Abstract: An HVECU (30) sets a target amount of charge of a battery (24) to a target value \( \text{SOC}_\text{t} \), that is lower than a normal target value \( \text{SOC}_\text{n} \) when the temperature of the battery (24) is lower than a predetermined temperature. During operation of an engine (12), the HVECU (30) reads an amount of charge \( C \) of the battery (24), and forces the battery (24) to be discharged if the amount of charge \( C \) is larger than the target value \( \text{SOC}_\text{t} \). At this time, the battery (24) is allowed to be charged with regenerative power, but is inhibited from being charged using driving force of the engine (12). The temperature of the battery (24) is increased due to heat generated upon charging and discharging of the battery (24), while assuring improved fuel consumption of the engine (12).
BATTERY CONTROL SYSTEM AND BATTERY CONTROL METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to battery control system and method for controlling the amount of charge of a secondary battery (car battery) provided in a vehicle, and more particularly to battery control system and method for controlling the amount of charge of a car battery that is charged with electric power, such as regenerative power generated through regenerative braking of the vehicle.

2. Description of the Related Art

[0002] Vehicles running under the driving force of an internal combustion engine include so-called "hybrid vehicle" having an electric motor in addition to the engine. The vehicle of this type includes a car battery in which electric power is stored, and the electric motor and other electrical components are driven using the power stored in the car battery. The car battery is charged with electric power generated when a generator is rotated under the driving force of the engine.

[0003] In the meantime, a method of charging a car battery with energy produced during deceleration of the vehicle has been widely employed. In this method, the rotation of the wheels during deceleration of the vehicle is transmitted to a generator, so as to rotate the generator and cause the generator to produce regenerative power used for charging the car battery. At this time, the generator provides a resistance to the rotation of the wheels, thereby to yield an effect of decelerating the vehicle. Furthermore, the engine is less likely to be driven for the purpose of charging the car battery.

[0004] Generally, in a vehicle, charge and discharge of the car battery is controlled so that the amount of charge of the car battery is kept within a specified range. In this manner, the car battery is used with high efficiency, and provides desired output power.
If a secondary battery, such as a car battery, has a reduced temperature, the internal resistance increases, and its charging efficiency and discharging efficiency are reduced, resulting in reductions of the amount of electric power that can be stored in the battery and the amount of electric power that can be delivered or discharged from the battery.

In connection with the above problem, JP-A-2000-92614 discloses a battery charge/discharge state control system which causes a secondary battery to be charged and discharged within a specified range of the amount of charge when the battery temperature is lower than a certain temperature, so that heat generated upon charging or discharging is used for increasing the temperature of the secondary battery.

Also, JP-A-2001-268715 discloses a technique of increasing the temperature of a car battery by discharging the car battery so as to reduce the driving force of the engine and increase the driving force of a motor, and also increasing the battery temperature by charging the car battery when the battery temperature is lower than a predetermined temperature and the amount of charge of the battery is lower than a predetermined value.

Furthermore, JP-A-2003-32804 discloses a battery control system that detects the output (i.e., power) that can be delivered or discharged from a secondary battery when the vehicle is driven, and discharges the secondary battery to provide the maximum dischargeable output or power when the detected output is smaller than a certain value and the temperature of the secondary battery is low, so as to increase the battery temperature. The control system also prevents the dischargeable output of the secondary battery from being reduced due to excessive discharge after the temperature is raised.

If the battery temperature is low when the car battery is charged with regenerative power, the regenerative charging performance deteriorates and the battery cannot achieve a desired amount or amount of charge. As a result, the time of running of the engine is prolonged, and the fuel consumption efficiency is
reduced.

SUMMARY OF THE INVENTION

[0010] The invention provides battery control system and method that ensure warm-up of a secondary battery while assuring an improved fuel consumption when the secondary battery is charged with regenerative power generated during deceleration of the vehicle.

[0011] One aspect of the invention relates to a battery control system and a method provided in a vehicle that runs with driving force of an internal combustion engine and an electric motor, for controlling charge and discharge of a secondary battery based on a target amount of charge. Another aspect of the invention relates to a battery control method for controlling charge and discharge of the secondary battery.

[0012] The battery control system according to the above-indicated one aspect of the invention includes (a) temperature detecting means for detecting a temperature of the secondary battery, (b) amount of charge detecting means for detecting a amount of charge of the secondary battery, (c) setting means for setting the target amount of charge to a first target amount of charge in a normal state, and sets the target amount of charge to a second target amount of charge that is lower than the first target amount of charge when it is determined that the battery temperature is lower than a predetermined temperature and the engine is in operation, and control means for controlling charge and discharge of the secondary battery, based on the amount of charge of the secondary battery and one of the first and second target amounts of charge to which the target amount of charge is set by the setting means.

