option “on-demand mode” is selected, next, the setting menu screen displays an option “CONV” and an option “HEV”. The option “CONV” and the option “HEV” respectively indicate classifications of the virtual vehicles that are selectable in the on-demand mode. The CONV is a classification indicating a conventional vehicle. The HEV is a classification indicating a hybrid electric vehicle. When the option “CONV” is selected, next, the setting menu screen displays an option “virtual vehicle A**1**”, an option “virtual vehicle A**2**”, and an option “virtual vehicle B**1**”. The virtual vehicle A**1**, the virtual vehicle A**2**, and the virtual vehicle

B**1** are the virtual vehicles classified into the CONV among the selectable virtual vehicles. Similarly, when the option “HEV” is selected, next, the setting menu screen displays an option “virtual vehicle C**1**” and an option “virtual vehicle C**2**”. The virtual vehicle C**1** and the virtual vehicle C**2** are the virtual vehicles classified into the HEV among the selectable virtual vehicles. When any one of these options is selected, the HMI **20** determines that a corresponding virtual vehicle is the target virtual vehicle. For example, when the option “virtual vehicle A**2**” is selected, the HMI **20** determines that the virtual vehicle A**2** is the target virtual vehicle. In this manner, the HMI **20** receives the selection input of the target virtual vehicle from the driver.

[0057] The classification of the virtual vehicles in the above description is an example, and the option related to the classification may be changed as appropriate. For example, the option related to the classification may further include an option indicating a plug-in hybrid electric vehicle or a fuel cell electric vehicle. Further, for example, the option related to the classification may indicate another classification such as a classification related to a type of an internal combustion engine to be mounted (for example, in-line four-cylinder turbocharged engine, flat six-cylinder engine, or a V12 engine). Alternatively, when the option “on-demand mode” is selected, the option related to the classification may not be displayed, and the option related to the virtual vehicle may be displayed.

[0058] For each option, the name displayed on the setting menu screen may be set as appropriate in consideration of the case of understanding of the driver. For example, in the option related to the virtual vehicle, the displayed name may be a more specific name, such as a vehicle model or a product name, which allows the driver to easily imagine the virtual vehicle.

[0059] As described above, the driver can select the control mode by operating the HMI **20**. The control device **101** performs the control of the battery electric vehicle **100** in accordance with the selected control mode.

[0060] The control device **101** according to the present embodiment functions as at least a motor control device that controls the electric motor **2** in response to the driving operation of the driver in the control of the battery electric vehicle **100**. Specifically, with the execution of the computer program **104** for electric motor control, which is stored in the storage device **103**, by the processing circuit **102**, the control device **101** functions as the motor control device. The electric motor **2** is the drive source of the battery electric vehicle **100**. Therefore, the motor control device may also be referred to as a device that performs drive control of the battery electric vehicle **100**. In the following, the control of the battery electric vehicle **100** by the motor control device will be described.

4 Motor Control Device

[0061] FIG. **3** is a diagram showing an example of a functional configuration of a motor control device **101***a*. The motor control device **101***a* calculates a target drive force of the battery electric vehicle **100** in response to the driving operation of the driver. The motor control device **101***a* controls the electric motor **2** via the inverter **16** to provide the calculated target drive force to the battery electric vehicle **100**.

[0062] The motor control device **101***a* receives the signals from the HMI **20** and a sensor system **50**. The sensor system **50** includes the vehicle speed sensor **30**, the accelerator pedal stroke sensor **32**, the brake pedal stroke sensor **34**, the rotation speed sensor **40**, and the battery management system **10**. The sensor system **50** may include other sensors (not shown). For example, the sensor system **50** may include a rudder angle sensor that detects a steering angle of the steering wheel, a yaw rate sensor that detects the yaw rate of the battery electric vehicle **100**, an inertial measurement unit (IMU) that detects the posture of the battery electric vehicle **100**, and a sensor (for example, camera, radar, or LiDAR) that detects the surrounding environment of the battery electric vehicle **100**.

[0063] The signal input to the motor control device **101***a* from the HMI **20** includes a signal indicating the control mode selected by the driver and a signal indicating the target virtual vehicle selected by the driver. The signal input to the motor control device **101***a* from the sensor system **50** includes a signal indicating the vehicle speed of the battery electric vehicle **100**, a signal indicating the operation state of the accelerator pedal **22**, a signal indicating the operation state of the brake pedal **24**, a signal indicating the rotation speed of the electric motor **2**, and a signal indicating a state of the battery **14** (for example, cell voltage, current, temperature, and SOC).

[0064] The motor control device **101***a* includes, as functional blocks, a mode information acquisition unit **110**, an on-demand mode drive force calculation unit **120**, a normal mode drive force calculation unit **130**, a target drive force switching unit **140**, and an electric motor controller **150**. The processing circuit **102** that executes the computer program **104** and the storage device **103** cooperate with each other to realize these functional blocks.

[0065] The mode information acquisition unit **110** receives the signal from the HMI **20** and acquires information regarding which one of the normal mode and the on-demand mode is selected. Further, the mode information acquisition unit **110** acquires information of the target virtual vehicle selected by the driver. The mode information acquisition unit **110** transmits the information of the selected control mode to the target drive force switching unit **140**. Further, the mode information acquisition unit **110** transmits the information of the selected target virtual vehicle to the on-demand mode drive force calculation unit **120**.

[0066] The on-demand mode drive force calculation unit **120** acquires the information of the target virtual vehicle selected by the driver from the mode information acquisition unit **110**. The on-demand mode drive force calculation unit **120** calculates the target drive force as the on-demand mode, based on the signal from the sensor system **50**. That is, the on-demand mode drive force calculation unit **120** calculates the target drive force to reproduce the sense of acceleration of the target virtual vehicle in response to the driving operation of the driver in the battery electric vehicle **100**. Details of the processing executed by the on-demand mode drive force calculation unit **120** will be described below.