[0013] The battery control system according to the above aspect of the invention controls charge and discharge of the secondary battery based on the first target amount of charge, in a normal state in which the battery temperature is judged as being sufficiently high. In this manner, the amount of charge of the secondary battery is kept approximately equal to the first target amount of charge.
[0014] If the battery temperature is judged as being low, and the engine is in operation, the battery control system controls charge and discharge of the secondary battery based on the second target amount of charge that is set lower than the first target amount of charge. Namely, the control system employs the second target amount of charge for warming up the secondary battery.

[0015] Since the second target amount of charge is lower than the first target amount of charge, power generally corresponding with a difference between the amounts of charge represented by the first and second target amounts of charge is discharged from the secondary battery, and heat generated due to the discharge is used for increasing the temperature of the battery.

[0016] Since the engine is operating when the secondary battery is warmed up, the target amount of charge can be set at a low level so that the battery can provide large discharge power, and the temperature of the secondary battery can be surely increased with high efficiency. During operation of the engine, for example, during starting of the engine, electric power required for driving a starter motor for starting the engine is delivered or discharged from the secondary battery, and, therefore, the secondary battery can be warmed up in a short time due to the discharge thereof.

[0017] When the discharge power of the secondary battery is increased during operation of the engine, the electric motor may be driven with the discharge power, so that a load of the engine is reduced and the fuel consumption is improved.

[0018] In the above-indicated one aspect of the invention, when the target amount of charge is set to the second target amount of charge, the secondary battery may be allowed to be charged with regenerative power produced through regenerative braking of the vehicle, and may be inhibited from being charged with power derived from the driving force of the internal combustion engine.

[0019] In the above case, the battery control system allows the secondary battery to be charged with regenerative power generated through regenerative
braking, while inhibiting the battery from being charged with power derived from
the driving force of the engine. The amount of regenerative power with which the
battery can be charged is increased by setting the target amount of charge to the
second target amount of charge and reducing the amount of charge of the
secondary battery.

[0020] In this manner, the increase of the temperature of the secondary
battery is promoted by utilizing heat generated upon regenerative charging, and
the battery temperature is further increased by discharging the power thus stored
in the secondary battery, so that the warm-up time is shortened. Also, the
secondary battery is inhibited from being charged with power derived from the
driving force of the engine, so that an otherwise possible increase in the load of the
engine is suppressed, and the fuel consumption is improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The foregoing and further objects, features and advantages of the
invention will become apparent from the following description of preferred
embodiments with reference to the accompanying drawings, wherein like numerals
are used to represent like elements and wherein:

FIG. 1 is a view schematically showing the construction of a principal part
of a vehicle that employs one embodiment of the invention!

FIG. 2 is a view schematically showing the construction of a battery control
system to which the invention is applied!

FIG. 3A is a graph generally indicating regenerative power with which a
battery can be charged, with respect to the battery temperature!

FIG. 3B is a graph generally indicating target SOC and target SOCL!

FIG. 4 is a flowchart illustrating an example of warm-up control performed
according to the embodiment of the invention!

FIG. 5A is a graph generally indicating changes in the amount of charge of
the battery during normal control and warm-up control of the invention! and
FIG. 5B is a graph generally indicating changes in the battery temperature during normal control and warm-up control of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] One embodiment of the invention will be described with reference to the accompanying drawings. FIG. 1 schematically illustrates the construction of a vehicle 10 that employs a battery control system of this embodiment. The vehicle 10 includes an engine 12 and a motor generator 14, which serve as power sources for running the vehicle. Drive shafts of the engine 12 and the motor generator 14 are respectively coupled to a power distribution device 16, and the power distribution device 16 is coupled to a continuously variable transmission 18. An output shaft 20 of the continuously variable transmission 18 is coupled to wheels 22 (front wheels 22A) of the vehicle 10.

[0023] The vehicle 10 is also provided with a secondary battery (hereinafter referred to as "battery") 24 and an inverter 26. The inverter 26 converts DC power stored in the battery 24 into AC power, which is supplied to the motor generator 14.

[0024] The motor generator 14 is in the form of, for example, a three-phase generator, and is adapted to be driven when supplied with AC power into which electric power stored in the battery 24 is converted via the inverter 26.

[0025] The power distribution device 16 switches the mode of transmission of driving force among the engine 12, motor generator 14 and the continuously variable transmission 18. More specifically, the power distribution device 16 is able to transmit the driving force of the engine 12 to the motor generator 14 and the continuously variable transmission 18, and is also able to transmit the driving force of the engine 12 and motor generator 14 to the continuously variable transmission 18.

[0026] With the above arrangement, the vehicle 10 operates as a so-called "hybrid vehicle" which runs with the wheels 22 driven by the driving force
transmitted from the engine 12 and/or motor generator 14 via the power distribution device 16.

[0027] The power distribution device 16 transmits the driving force of the engine 12 and the rotational energy of the wheels 22 to the motor generator 14. The motor generator 14 used in the vehicle 10 operates as a three-phase generator, which produces AC power when it is driven with the driving force of the engine 12 or the rotational energy of the wheels 22 transmitted thereto.

[0028] The vehicle 10 is also provided with a motor generator 28. The motor generator 28 is coupled to the axle of the wheels 22 (rear wheels 22B) on the rear side of the vehicle 10 via a power transmitting mechanism (not shown), and the rotational energy of the wheels 22 is transmitted to the motor generator 28. The motor generator 28 is also connected to the battery 24 via the inverter 26.

[0029] The motor generator 28 is in the form of a three-phase generator, which produces AC power when the rotational energy is transmitted from the wheels 22 to the motor generator 28.

[0030] The inverter 26 has the function of converting AC power generated by the motor generators 14, 28 into DC power of a certain voltage. In the vehicle 10, the battery 24 may be charged with electric power derived from rotation of the motor generator 14 that is driven by the driving force of the engine 12.

[0031] In the vehicle 10, the battery 24 may also be charged with electric power (regenerative power) produced when the rotational energy of the wheels 22 is transmitted to the motor generators 14, 28 during deceleration of the vehicle 10.

[0032] In the vehicle 10, the battery 24 is normally charged with regenerative power, and the engine 14 need not be started for the purpose of charging the battery 24; therefore, the fuel consumption is improved.

[0033] As shown in FIG. 2, a hybrid ECU (hereinafter referred to as "HVECU") 30 is provided in the vehicle 10, and an engine ECU 32 for controlling the operation of the engine 12, a battery ECU 34 for detecting the state of the battery 24, and other components are connected to the HVECU 30. In the vehicle
10, the HVECU 30 and the battery ECU 34 constitute a battery control system 36 for controlling charge and discharge of the battery 24.

[0034] The motor generators 14, 28 are connected to the HVECU 30 via the inverter 26. The HVECU 30 controls the operation of, for example, the inverter 26, so as to control driving of the motor generator 14, power generation of the motor generator 14 using the driving force of the engine 12, and regenerative power generation of the motor generators 14, 28.

[0035] The engine ECU 32 controls driving of the engine 12 in accordance with driver's operating conditions, such as an amount of depression of the accelerator pedal (not shown). The vehicle 10 further includes various accessories (not shown), and the HVECU 30 and the engine ECU 32 control the operations of these accessories.

[0036] The HVECU 30 detects running conditions of the vehicle 10, operating conditions of the engine 12, and the driver's operating conditions, and drives the motor generator 14 using the power stored in the battery 24, based on the outputs of detections. On the basis of the running conditions of the vehicle 10 and the driver's operating conditions, the HVECU 30 also sends a request for stopping the engine 12 to the engine ECU 32 when predetermined engine stopping conditions are satisfied, so as to stop the engine 12 and drive the motor generator 14 as needed for running the vehicle 10.

[0037] While the motor generator 28 performs only regenerative power generation in this embodiment, the motor generator 28 in the form of a three-phase generator may be arranged to drive the rear wheels 22B.

[0038] The HVECU 30 and the engine ECU 32 control driving and stopping of the engine 12 and the motor generator 14 by generally known control methods, which will not be explained in detail in this specification.

[0039] Connected to the battery ECU 34 are a voltage sensor 38 for detecting a voltage (battery voltage) across the terminals of the battery 24 and a current sensor 40 for detecting input current and output current (battery current)
of the battery 24. The battery ECU 34 detects the battery voltage by means of the voltage sensor 38, and detects the battery current by means of the current sensor 40, and also calculates the amount of charge C of the battery 24, based on the battery voltage and the battery current.

[0040] The HVECU 30 keeps the amount of charge of the battery 24 within a predetermined range, based on the amount of charge C of the battery 24 detected by the battery ECU 34. Namely, the HVECU 30 charges the battery 24 with regenerative power, and drives the motor generator 14 using the power stored in the battery 24.

[0041] If the amount of charge C of the battery 24 exceeds the predetermined range, the HVECU 30 drives, for example, the motor generator 14 to increase a load driven by the use of power of the battery 24, thereby to reduce the amount of charge C of the battery 24.

[0042] If the amount of charge C of the battery 24 is reduced, the HVECU 30 drives the engine 12 so as to charge the battery 24 with electric power produced by the motor generator 14 that is rotated with the driving force of the engine 12.

[0043] The charging and discharging of the battery 24 are controlled by known methods. As shown in FIG. 1, the vehicle 10 is provided with a starter motor 44, and the power of the battery 24 is used for driving the starter motor 44 when the engine 12 is driven (started).

[0044] In the meantime, electric power with which the battery 24 can be charged (i.e., regenerative power with which the battery 24 can be charged) changes in accordance with the temperature of the battery 24, as shown in FIG. 3A. As the battery temperature Tb decreases, the regenerative power with which the battery 24 can be charged also decreases. As the regenerative power with which the battery 24 can be charged decreases, electric power that can be delivered from the battery 24 is also reduced.