[0067] The normal mode drive force calculation unit **130** calculates the target drive force as the normal mode, based on the signal from the sensor system **50**. That is, the normal mode drive force calculation unit **130** calculates the target drive force to cause the battery electric vehicle **100** to operate as the normal BEV. For example, the normal mode drive force calculation unit **130** calculates the target drive force by using a map with the accelerator operation amount of the accelerator pedal **22** and the rotation speed of the electric motor **2** as parameters. Further, the normal mode drive force calculation unit **130** may be configured to calculate the target drive force with the brake operation amount of the brake pedal **24** or the SOC of the battery **14** as a parameter. However, in the present embodiment, the processing executed by the normal mode drive force calculation unit **130** is not particularly limited. Other suitable known techniques may be employed for the processing executed by the normal mode drive force calculation unit **130**.

[0068] The target drive force switching unit **140** switches the target drive force of the battery electric vehicle **100** used for the control of the electric motor **2** according to the selected control mode. The target drive force switching unit **140** acquires the information of the control mode selected from the mode information acquisition unit **110**. When the on-demand mode is selected, the target drive force switching unit **140** transmits the target drive force calculated by the on-demand mode drive force calculation unit **120** to the electric motor controller **150** as the target drive force of the battery electric vehicle **100**. On the other hand, when the normal mode is selected, the target drive force switching unit **140** transmits the target drive force calculated by the normal mode drive force calculation unit **130** to the electric motor controller **150** as the target drive force of the battery electric vehicle **100**.

[0069] When the on-demand mode is selected, the normal mode drive force calculation unit **130** may be configured not to execute the processing. Similarly, when the normal mode is selected, the on-demand mode drive force calculation unit **120** may be configured not to execute the processing.

[0070] The electric motor controller **150** receives the target drive force of the battery electric

vehicle **100** via the target drive force switching unit **140**. That is, when the on-demand mode is selected, the electric motor controller **150** receives the target drive force calculated by the on-demand mode drive force calculation unit **120**. On the other hand, when the normal mode is selected, the electric motor controller **150** receives the target drive force calculated by the normal mode drive force calculation unit **130**. The electric motor controller **150** changes the motor torque output by the electric motor **2** such that the input target drive force is provided to the battery electric vehicle **100**. More specifically, the electric motor controller **150** generates the control signal for the inverter **16** according to the input target drive force. The electric motor controller **150** changes the motor torque output by the electric motor **2** via the PWM control by the inverter **16**.
[0071] In this manner, the motor control device **101***a* controls the electric motor **2** to provide the target drive force according to the control mode to the battery electric vehicle **100**. Therefore, with the motor control device **101***a*, the acceleration characteristic of the battery electric vehicle **100** when the on-demand mode is selected is an acceleration characteristic simulated based on the acceleration characteristic of the target virtual vehicle selected by the driver. On the other hand, the acceleration characteristic of the battery electric vehicle **100** when the normal mode is selected is the acceleration characteristic of the normal BEV.
[0072] FIG. **4** is a graph showing an example of an acceleration characteristic VAC of the battery electric vehicle **100** when the on-demand mode is selected. FIG. **4** also shows the acceleration characteristic (one-dot chain line) of the normal BEV for comparison. The acceleration characteristic VAC of the battery electric vehicle **100** when the on-demand mode is selected changes, with a change in the target virtual vehicle, to various patterns according to the target virtual vehicle. This is because the calculated target drive force in the on-demand mode is changed by the target virtual vehicle selected by the driver. As a result, in the on-demand mode, it is possible for the driver to enjoy the sense of acceleration of the various virtual vehicles in the battery electric vehicle **100**.
[0073] Hereinafter, details of the calculation of the target drive force in the on-demand mode, that is, the processing executed by the on-demand mode drive force calculation unit **120** will be described.
4.1 Calculation of Target Drive Force in On-Demand Mode
[0074] The on-demand mode drive force calculation unit **120** calculates the target drive force such that the sense of acceleration of the target virtual vehicle in response to the driving operation of the driver is reproduced in the battery electric vehicle **100**. In particular, the on-demand mode drive force calculation unit **120** adopts a method (hereinafter referred to as “virtual acceleration-based method”) in which a virtual acceleration when the target virtual vehicle is driven is calculated (simulated) by using a vehicle model of the target virtual vehicle (hereinafter referred to as “target vehicle model”) and the target drive force is calculated such that an acceleration of the battery electric vehicle **100** is the virtual acceleration.
[0075] By the way, the acceleration that can be realized by the battery electric vehicle **100**, that is, an acceleration capability of the battery electric vehicle **100** is naturally limited in relation to an output characteristic of the motor torque of the electric motor **2**. In particular, the acceleration capability of the battery electric vehicle **100** is equivalent to the acceleration characteristic of the normal BEV. That is, the acceleration characteristic that can be realized by the battery electric vehicle **100** is within a range of the acceleration characteristic of the normal BEV.
[0076] For this reason, in the virtual acceleration-based method, when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**, a situation occurs in which the acceleration characteristic of the target virtual vehicle cannot be realized as it is in the battery electric vehicle **100**. FIG. **5** is a graph showing an example of the acceleration characteristic VAC of the battery electric vehicle **100** that is normally realized when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**. In the example shown in FIG. **5**, in the acceleration

characteristic VAC of the battery electric vehicle **100**, the acceleration characteristic (broken line) of the target virtual vehicle cannot be realized as it is due to the limit by the acceleration capability (one-dot chain line) of the battery electric vehicle **100**. In such an acceleration characteristic VAC of the battery electric vehicle **100**, the sense of acceleration of the target virtual vehicle may not be reproduced when the driver depresses the accelerator pedal **22** to accelerate the battery electric vehicle **100**, or the like.

[0077] In the example shown in FIG. **5**, one factor that the acceleration characteristic of the target virtual vehicle is not sufficiently realized in the acceleration characteristic VAC is a shape of an acceleration fluctuation in a section in which the acceleration capability of the battery electric vehicle **100** is exceeded. For example, during a section SC, the acceleration characteristic of the target virtual vehicle has a large fluctuation shape in the acceleration, while the acceleration in the acceleration characteristic VAC is constant at a realizable maximum acceleration of the battery electric vehicle **100**. Further, a second factor that the acceleration characteristic of the target virtual vehicle is not sufficiently realized in the acceleration characteristic VAC is a magnitude of the acceleration in the section in which the acceleration capability of the battery electric vehicle **100** is exceeded. For example, during the section SC, there is a difference between the acceleration in the acceleration characteristic of the target virtual vehicle and the acceleration in the acceleration characteristic VAC.