[0045] As is understood from the above description, when the vehicle 10 starts running at a low outside-air temperature, for example, it may be difficult to
efficiently drive the motor generator 14 since the battery temperature is low.

[0046] In this embodiment, therefore, the HVECU 30 detects the battery temperature, and performs a warm-up control for increasing the battery temperature when the battery temperature is low.

[0047] As shown in FIG. 2, the battery 24 includes a temperature sensor 42 as a temperature detecting means. The temperature sensor 42 is connected to the battery ECU 34, and the battery ECU 34 detects the battery temperature Tb by means of the temperature sensor 42.

[0048] Also, the HVECU 30 reads the battery temperature Tb detected by the battery ECU 34. If the battery temperature Tb is lower than a predetermined temperature (set temperature Tbs), the HVECU 30 performs the warm-up control for increasing the battery temperature Tb.

[0049] The HVECU 30 sets a first target amount of charge (hereinafter referred to as "target value SOC") with respect to electric power charging the battery 24, in view of the charging efficiency and durability of the battery 24. The HVECU 30 controls charge and discharge of the battery 24 so that the amount of charge of the battery 24 becomes equal to the target value SOC.

[0050] Since the regenerative power with which the battery 24 can be charged changes with the battery temperature Tb, as shown in FIG. 3A, the target value SOC also changes with the battery temperature Tb, as shown in FIG. 3B.

[0051] The HVECU 30 uses a second target amount of charge (hereinafter referred to as "target value SOCl") that is set lower than the target value SOC, as a target amount of charge employed during the warm-up control performed when the battery temperature Tb is low. In the case where the target value SOC is set to about 60% relative to the maximum amount of charge of the battery 24 (or full charge of the battery 24) (Cmax) so that the power stored in the battery 24 is kept between about 40% and about 60% of full charge, the target value SOCl is set to about 30% to 40%. The target value SOCl is set to within a range in which the amount of power stored in the battery 24 does not exceed Cmax with which the
battery 24 can be charged through regenerative braking.

[0052] The HVECU 30 stores a map of the target value SOC and the target value SOCL with respect to the battery temperature Tb in a memory (not shown). In the warm-up control for the battery 24, the HVECU 30 discharges electric power stored in the battery 24, based on the battery temperature Tb and the target value SOCL.

[0053] In order to reduce the amount of charge C of the battery 24 down to the target value SOCL, the HVECU 30 performs the warm-up control only during operation of the engine 12 while inhibiting the battery 24 from being charged with power generated by driving the engine 12. During the warm-up control, however, the battery 24 is allowed to be charged with regenerative power.

[0054] The battery 24 has an internal resistance, and generates heat due to current that flows when the battery 24 is discharged or charged with regenerative power, so that the heat thus generated increases the temperature of the battery 24.

[0055] In the following, the warm-up control for the battery 24 performed by the battery control system 36 according to this embodiment will be described.

[0056] When an ignition switch (not shown) is turned on, and the vehicle 10 having the battery 24 is started, an operation to warm up the engine 12 is performed if the outside-air temperature is low and the engine 12 is cold. With a warm-up operation, the temperature of the coolant (or cooling water) of the engine is raised to be equal to or higher than a certain level.

[0057] Upon turn-on of the ignition switch (not shown), the HVECU 30 of the battery control system 36 starts charge and discharge control of the battery 24. At this time, the HVECU 30 determines whether the battery 24 needs to be warmed up, and executes the warm-up control for the battery 24 if it is determined that the battery 24 needs to be warmed up.

[0058] To determine whether the battery 24 needs to be warmed up, the battery ECU 34 detects the battery temperature Tb, and the HVECU 30
determines whether the battery temperature $T_b$ is lower than a predetermined temperature (set temperature $T_{bs}$).

[0059] FIG. 4 schematically illustrates a control routine of the warm-up control (charge and discharge control) for the battery 24 performed by the HVECU 30. The routine of FIG. 4 is executed when the ignition switch (not shown) is turned on to start the vehicle 10, and is finished when the ignition switch is turned off.

[0060] In step 100, the HVECU 30 reads the battery temperature $T_b$ of the battery 24 detected by the battery ECU 34 by means of the temperature sensor 42. In the next step 102, the HVECU 30 determines whether the battery temperature $T_b$ is lower than the set temperature $T_{bs}$. For example, the highest temperature at which the battery 24 needs to be warmed up, or the lowest temperature at which the battery 24 is able to operate appropriately, or the like, may be employed as the set temperature $T_{bs}$.

[0061] If the battery temperature $T_b$ is equal to or higher than the set temperature $T_{bs}$ ($T_b \geq T_{bs}$), the HVECU 30 determines that warm-up of the battery 24 is not necessary, makes a negative decision (NO) in step 102, and shifts to a normal control (step 104). In the normal control, the HVECU 30 controls the amount of charge of the battery 24 by controlling charging of the battery 24 with regenerative power and driving of a load (discharging) using the power stored in the battery 24.

[0062] If the battery temperature $T_b$ is lower than the set temperature $T_{bs}$ ($T_b < T_{bs}$), the HVECU 30 makes an affirmative decision (YES) in step 102, and starts the warm-up control for increasing the battery temperature $T_b$.

[0063] In the warm-up control, the HVECU 30 initially sets a target amount of charge of the battery 24 to a target value SOCL for use in a warm-up operation in step 106, in place of the target value SOC for use in the normal control.

[0064] Subsequently, the HVECU 30 determines in step 108 whether the
engine 12 is in operation, namely, whether the engine 12 is being warmed up or the vehicle 10 is running with the engine 12 being driven. If the engine 12 is not in operation, the HVECU 30 makes a negative decision (NO) in step 108, and shifts to the normal control without performing warm-up of the battery 24.

[0065] If the engine 12 is in operation, for example, if the engine 12 is being warmed up or the vehicle 10 is running with the driving force of the engine 12, on the other hand, the HVECU 30 makes an affirmative decision (YES) in step 108, and proceeds to step 110 to read the amount of charge C of the battery 24 calculated by the battery ECU 34.

[0066] The battery ECU 34 starts operating when the ignition switch (not shown) is turned on, causes the voltage sensor 38 and the current sensor 40 to detect the battery voltage and the battery current, respectively, and calculates the amount of charge C of battery 24 from the battery voltage and the battery current.

[0067] After reading the amount of charge C of the battery 24 from the battery ECU 34, the HVECU 30 determines in step 112 whether the amount of charge C of the battery 24 exceeds the target value SOCL.

[0068] If the amount of charge C of the battery 24 exceeds the target value SOCL (C > SOCL), the HVECU 30 makes an affirmative decision (YES) in step 112, and proceeds to step 114 to force the battery 24 to be discharged. At the same time, the HVECU 30 inhibits the battery 24 from being charged with electric power generated by the motor generator 14 when it is driven with the driving force of the engine 12.

[0069] With the engine 12 being in operation, the forced discharging of the battery 24 may be effected by driving the motor generator 14 so as to assist in driving of the engine 12. If the vehicle 10 includes accessories to be driven with electric power of the battery 24, the discharging of the battery 24 may also be effected by driving the accessories.

[0070] If electric power is generated through regenerative braking during the warm-up control, the battery 24 is charged with the regenerative power
derived from regenerative braking, but the motor generator 14 is inhibited from generating electric power by utilizing the driving force of the engine 12. If the motor generator 14 is driven with the driving force of the engine 12, the motor generator 14 becomes a load of the engine 12, and the load of the engine 12 increases.

[0071] By inhibiting driving of the motor generator 14 using the driving force of the engine 12, the HVECU 30 reduces the load of the engine 12, and thus assures improved fuel consumption of the engine 12.

[0072] After the forced discharging of the battery 24 is started in step 114, the HVECU 30 reads the battery temperature \( T_b \) from the battery ECU 34 in step 116, and then determines whether the battery temperature \( T_b \) is lower than the set temperature \( T_{bs} \) in step 118. If the battery temperature \( T_b \) is lower than the set temperature \( T_{bs} \), the HVECU 30 returns to step 108 to determine whether the engine 12 is in operation.

[0073] If the engine 12 keeps operating, and the battery temperature \( T_b \) does not reach the set temperature \( T_{bs} \), while the amount of charge \( C \) of the battery 24 exceeds the target value SOCL for use in the warm-up control, the HVECU 30 makes affirmative decisions (YES) in step 108 and step 112, and proceeds to step 114 to increase the power discharged from the battery 24. For example, if the battery 24 is discharged by driving the motor generator 24, the driving force of the motor generator 24 increases, and the load of the engine 12 is reduced. With the load of the engine 12 thus reduced, the fuel consumption of the engine 12 is improved.

[0074] The battery 24 has an internal resistance, and generates heat when it is forced to be discharged or charged with regenerative power, so that the heat thus generated increases the temperature of the battery 24. Thus, the battery temperature \( T_b \) is increased through forced discharging of the battery 24 during warm-up of the battery 24.

[0075] If the battery temperature \( T_b \) becomes equal to or higher than the
set temperature $T_{bs}$ as a result of the warm-up control for the battery 24 as described above, the HVECU 30 makes a negative decision (NO) in step 118, finishes the warm-up control for the battery 24, and shifts to normal control in step 104. If the engine 12 stops operating and the HVECU 30 makes a negative decision (NO) in step 108, or if the amount of charge $C$ of the battery 24 is reduced down to the target value SOCL and the HVECU 30 makes a negative decision (NO) in step 112, the HVECU 30 finishes the warm-up control for the battery 24, and shifts to normal control in step 104. If the engine 12 is brought into operation before the battery temperature $T_b$ reaches the set temperature $T_{bs}$ during the normal control, the HVECU 30 shifts back to the warm-up control so as to increase the battery temperature $T_b$.