[0078] Among the two factors, the difference in the shape of the acceleration fluctuation has a significant influence on the sense of acceleration provided to the driver.

[0079] On the other hand, when the difference in the shape of the acceleration fluctuation is small, the influence on the sense of acceleration provided to the driver is small even though there is a difference in the magnitude of the acceleration.

[0080] Based on the above viewpoint, the on-demand mode drive force calculation unit **120** according to the present embodiment is configured to realize the acceleration characteristic VAC of the battery electric vehicle **100** capable of reproducing the sense of acceleration of the target virtual vehicle, even when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**. That is, the on-demand mode drive force calculation unit **120** is configured to realize the acceleration characteristic VAC of the battery electric vehicle **100** having the shape of the acceleration fluctuation in the acceleration characteristic of the target virtual vehicle within the range of the acceleration capability of the battery electric vehicle **100**. More specifically, the on-demand mode drive force calculation unit **120** is configured to further execute processing of multiplying the virtual acceleration by a coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle, in the virtual acceleration-based method. With this processing, the virtual acceleration is adjusted not to exceed the acceleration capability of the battery electric vehicle **100**. Further, since this processing is a coefficient multiplication, the shape of the acceleration fluctuation is maintained. The on-demand mode drive force calculation unit **120** calculates the target drive force in which the acceleration of the battery electric vehicle **100** is adjusted to the virtual acceleration.

[0081] FIG. **6** is a diagram showing an example of a functional configuration of the on-demand mode drive force calculation unit **120**. The on-demand mode drive force calculation unit **120** includes, as functional blocks, a virtual acceleration calculation unit **121**, an adjustment unit **122**, and a target drive force calculation unit **123**. Further, the on-demand mode drive force calculation unit **120** is configured to access a vehicle model database D**10**.

[0082] The vehicle model database D**10** manages a plurality of vehicle models **200** obtained by modeling the virtual vehicles. The vehicle model database D**10** may be realized as the data **105** stored in the storage device **103**. Further, a new vehicle model **200** may be downloaded in the vehicle model database D**10** at any time. In the example shown in FIG. **6**, the vehicle model database D**10** manages three vehicle models **200**-A, **200**-B, and **200**-C. In each vehicle model **200**, the operation of the virtual vehicle in response to the driving operation of the driver is simulated with the operation state of the driving operation member and the traveling state of the battery electric vehicle **100** as inputs. Each vehicle model **200** is configured to simulate at least a drive force provided to the virtual vehicle in response to the driving operation, particularly the operation of the accelerator pedal **22**, and an acceleration and deceleration operation of the virtual vehicle due to action of the drive force. A simulation result of the acceleration and deceleration operation of the virtual vehicle in each vehicle model **200** includes the virtual acceleration of the virtual vehicle. That is, each vehicle model **200** is configured to calculate the virtual acceleration of the virtual vehicle in response to the driving operation of the driver.

[0083] Typically, each vehicle model **200** is configured of a control model that simulates a control system related to the powertrain of the virtual vehicle and a plant model that simulates the acceleration and deceleration operation of the virtual vehicle in response to a control signal from the control model. In this case, the plant model includes a model of the powertrain that operates based on the control signal from the control model and a model for simulating the operation of the virtual vehicle due to the action of the virtual drive force output from the powertrain model. An example of a configuration of the vehicle model **200** will be described below.

[0084] Further, each vehicle model **200** has a parameter **201** related to the operation of the virtual vehicle in the simulation. Examples of the parameter **201** include a vehicle weight, a tire diameter, each gear ratio, a maximum engine torque, engine torque responsiveness, and a transmission timing. A content of the parameter **201** may be different for each vehicle model **200**. The vehicle model **200** expresses a model of one virtual vehicle by a combination with a set value of the parameter **201** thereof. For example, each virtual vehicle corresponds to a combination of the vehicle model **200** and the set value of the parameter **201**, as shown in a table below. As shown in the table below, the same vehicle model **200** may correspond to different virtual vehicles. This is a case where types of powertrain systems thereof are the same as each other and the respective virtual vehicles can be expressed by changes in the set value of the parameter **201**, or the like.

TABLE-US-00001 TABLE 1 Virtual vehicle Vehicle model Parameter Virtual vehicle A1 200-A Set value A1 Virtual vehicle A2 200-A Set value A2 Virtual vehicle B1 200-B Set value B1 Virtual vehicle C1 200-C Set value C1 Virtual vehicle C2 200-C Set value C2

[0085] The virtual acceleration calculation unit **121** acquires the information of the target virtual vehicle from the mode information acquisition unit **110**. The virtual acceleration calculation unit **121** reads out the vehicle model **200** (target vehicle model) corresponding to the target virtual vehicle from the acquired information with reference to the vehicle model database D**10**. The example shown in FIG. **6** shows a case where the virtual acceleration calculation unit **121** reads out the vehicle model **200-**B. Further, the virtual acceleration calculation unit **121** sets the parameter **201** of the readout vehicle model **200** according to the target virtual vehicle. For example, when the target virtual vehicle is the “virtual vehicle B**1**” in the above table, the virtual acceleration calculation unit **121** sets a parameter **201-**B of the vehicle model **200-**B to a set value B**1**.