[0076] Referring to FIG. 3B, when the battery temperature $T_b$ is equal to $T_{b1}$ ($T_{b1} < T_{bs}$), and the amount of charge $C$ of the battery 24 is equal to $C_1$, for example, the regenerative power with which the battery 24 can be charged is equal to $\Delta C_a$ under the normal control using the target value SOC. Under the warm-up control using the target value SOCL, on the other hand, electric power that can be discharged from the battery 24 is equal to $\Delta C_b$.

[0077] In order to force the battery 24 to be charged during warm-up of the battery 24, it is necessary to drive the motor generator 14 using the driving force of the engine 12. In this method, however, the load of the engine 12 is increased, and the fuel consumption efficiency is reduced.

[0078] In this embodiment, on the other hand, the HVECU 30 sets the target amount of charge of the battery 24 to the target value SOCL that is lower than the target value SOC during the warm-up control, thereby to discharge the power $\Delta C_b$ forcibly for a reduction of the amount of charge of the battery 24. As a result, the battery 24 is capable of regenerative charging and forced discharging in a power range of ($\Delta C_a + \Delta C_b$).

[0079] With the charging and discharging as described above, the temperature of the battery 24 can be surely increased without using electric power.
generated by using the driving force of the engine 12. Namely, the HVECU 30 inhibits the battery 24 from being charged with electric power generated by driving the motor generator 24 using the driving force of the engine 12, thereby to prevent the motor generator 24 from adding to a load of the engine 12. In this manner, the HVECU 30 avoids reduction of the fuel consumption efficiency due to an otherwise possible increase in the load of the engine 12.

[0080] When warm-up of the battery 24 is finished, the HVECU 30 performs the normal control using the target value SOC. Thus, even if the warm-up control is finished before the battery temperature $T_b$ reaches the set temperature $T_{bs}$, the target amount of charge is set to the target value SOC, and the battery 24 is charged with regenerative power generated during running of the vehicle 10, so that the temperature of the battery 24 is increased.

[0081] Namely, if the HVECU 30 performs the normal control of charge and discharge of the battery 24, the amount of charge of the battery 24 becomes equal to a generally constant amount corresponding with the target value SOC, as indicated by the broken line in FIG. 5A. In this case, the battery temperature $T_b$ increases at a relatively low rate as the battery 24 is charged or discharged, as indicated by the broken line in FIG. 5B.

[0082] If the HVECU 30 performs the warm-up control using the target value SOCL that is lower than the target value SOC, and forces the battery 24 to be discharged, the amount of charge C of the battery 24 is reduced down to the amount of charge corresponding with the target value SOCL. Thus, the warm-up control is performed with the result that the amount of charge of the battery 24 is reduced.

[0083] As the amount of charge of the battery 24 decreases, the battery temperature $T_b$ rapidly increases at a higher rate than the case where the normal control is performed, as indicated by the solid line in FIG. 5B.

[0084] By reducing the amount of charge of the battery 24 through the warm-up control as described above, charging and discharging of the battery 24 is
promoted (i.e., the battery 24 is more likely to be charged and discharged), and the battery 24 is warmed up in a short time.

[0085] Since the HVECU 30 performs the warm-up control only during operation of the engine 12, the amount of charge of the battery 24 can be reduced to the amount of charge that ensures only the electric power required for starting the engine 12 and the electric power required for driving the motor generator 14 up to the time of switching to driving of the engine 12. Thus, the target value SOCL can be set to be significantly lower than the target value SOC. Also, since the HVECU 30 performs the warm-up control during operation of the engine 12, which makes it unnecessary to provide electric power (e.g., power for driving the starter motor 44) required for starting the engine 12, the target value SOCL can be further reduced, and the amount of power to be discharged can be increased.

[0086] By setting the target value SOCL to a significantly reduced value in the above manner, it is possible to increase the amount of electric power discharged forcibly from the battery 24, thereby to enable the battery 24 to generate a large amount of heat and efficiently increase the battery temperature Tb in a short time. In addition, the amount of charge of the battery 24 is reduced at the time of the completion of the warm-up control! therefore, the amount of regenerative power with which the battery 24 can be charged is increased, and the battery 24 can be efficiently charged with the regenerative power.

[0087] Furthermore, when the battery 24 is forced to be discharged for a reduction of the amount of charge thereof, the motor generator 14 is driven so as to assist the engine 12 with driving force for running the vehicle, and, therefore, the fuel consumption of the engine 12 is improved.

[0088] Since the battery control system 36 discharges the battery 24 during the operation of the engine 12, and it assists the engine 12. The load of the engine 12 is reduced, so that the fuel consumption can be further improved. When the outside-air temperature is low, such as in winter, and the engine 12 needs to be warmed up, in particular, the fuel consumption can be surely improved
by several percent or more.