[0086] The virtual acceleration calculation unit **121** uses the readout target vehicle model to calculate a virtual acceleration VG of the target virtual vehicle in response to the operation of the driving operation member of the battery electric vehicle **100**. More specifically, the virtual acceleration calculation unit **121** receives the signal from the sensor system **50**, and acquires information of the operation state of the driving operation member and information of the traveling state of the battery electric vehicle **100** for use as inputs to the target vehicle model. For example, the virtual acceleration calculation unit **121** acquires the accelerator operation amount of the accelerator pedal **22** and the vehicle speed of the battery electric vehicle **100**. In addition, the virtual acceleration calculation unit **121** may acquire information such as the accelerator operation speed of the accelerator pedal **22**, the brake operation amount and the brake operation speed of the brake pedal **24**, the steering angle of the steering wheel, and the yaw rate of the battery electric vehicle **100**, according to the configuration of the target vehicle model. The virtual acceleration calculation unit **121** inputs the acquired information to the target vehicle model. The virtual acceleration calculation unit **121** simulates the acceleration and deceleration operation of the target virtual vehicle using the target vehicle model to calculate the virtual acceleration VG of the target virtual vehicle. The virtual acceleration VG calculated by the virtual acceleration calculation unit **121** is transmitted to the adjustment unit **122**.

[0087] The adjustment unit **122** executes processing (adjustment processing) of calculating an adjusted virtual acceleration AVG by multiplying the virtual acceleration VG by a coefficient a of 1 or less according to the acceleration characteristic of the target virtual vehicle. The adjustment unit **122** includes a coefficient setter **122*a*** and a multiplier **122*b***. The coefficient setter **122*a*** sets the coefficient a according to the acceleration characteristic of the target virtual vehicle. The multiplier **122*b*** multiplies the virtual acceleration VG by the coefficient a set by the coefficient setter **122*a***. A multiplication result by the multiplier **122*b*** is the adjusted virtual acceleration AVG. That is, AVG=a.Math.VG. The adjusted virtual acceleration AVG calculated by the adjustment unit **122** is transmitted to the target drive force calculation unit **123**.

[0088] The setting of the coefficient a by the coefficient setter **122*a*** is performed based on whether or not the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**. Thus, the coefficient setter **122*a*** manages the acceleration characteristic of each of the virtual vehicles that can be selected in the on-demand mode. The coefficient setter **122*a*** acquires the information of the target virtual vehicle from the mode information acquisition unit **110**, and refers to the acceleration characteristic of the target virtual vehicle. Further, the coefficient setter **122*a*** manages the acceleration characteristic (acceleration capability of the battery electric vehicle **100**) of the battery electric vehicle **100** as the normal BEV.

[0089] When the acceleration characteristic of the target virtual vehicle does not exceed the acceleration capability of the battery electric vehicle **100**, the coefficient setter **122*a*** sets the coefficient a to 1. That is, in the multiplier **122*b***, the virtual acceleration VG is the adjusted virtual acceleration AVG as it is.

[0090] On the other hand, when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**, the coefficient setter **122*a*** sets the coefficient a to a value at which the adjusted virtual acceleration AVG is within the range of the acceleration capability of the battery electric vehicle **100**. As a more specific example, the coefficient setter **122*a*** can set the coefficient a to a value obtained by dividing the realizable maximum acceleration of the battery electric vehicle **100** (hereinafter referred to as “possible maximum acceleration”) by the maximum acceleration in the acceleration characteristic of the target virtual vehicle (hereinafter referred to as “virtual maximum acceleration”). That is, the coefficient setter **122*a*** performs setting of coefficient a=possible maximum acceleration/virtual maximum acceleration. FIG. **7** shows an example of the acceleration characteristic VAC of the battery electric vehicle **100** realized when coefficient a=possible maximum acceleration/virtual maximum acceleration. As shown in FIG. **7**, with the multiplication of the coefficient a set as described above, it is possible to realize the acceleration characteristic VAC of the battery electric vehicle **100** having the shape of the acceleration fluctuation in the acceleration characteristic of the target virtual vehicle. The coefficient setter **122*a*** may be configured to set the coefficient a to a value smaller than possible maximum acceleration/virtual maximum acceleration.

[0091] Referring to FIG. **6** again. The target drive force calculation unit **123** acquires the adjusted virtual acceleration AVG from the adjustment unit **122**, and calculates the target drive force for setting the acceleration of the battery electric vehicle **100** to the adjusted virtual acceleration AVG. For example, the target drive force calculation unit **123** converts the adjusted virtual acceleration AVG into a target drive force F.sub.veh by using a simple inverse model of the battery electric vehicle **100**, as indicated by the following equation. In the following equation, m is the vehicle weight of the battery electric vehicle **100**, and F.sub.load is actual traveling resistance applied to the battery electric vehicle **100**. The on-demand mode drive force calculation unit **120** outputs the target drive force calculated by the target drive force calculation unit **123**.

[00001]$F_{veh} = m * \mathrm{AVG} - F_{load}$
[0092] As described above, it is possible to provide the functional configuration of the on-demand mode drive force calculation unit **120** according to the present embodiment. FIG. **8** is a flowchart showing a processing flow of the processing executed by the on-demand mode drive force calculation unit **120** based on the functional configuration described above. The processing flow shown in FIG. **8** is repeatedly executed in a predetermined processing cycle.
[0093] In step S**110**, the on-demand mode drive force calculation unit **120** acquires various types of information. For example, the on-demand mode drive force calculation unit **120** acquires the information of the target virtual vehicle from the mode information acquisition unit **110**. Further, the on-demand mode drive force calculation unit **120** acquires, from the sensor system **50**, the information of the operation state of the driving operation member and the information of the traveling state of the battery electric vehicle **100**.
[0094] Next, in step S**120**, the on-demand mode drive force calculation unit **120** reads out the vehicle model **200** (target vehicle model) corresponding to the target virtual vehicle with reference to the vehicle model database D**10**.
[0095] Next, in step S**130**, the on-demand mode drive force calculation unit **120** calculates the virtual acceleration VG of the target virtual vehicle in response to the operation of the driving operation member by using the target vehicle model.
[0096] Next, in step S**140**, the on-demand mode drive force calculation unit **120** sets the coefficient a of 1 or less for the adjustment processing, according to the acceleration characteristic of the target virtual vehicle. FIG. **9** is a flowchart showing an example of processing related to step S**140**. Each piece of processing shown in FIG. **9** is executed by the coefficient setter **122***a* of the adjustment unit **122**. In the example shown in FIG. **9**, first, the coefficient setter **122***a* determines in step S**140** whether or not the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100** (step S**141**). When the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100** (Yes in step S**141**), the coefficient setter **122***a* sets the coefficient a to possible maximum acceleration/virtual maximum acceleration (step S**142**). On the other hand, when the acceleration characteristic of the target virtual vehicle does not exceed the acceleration capability of the battery electric vehicle **100** (No in step S**141**), the coefficient setter **122***a* sets the coefficient a to 1 (step S**143**).
[0097] Referring to FIG. **8** again. After step S**140**, next, in step S**150** (adjustment processing), the on-demand mode drive force calculation unit **120** calculates the adjusted virtual acceleration AVG by multiplying the virtual acceleration VG by the coefficient a.
[0098] Next, in step S**160**, the on-demand mode drive force calculation unit **120** calculates the target drive force for setting the acceleration of the battery electric vehicle **100** to the adjusted virtual acceleration AVG. Thereafter, this processing ends.
[0099] As described above, with the on-demand mode drive force calculation unit **120** according to the present embodiment, the adjusted virtual acceleration AVG is calculated by multiplying the virtual acceleration VG by the coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle. The target drive force for setting the acceleration of the battery electric vehicle **100** to the adjusted virtual acceleration AVG is calculated. Accordingly, as shown in FIG. **7**, even when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**, it is possible to realize the acceleration characteristic VAC of the battery electric vehicle **100** capable of reproducing the sense of acceleration of the target virtual vehicle within the range of the acceleration capability of the battery electric vehicle **100**. In this manner, according to the present embodiment, it is possible to reproduce the sense of acceleration of the virtual vehicle that exceeds the acceleration capability of the battery electric vehicle **100** in the battery electric vehicle **100**. As a result, it is possible for the driver to enjoy the sense of acceleration of the virtual vehicle that exceeds the acceleration capability of the battery

electric vehicle **100**. Further, it is possible to increase the variation of the virtual vehicle capable of reproducing the sense of acceleration in the on-demand mode and to improve the satisfaction of the user.

4.1.2 Configuration Example of Vehicle Model

[0100] An example of the configuration of the vehicle model **200** managed by the vehicle model database D**10** will be described. FIG. **10** is a diagram showing an example of the configuration of the vehicle model **200**. The vehicle model **200** includes a control model **210** and a plant model **220**. The control model **210** simulates the control system related to the powertrain of the virtual vehicle. The plant model **220** simulates the acceleration and deceleration operation of the virtual vehicle in response to the control signal from the control model **210**. The plant model **220** includes a model of the powertrain that operates based on the control signal from the control model **210** and a model for simulating the operation of the virtual vehicle due to the action of the virtual drive force output from the powertrain model. The control model **210** may also simulate the control system that calculates a request output for the powertrain of the virtual vehicle. Further, the plant model **220** may also simulate a physical constraint on the request output for the powertrain.

[0101] Each specification of the control model **210** and the plant model **220** is different for each type of the powertrain system. For example, configurations of the control system, a transmission, and a drive system are different between the CONV and the HEV. Thus, in each of the vehicle model **200** of the CONV and the vehicle model **200** of the HEV, both the control model **210** and the plant model **220** have different specifications. The example shown in FIG. **10** particularly shows a case where the virtual vehicle is an automatic transmission vehicle (AT vehicle) including the internal combustion engine.

[0102] The control model **210** includes a target virtual drive force calculation unit **211** and a request output calculation unit **212**. The target virtual drive force calculation unit **211** calculates the virtual drive force (target virtual drive force) requested by an output of the powertrain of the virtual vehicle, based on the accelerator operation amount and the vehicle speed. For example, the target virtual drive force calculation unit **211** performs the calculation using a map in which the target virtual drive force is provided for a combination of the accelerator operation amount and the vehicle speed. The request output calculation unit **212** calculates the request output for the powertrain such that the calculated target virtual drive force can be satisfied. The calculated request output includes a target engine torque of the internal combustion engine or a target gear stage of the transmission. The control model **210** transmits the calculated request output to the plant model **220**.

[0103] The plant model **220** includes an internal combustion engine model **221**, a transmission model **222**, a drive system model **223**, and a vehicle and environment model **224**. The internal combustion engine model **221**, the transmission model **222**, and the drive system model **223** are models of the powertrain from the drive source to the drive tire-wheel assemblies. The vehicle and environment model **224** is to simulate the operation of the virtual vehicle due to the action of the virtual drive force output by the powertrain model.

[0104] The internal combustion engine model **221** is for the internal combustion engine of the virtual vehicle. The internal combustion engine model **221** simulates, for example, the operation of the internal combustion engine in response to an input of the target engine torque. The internal combustion engine model **221** outputs a virtual engine rotation speed and a virtual engine torque. The parameter **201** that may be changed according to the target virtual vehicle in the internal combustion engine model **221** is, for example, the maximum engine torque and the engine torque responsiveness.

[0105] The transmission model **222** is for the transmission of the virtual vehicle. The transmission model **222** simulates, for example, the operation of the transmission in response to an input of the target gear stage. The transmission model **222** outputs a virtual transmission output torque from the virtual engine torque output by the internal combustion engine model **221** and the gear ratio decided by a virtual gear stage. The transmission model **222** includes a stepped transmission model simulated based on a stepped transmission and a continuously variable transmission model simulated based on a continuously variable transmission. Any one of the stepped transmission model and the continuously variable transmission model is selected according to the target virtual vehicle. The parameter **201** that may be changed according to the target virtual vehicle in the transmission model **222** is, for example, each gear ratio and the transmission timing. In a case of the stepped transmission model, the gear ratio means a gear ratio of each gear stage.