[0089] While the battery 24 is forced to be discharged when the amount of charge C exceeds the target value SOC or SOCL in the illustrated embodiment, the battery 24 may be charged with regenerative power so that the amount of charge C exceeds the target value SOC or SOCL if there is no need to assist in driving of the engine 12 and there are no accessories to be driven with the power of the battery 24.

[0090] In the illustrated embodiment, the HVECU 30 performs the warm-up control for the battery 24 when the battery temperature Tb is reduced, even after shifting to the normal control. However, the invention is not limited to this flow of control. For example, the HVECU 30 may switch between the warm-up control and the normal control depending upon whether the engine 12 is operated or stopped until the battery temperature Tb reaches the set temperature Tbs, and may finish the warm-up control and performs only the normal control once the battery temperature Tb exceeds the set temperature Tbs.

[0091] In the illustrated embodiment, the battery ECU 34 detects the battery temperature Tb using the temperature sensor 42, and the HVECU 30 determines from the battery temperature Tb whether the battery 24 needs to be warmed up or not. However, any other conditions may be used provided that the conditions provide the basis of determining whether the battery temperature Tb is low and the battery 24 needs to be warmed up.

[0092] For example, if the outside-air temperature is low, as in winter, the battery temperature before starting of the vehicle 10 is reduced in accordance with the outside-air temperature.

[0093] It is, therefore, possible to determine whether the battery 24 needs to be warmed up, based on the outside-air temperature measured upon start of the vehicle 10.

[0094] Where the vehicle 10 is equipped with an air conditioner for heating the interior of the vehicle, it can be determined whether the battery temperature is
reduced, based on the temperature at which the air conditioner is set. Namely, when the outside-air temperature is low, and the air conditioner needs to be operated for heating, the operating temperature of the air conditioner is set to a high level.

[0095] Hence, it may be determined that the outside-air temperature is low and the battery temperature is also low, based on the set temperature of the air conditioner or the load of the air conditioner when it is operated, and a warm-up control for the battery 24 may be performed based on the determination.

[0096] If the vehicle, such as a hybrid vehicle, is equipped with an air conditioner including an electric heater, or the like, as an auxiliary heating means, the electric heater is operated when the outside-air temperature is low. Thus, it may be determined whether the warm-up control of the battery 24 is to be performed, depending upon whether the electric heater is operated or not.

[0097] While the invention is applied to the vehicle 10 in which the secondary battery is mainly charged with regenerative power in the illustrated embodiment, the invention may also be applied to other types of vehicles, such as a vehicle in which a secondary battery is charged with power derived from the driving force of the engine.
CLAIMS:

1. A battery control system provided in a vehicle, that runs with driving force of an internal combustion engine and an electric motor, for controlling charge and discharge of a secondary battery based on a target amount of charge, characterized by comprising:
   a temperature detector that detects battery temperature of the secondary battery;
   a charge amount detector that detects amount of charge of the secondary battery;
   a setting unit that sets the target amount of charge to a first target amount of charge in a normal state, and sets the target amount of charge to a second target amount of charge that is lower than the first target amount of charge when it is determined that the battery temperature is lower than a predetermined temperature and the engine is in operation; and
   a controller that controls charge and discharge of the secondary battery, based on the amount of charge of the secondary battery and one of the first and second target amounts of charge to which the target amount of charge is set by the setting unit.

2. A battery control system according to claim 1, wherein:
   the setting unit sets the first target amount of charge to about 40% to about 60% of full charge of the secondary battery; and
   the setting unit sets the second target amount of charge to about 30% to about 40% of full charge of the secondary battery.

3. A battery control system according to claim 1 or claim 2, wherein
   when the target amount of charge is set to the second target amount of charge, the controller allows the secondary battery to be charged with regenerative
power produced through regenerative braking of the vehicle, and inhibits the secondary battery from being charged with power derived from the driving force of the internal combustion engine.

4. A battery control system according to any one of claims 1 to 3, wherein once the battery temperature of the secondary battery exceeds the predetermined temperature, the setting unit fixes the target amount of charge to the first target amount of charge.

5. A battery control system according to any one of claims 1 to 4, wherein the temperature detector detects the battery temperature based on a set temperature of an air conditioner provided in the vehicle and/or a load at which the air conditioner performs a heating operation.

6. A battery control method for controlling charge and discharge of a secondary battery based on a target amount of charge, in a vehicle that runs with driving force of an internal combustion engine and an electric motor, characterized by comprising:

- detecting battery temperature of the secondary battery;
- detecting amount of charge of the secondary battery;
- setting the target amount of charge to a first target amount of charge in a normal state, and setting the target amount of charge to a second target amount of charge that is lower than the first target amount of charge when it is determined that the battery temperature is lower than a predetermined temperature and the engine is in operation; and
- controlling charge and discharge of the secondary battery, based on the amount of charge of the secondary battery and one of the first and second target amounts of charge to which the target amount of charge is set.
7. A battery control method according to claim 6, wherein:
the first target amount of charge is set to about 40% to about 60% of full charge of the secondary battery; and
the second target amount of charge is set to about 30% to about 40% of full charge of the secondary battery.