[0106] The drive system model **223** is for the drive system of the virtual vehicle. In the drive system model **223** model, for example, a mechanical structure from the transmission to the drive tire-wheel assemblies is modeled. The drive system model **223** calculates a drive tire-wheel assembly torque by using the virtual transmission output torque output by the transmission model **222** and a predetermined deceleration ratio, and outputs the virtual drive force of the virtual vehicle. The parameter **201** that may be changed according to the target virtual vehicle in the drive system model **223** is, for example, a deceleration ratio and a maximum allowable torque of a propeller shaft.

[0107] The vehicle and environment model **224** represents a dynamic characteristic of the virtual vehicle and a traveling environment of the virtual vehicle. The vehicle and environment model **224** calculates the traveling resistance applied to the virtual vehicle from the traveling environment of the virtual vehicle. The vehicle and environment model **224** simulates the acceleration and deceleration operation of the virtual vehicle from the virtual drive force output from the drive system model **223**, the calculated traveling resistance, and the dynamic characteristics of the virtual vehicle. The vehicle and environment model **224** outputs the virtual acceleration from the acceleration and deceleration operation of the virtual vehicle. The parameter **201** that may be changed according to the target virtual vehicle in the vehicle and environment model **224** is, for example, the vehicle weight, the tire diameter, and a CD value.

[0108] It is possible to configure the vehicle model **200** as described above. The vehicle model **200** shown in FIG. **4** is an example. It is also possible to configure a part of the vehicle model **200** in more detail according to an event to be emphasized. For example, a case is considered in which a shock or a response accompanying shifts in a gear and a clutch of a transmission at a time of kick down is to be emphasized. In this case, the transmission model **222** may be configured to finely reproduce a gear mechanism, such as planetary and Ravigneaux, of the transmission, inertia of each component, a change in a transmission path due to engagement and disengagement of the clutch, and the like. On the other hand, when a calculation load in the vehicle model **200** is desired to be reduced, the transmission model **222** may be simply configured to reproduce only the gear ratio.

4.1.3 Modification Example of Coefficient Setting by Coefficient Setter

[0109] In the above description, an example of the setting of the coefficient a by the coefficient setter **122***a* is shown regarding the adjustment processing (refer to FIG. **9**). In this example, the acceleration characteristic VAC of the battery electric vehicle **100** having the shape of the acceleration fluctuation in the acceleration characteristic of the target virtual vehicle is realized in all vehicle speed ranges (refer to FIG. **7**). Further, since the acceleration characteristic indicates the acceleration when the accelerator operation amount is the maximum, the acceleration characteristic is considered up to the maximum accelerator operation amount in this example. On the other hand, depending on a magnitude of the accelerator operation amount or the vehicle speed range in an acceleration scene requested by the driver, the virtual acceleration VG of the target virtual vehicle may be able to be realized as it is in the battery electric vehicle **100**. With the setting of the coefficient a in consideration of this case further, it is possible to more faithfully reproduce the sense of acceleration of the target virtual vehicle. In the present embodiment, a first modification example or a second modification example described below may be employed for the setting of the coefficient a by the coefficient setter **122***a*.

[0110] In the first modification example, the coefficient a is set to 1 while the virtual acceleration VG calculated by the virtual acceleration calculation unit **121** is realizable, regardless of the acceleration characteristic of the target virtual vehicle. The setting of the coefficient a by the coefficient setter **122***a* according to the first modification example will be described with reference to FIG. **11**. FIG. **11** is a flowchart showing an example of the processing (processing related to step S**140** shown in FIG. **8**) executed by the coefficient setter **122***a* when the first modification example is employed.

[0111] In step S**241**, the coefficient setter **122***a* determines whether or not the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**. When the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100** (Yes in step S**241**), the processing proceeds to step S**242**. When the acceleration characteristic of the target virtual vehicle does not exceed the acceleration capability of the battery electric vehicle **100** (No in step S**241**), the coefficient setter **122***a* sets the coefficient a to 1 (step S**243**).

[0112] In step S**242**, the coefficient setter **122***a* determines whether or not the virtual acceleration VG calculated by the virtual acceleration calculation unit **121** is larger than the acceleration that can be realized by the battery electric vehicle **100**. That is, determination is made whether or not the battery electric vehicle **100** can realize the virtual acceleration VG. When the battery electric vehicle **100** cannot realize the virtual acceleration VG (Yes in step S**242**), the coefficient setter **122***a* sets the coefficient a to possible maximum acceleration/virtual maximum acceleration (step S**244**). Thereafter, the processing proceeds to step S**246**. On the other hand, when the battery electric vehicle **100** can realize the virtual acceleration VG (No in step S**242**), the coefficient setter **122***a* sets the coefficient a to 1 (step S**245**). Thereafter, the processing proceeds to step S**246**.

[0113] In step S**246**, the coefficient setter **122***a* executes sudden change relaxation processing. The sudden change relaxation processing relaxes a sudden change in a value of the coefficient a when the set value of the coefficient a is switched. For example, when the set value of the coefficient a is switched from **1** to possible maximum acceleration/virtual maximum acceleration, the value of the coefficient a is gradually changed from **1** to possible maximum acceleration/virtual maximum acceleration. With the sudden change relaxation processing, it is possible to suppress the sudden change in the adjusted virtual acceleration AVG and the target drive force.

[0114] As described above, according to the first modification example, the coefficient a is set to 1 while the battery electric vehicle **100** can realize the virtual acceleration VG. That is, the adjustment unit **122** sets, as the adjusted virtual acceleration AVG, the virtual acceleration VG as it is. Accordingly, in a region where the virtual acceleration VG is realizable, it is possible to reproduce the acceleration characteristic of the target virtual vehicle as it is. That is, the driver can sense both the shape of the fluctuation in the acceleration of the target virtual vehicle and the magnitude of the acceleration.

[0115] Next, the second modification example of the setting of the coefficient a by the coefficient setter **122***a* will be described. In the second modification example, the value of the coefficient a is changed based on the accelerator operation amount of the accelerator pedal **22** and the vehicle speed of the battery electric vehicle **100** when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**.