8. A battery control method according to claim 6 or claim 7, wherein
when the target amount of charge is set to the second target amount of charge, the secondary battery is allowed to be charged with regenerative power produced through regenerative braking of the vehicle, and is inhibited from being charged with power derived from the driving force of the internal combustion engine.

9. A battery control method according to any one of claims 6 to 8, wherein
once the battery temperature of the secondary battery exceeds the predetermined temperature, the target amount of charge is fixed to the first target amount of charge.

10. A battery control method according to any one of claims 6 to 9, wherein
the battery temperature is detected based on a set temperature of an air conditioner provided in the vehicle and/or a load at which the air conditioner performs a heating operation.

11. A battery control system for controlling a secondary battery, comprising-
a temperature detector that detects battery temperature of the secondary battery;
a charge amount detector that detects amount of charge of the secondary battery;
a setting unit that sets target amount of charge to a first target amount of charge in a normal state, and sets the target amount of charge to a second target amount of charge that is lower than the first target amount of charge when it is determined that the battery temperature is lower than a predetermined temperature and an internal combustion engine is in operation; and

a controller that controls charge and discharge of the secondary battery, based on the amount of charge of the secondary battery and one of the first and second target amounts of charge to which the target amount of charge is set by the setting unit.

12. A battery control system according to claim 11, wherein

the setting unit sets the first target amount of charge to about 40% to about 60% of full charge of the secondary battery; and

the setting unit sets the second target amount of charge to about 30% to about 40% of full charge of the secondary battery.

13. A battery control system according to claim 11, wherein

when the target amount of charge is set to the second target amount of charge, the controller allows the secondary battery to be charged with regenerative power produced through regenerative braking of a vehicle, and inhibits the secondary battery from being charged with power derived from driving force of the internal combustion engine.

14. A battery control system according to claim 11, wherein

once the battery temperature of the secondary battery exceeds the predetermined temperature, the setting unit fixes the target amount of charge to the first target amount of charge.

15. A battery control system according to claim 11, wherein

the temperature detector detects the battery temperature based on a set
temperature of an air conditioner provided in a vehicle and/or a load at which the air conditioner performs a heating operation.

16. A battery control method for controlling a secondary battery, comprising:
   - detecting battery temperature of the secondary battery;
   - detecting amount of charge of the secondary battery;
   - setting the target amount of charge to a first target amount of charge in a normal state, and setting the target amount of charge to a second target amount of charge that is lower than the first target amount of charge when it is determined that the battery temperature is lower than a predetermined temperature and an internal combustion engine is in operation; and
   - controlling charge and discharge of the secondary battery, based on the amount of charge of the secondary battery and one of the first and second target amounts of charge to which the target amount of charge is set.

17. A battery control method according to claim 16, wherein
   - the first target amount of charge is set to about 40% to about 60% of full charge of the secondary battery; and
   - the second target amount of charge is set to about 30% to about 40% of full charge of the secondary battery.

18. A battery control method according to claim 16, wherein
   - when the target amount of charge is set to the second target amount of charge, the secondary battery is allowed to be charged with regenerative power produced through regenerative braking of a vehicle, and is inhibited from being charged with power derived from driving force of the internal combustion engine.

19. A battery control method according to claim 16, wherein
once the battery temperature of the secondary battery exceeds the
predetermined temperature, the target amount of charge is fixed to the first target amount of charge.

20. A battery control method according to claim 16, wherein
the battery temperature is detected based on a temperature setting of an
air conditioner provided in a vehicle and/or a load at which the air conditioner
performs a heating operation.
FIG. 3A

Reactive Charging Power (Battery Capacity)

(kW)
LARGE

Small

Low

Battery Temperature $T_b$ (°C)

High
FIG. 4

BATTERY CONTROL

READ BATTERY TEMPERATURE Tb

102

BATTERY TEMPERATURE Tb < Tbs ?

YES

SET TARGET AMOUNT OF CHARGE TO TARGET VALUE SOC

106

NO

108

IS ENGINE IN OPERATION?

YES

READ AMOUNT OF CHARGE C OF BATTERY

110

NO

STATE OF CHARGE C > SOC ?

YES

FORCE BATTERY TO BE DISCHARGED (INHIBIT CHARGING WITH DRIVING FORCE OF ENGINE)

112

NO

READ BATTERY TEMPERATURE Tb

114

116

118

BATTERY TEMPERATURE Tb < Tbs ?

YES

NORMAL CONTROL (TARGET VALUE SOC)

104