[0116] In driving in which the accelerator operation amount is small and a gentle acceleration is to be performed, a situation hardly occurs in which the virtual acceleration VG exceeds the realizable acceleration of the battery electric vehicle **100**. On the other hand, in driving in which the accelerator operation amount is large and a strong acceleration is to be performed, the virtual acceleration VG is expected to exceed the realizable acceleration of the battery electric vehicle **100**. Therefore, the coefficient setter **122***a* according to the second modification example is configured to set the value of the coefficient a according to the following policies (1) to (3) based on the accelerator operation amount. [0117] (1) When the accelerator operation amount is smaller than a first threshold value, determination is made that the gentle acceleration is performed, and the coefficient a is set to 1. [0118] (2) When the accelerator operation amount is equal to or larger than a second threshold value, determination is made that strong acceleration is performed, and the value of the coefficient a is set such that the virtual acceleration VG is within the acceleration capability of the battery electric vehicle **100**. [0119] (3) When the accelerator operation amount is equal to or larger than the first threshold value and smaller than the second threshold value, determination is made as to whether or not the further strong acceleration is expected to be performed from a traveling scene of the battery electric vehicle **100**. When the strong acceleration is expected to be performed (for example, at a time of start acceleration and at a time of kick down), the value of the coefficient a is set such that the virtual acceleration VG is within the range of the acceleration capability of the battery electric vehicle **100**. Otherwise, the coefficient a is set to 1.

[0120] Further, the vehicle speed of the battery electric vehicle **100** is related to a magnitude of a difference, when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**, between the acceleration characteristic thereof and the acceleration capability thereof. For example, in the example shown in FIG. **7**, the difference between the acceleration characteristics of the target virtual vehicle and the acceleration capability of the battery electric vehicle **100** is large in a low vehicle speed range and a high vehicle speed range. On the other hand, in a middle vehicle speed range, the difference between the acceleration characteristic of the target virtual vehicle and the acceleration capability of the battery electric vehicle **100** is small. Therefore, in the above policies, the coefficient setter **122***a* according to the second modification example can be further configured to set the value of the coefficient a according to the vehicle speed range of the vehicle speed of the battery electric vehicle **100**. For example, when the vehicle speed of the battery electric vehicle **100** is in the low vehicle speed range or the high vehicle speed range, the coefficient setter **122***a* sets the value of the coefficient a to possible maximum acceleration/virtual maximum acceleration. On the other hand, when the vehicle speed of the battery electric vehicle **100** is in the middle vehicle speed range, the coefficient setter **122***a* sets the value of the coefficient a to a value larger than possible maximum acceleration/virtual maximum acceleration.

[0121] FIG. **12** is a diagram showing an example of the coefficient setter **122***a* according to the second modification example. In the example shown in FIG. **12**, as compared with the case shown in FIG. **6**, the accelerator operation amount of the accelerator pedal **22**, the vehicle speed of the battery electric vehicle **100**, and scene determination information are further input to the coefficient setter **122***a*. The scene determination information is related to the above policy (**3**) and for determining the traveling scene of the battery electric vehicle **100**. The scene determination information is acquired by estimating the traveling environment around the battery electric vehicle **100** by using the camera, the LiDAR, the radar, the rudder angle sensor, map information, GPS, and the like. For example, when information such as "there is no vehicle in front", "a road is a straight line", "a road width is wide", and "a traffic light in front is blue" is acquired from the scene determination information, the coefficient setter **122***a* determines that there is a traveling scene in which the strong acceleration is expected to be performed when the accelerator operation amount is equal to or larger than the first threshold value.

[0122] As described above, according to the second modification example, when the acceleration characteristic of the target virtual vehicle exceeds the acceleration capability of the battery electric vehicle **100**, the value of the coefficient a is changed based on the accelerator operation amount of the accelerator pedal **22** and the vehicle speed of the battery electric vehicle **100**. Accordingly, it is possible to reproduce the sense of acceleration of the target virtual vehicle in a wider scene in consideration of the acceleration scene requested by the driver.

5 Sound Control Device

[0123] The control device **101** according to the present embodiment may function, regarding the control of the battery electric vehicle **100**, as a sound control device that controls the in-vehicle speaker **21** to output the pseudo engine sound according to the target virtual vehicle. Specifically, the processing circuit **102** executes the computer program **104** for the in-vehicle speaker control, which is stored in the storage device **103**, to cause the control device **101** to function as the sound control device. In the following, the control of the battery electric vehicle **100** by the sound control device will be described.

[0124] FIG. **13** is a diagram showing a functional configuration of a sound control device **101***b*. The sound control device **101***b* generates, from the in-vehicle speaker **21**, the pseudo engine sound that simulates an engine sound in the virtual vehicle including the internal combustion engine.

[0125] The mode information acquisition unit **110** transmits the information of the selected control mode and the information of the target virtual vehicle to a pseudo engine sound generation unit **160**.

[0126] The pseudo engine sound generation unit **160** functions when the control mode is the on-demand mode and the target virtual vehicle is the virtual vehicle including the internal combustion engine. In this case, in the sound control device **101***b*, the vehicle model **200** (target vehicle model) of the target virtual vehicle is read out from the vehicle model database D**10** based on the information of the target virtual vehicle from the mode information acquisition unit **110**. Further, the parameter **201** is set according to the target virtual vehicle. The pseudo engine sound generation unit **160** generates the pseudo engine sound based on the virtual engine torque and the virtual engine rotation speed, which are calculated using the target vehicle model.

[0127] The pseudo engine sound generation unit **160** refers to the storage device **103** to acquire a sound source of the pseudo engine sound related to the target virtual vehicle. The storage device **103** may store the sound source of the pseudo engine sound related to each virtual vehicle including the internal combustion engine.

[0128] The pseudo engine sound generation unit **160** includes processing **161** of calculating an engine sound pressure and processing **162** of calculating an engine sound frequency. In the processing **161**, a sound pressure of the pseudo engine sound is calculated from the virtual engine torque using a sound pressure map M**11**. The sound pressure map M**11** is created such that the sound pressure is higher as the virtual engine torque is higher. In the processing **162**, a frequency of a virtual engine sound is calculated from the virtual engine rotation speed by using a frequency map M**12**. The frequency map M**12** is created such that the frequency is higher as the virtual engine rotation speed is higher. The virtual engine torque and the virtual engine rotation speed change by the operation of the driving operation member by the driver.

[0129] The sound control device **101***b* outputs, from the in-vehicle speaker **21**, the pseudo engine sound generated by the pseudo engine sound generation unit **160**. With the sound control related to the pseudo engine sound by the sound control device **101***b* in this manner, it is possible to further provide the driver with a sense of reality as if the driver drives the target virtual vehicle when the control mode is the on-demand mode.

6 Display Control Device

[0130] The control device **101** according to the present embodiment may function, when the control mode is the on-demand mode, as a display control device that controls the HMI **20** to display the virtual engine rotation speed or the virtual gear stage of the target virtual vehicle. Accordingly, it is possible to further provide the driver with the sense of reality as if the driver drives the target virtual vehicle.

7 Others

[0131] The battery electric vehicle **100** according to the above embodiment is an FF vehicle in which the front tire-wheel assemblies are driven by one electric motor **2**. However, the technical features according to the present embodiment can also be applied to a battery electric vehicle in which two electric motors are disposed in front and rear of the vehicle and respectively drive front tire-wheel assemblies and rear tire-wheel assemblies. Further, the technical features can also be applied to a battery electric vehicle including an in-wheel motor in each tire-wheel assembly.

[0132] The technical features according to the present embodiment are not limited to the battery electric vehicle, and can be widely applied to the battery electric vehicle using the electric motor as a power device for traveling. For example, the technical features according to the present embodiment can be applied to a hybrid electric vehicle (HEV) or a plug-in hybrid electric vehicle (PHEV) having a mode in which the vehicle travels solely by the drive force of the electric motor. Further, the technical features can be applied to a fuel cell electric vehicle (FCEV) that supplies electric energy generated by a fuel cell to the electric motor.

Claims

1. A battery electric vehicle comprising: an electric motor as a drive source; a driving operation member used for driving of the battery electric vehicle; a storage device configured to store a database, the database being configured to manage a plurality of vehicle models obtained by modeling a plurality of virtual vehicles having different acceleration characteristics in response to a driving operation of a driver; and a processing circuit configured to read out a target vehicle model corresponding to a target virtual vehicle from the database, the target virtual vehicle being selected by the driver from the virtual vehicles, calculate a virtual acceleration of the target virtual vehicle in response to an operation of the driving operation member using the target vehicle model based on an operation state of the driving operation member and a traveling state of the battery electric vehicle, execute adjustment processing of calculating an adjusted virtual acceleration by multiplying the virtual acceleration by a coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle, and control the electric motor such that an acceleration of the battery electric vehicle is the adjusted virtual acceleration.
2. The battery electric vehicle according to claim 1, wherein in the adjustment processing, the processing circuit is configured to set the coefficient to a value obtained by dividing a realizable maximum acceleration of the battery electric vehicle by a maximum acceleration in the acceleration characteristic of the target virtual vehicle when the acceleration characteristic of the target virtual vehicle exceeds an acceleration capability of the battery electric vehicle.
3. The battery electric vehicle according to claim 1, wherein in the adjustment processing, the processing circuit is configured to set the coefficient to 1 when the acceleration characteristic of the target virtual vehicle does not exceed an acceleration capability of the battery electric vehicle.
4. The battery electric vehicle according to claim 1, wherein in the adjustment processing, the processing circuit is configured to set the coefficient to 1 while the virtual acceleration is realizable by the battery electric vehicle, regardless of the acceleration characteristic of the target virtual vehicle.
5. The battery electric vehicle according to claim 1, wherein: the driving operation member includes an accelerator pedal; and in the adjustment processing, the processing circuit is configured to change a value of the coefficient based on an accelerator operation amount of the accelerator pedal and a vehicle speed of the battery electric vehicle when the acceleration characteristic of the target virtual vehicle exceeds an acceleration capability of the battery electric vehicle.
6. The battery electric vehicle according to claim 1, wherein the processing circuit is configured to calculate a target drive force of the battery electric vehicle to set the acceleration of the battery electric vehicle to the adjusted virtual acceleration, and change a motor torque output by the electric motor to provide the target drive force to the battery electric vehicle.
7. The battery electric vehicle according to claim 1, wherein: each of the vehicle models has one or a plurality of parameters related to the acceleration characteristic; and the processing circuit is further configured to set the one or the plurality of parameters of the target vehicle model according to the target virtual vehicle.
8. A control device for a battery electric vehicle, the battery electric vehicle including an electric motor as a drive source, and a driving operation member used for driving of the battery electric vehicle, the control device comprising: a storage device configured to store a database, the database

being configured to manage a plurality of vehicle models obtained by modeling a plurality of virtual vehicles having different acceleration characteristics in response to a driving operation of a driver; and a processing circuit configured to read out a target vehicle model corresponding to a target virtual vehicle from the database, the target virtual vehicle being selected by the driver from the virtual vehicles, calculate a virtual acceleration of the target virtual vehicle in response to an operation of the driving operation member using the target vehicle model based on an operation state of the driving operation member and a traveling state of the battery electric vehicle, execute adjustment processing of calculating an adjusted virtual acceleration by multiplying the virtual acceleration by a coefficient of 1 or less according to the acceleration characteristic of the target virtual vehicle, and control the electric motor such that an acceleration of the battery electric vehicle is the adjusted virtual acceleration.

9. The control device according to claim 8, wherein in the adjustment processing, the processing circuit is configured to set the coefficient to a value obtained by dividing a realizable maximum acceleration of the battery electric vehicle by a maximum acceleration in the acceleration characteristic of the target virtual vehicle when the acceleration characteristic of the target virtual vehicle exceeds an acceleration capability of the battery electric vehicle.

10. The control device according to claim 8, wherein in the adjustment processing, the processing circuit is configured to set the coefficient to 1 when the acceleration characteristic of the target virtual vehicle does not exceed an acceleration capability of the battery electric vehicle.