method in which a control charge/discharge current is not made to flow, while Patent Document 2 indicates that a charge/discharge start voltage is made variable with an increase and decrease in a charging rate, but in a case of a technique in Patent Document 2, charging rate control for suppressing a biased SOC during operation of a power storage device is incorporated, resulting in occurrence of a wasteful charge/discharge loss for control of the SOC.

[0012] Further, when the charge/discharge control which changes a charge start voltage and discharge start voltage according to the SOC is used, it is not indicated that what charge/discharge characteristics to have specifically makes it possible to reduce the charge/discharge loss of a power storage element, suppress a regenerative cancellation sufficiently, and charge and discharge according to a change in a load distribution of a line and an operation state (operating state of rectifier of substation) of a feeding facility.

MEANS OF SOLVING THE PROBLEMS

[0013] Embodiments of the present invention provide a power storage device capable of improving charge/discharge efficiency of a power storage element, also corresponding to a power supply stop from a substation facility for feeding and a change in a train load distribution on a feeding circuit, and making a state of charge of the power storage element fall within a range of a predetermined state of charge, while suppressing a regenerative cancellation of a vehicle at the maximum.

[0014]

According to an aspect, there is provided a power storage device comprising: a power storage element capable of storing power and charging and discharging; a converter converting voltage between a direct-current power supply system and the power storage element; a voltage detecting unit detecting a voltage of the direct-current power supply system through the converter; a charging rate detection unit detecting a charging rate of the power storage element; a storage unit which stores a table defining, in sectional ranges of a charging rate in which a charging rate indicating a range of an amount of charge in which the power storage element is capable of storing power is divided into some sections, a charge characteristic in which any one or more of a first voltage in which charge is started and a second voltage in which charge is started with a maximum current are represented and a discharge characteristic in which any one or more of a third voltage in which discharge is started and a fourth voltage in which discharge is started with a maximum current are represented; and a current control unit selecting a characteristic according to a charging rate of the power storage element which is detected by the charging rate detection unit from the table, sets each voltage of a selected characteristic at a control point of a charge/discharge control characteristic for charging and discharging to/from the power storage element, and performs charge and discharge between the direct-current power supply system and the power storage element through the converter according to a voltage of the direct-current power supply system which is detected by the voltage detecting unit in accordance with the charge/discharge control characteristic, wherein in the storage unit, a control characteristic for changing four voltages of the first voltage to the fourth voltage is defined for each range of the charging rate, wherein the control characteristic comprises: a first charge characteristic including either or both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate; a first discharge characteristic including either or both characteristics of a characteristic in which the third voltage drops with a decrease in the charging rate and a characteristic in which the fourth voltage drops with a decrease in the charging rate; a second discharge characteristic provided between the first charge characteristic and the first discharge characteristic and including either or both characteristics of a characteristic in which the third voltage rises with a rise in the charging rate and a characteristic in which the fourth voltage rises until reaching a maximum discharge start voltage with a rise in the charging rate; and third charge/discharge characteristics provided between the second discharge characteristic and the first charge characteristic, in which either or both voltages of the first voltage and the

second voltage and either or both voltages of the third voltage and the fourth voltage become constant regardless of the charging rate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a diagram illustrating a configuration of an electric railcar power feeding system of an embodiment.

FIG. 2 is a chart illustrating a control characteristic which performs charge/discharge control of a power storage element according to a variation in a voltage of a feeder line.

FIG. 3 is a characteristic chart illustrating a relationship between a charging rate and voltages of control points.

DETAILED DESCRIPTION

[0016] Hereinafter, an embodiment will be described in detail referring to the drawings.

Claim:

1. A power storage device comprising:

a power storage element capable of storing power and charging and discharging;

a converter converting voltage between a direct-current power supply system and the power storage element;

a voltage detecting unit detecting a voltage of the direct-current power supply system through the converter;

a charging rate detection unit detecting a charging rate of the power storage element;

a storage unit which stores a table defining, in sectional ranges of a charging rate in which a charging rate indicating a range of an amount of charge in which the power storage element is capable of storing power is divided into some sections, a charge characteristic in which any one or more of a first voltage in which charge is started and a second voltage in which charge is started with a maximum current are represented and a discharge characteristic in which any one or more of a third voltage in which discharge is started and a fourth voltage in which discharge is started with a maximum current are represented; and

a current control unit selecting a characteristic according to a charging rate of the power storage element which is detected by the charging rate detection unit from the table, sets each voltage of a selected characteristic at a control point of a charge/discharge control characteristic for charging and discharging to/from the power storage element, and performs charge and discharge between the direct-current power supply system and the power storage element through the converter according to a voltage of the direct-current power supply system which is detected by the voltage detecting unit in accordance with the charge/discharge control characteristic, wherein

in the storage unit,

a control characteristic for changing four voltages of the first voltage to the fourth

voltage is defined for each range of the charging rate, wherein

the control characteristic comprises:

a first charge characteristic including either or both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate;

a first discharge characteristic including either or both characteristics of a characteristic in which the third voltage drops with a decrease in the charging rate and a characteristic in which the fourth voltage drops with a decrease in the charging rate;

a second discharge characteristic provided between the first charge characteristic and the first discharge characteristic and including either or both characteristics of a characteristic in which the third voltage rises with a rise in the charging rate and a characteristic in which the fourth voltage rises until reaching a maximum discharge start voltage with a rise in the charging rate; and

third charge/discharge characteristics provided between the second discharge characteristic and the first charge characteristic, in which either or both voltages of the first voltage and the second voltage and either or both voltages of the third voltage and the fourth voltage become constant regardless of the charging rate.

2. The power storage device according to claim 1, wherein

the control characteristic comprises

a second charge characteristic provided between the second discharge characteristic and the first discharge characteristic and including either of both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate.

3. The power storage device according to claim 1, wherein

the control characteristic comprises

first charge/discharge characteristics provided between the second discharge characteristic and the first discharge characteristic and having a discharge characteristic including either or both characteristics of a characteristic in which the third voltage rises

with a rise in the charging rate and a characteristic in which the fourth voltage rises with a rise in the charging rate, and a charge characteristic in which either or both voltages of the first voltage and the second voltage become constant voltage regardless of the charging rate in a sectional range of a charging rate where this discharge characteristic is set.

4. The power storage device according to claim 1, wherein

the control characteristic comprises

second charge/discharge characteristics provided between the second discharge characteristic and the first discharge characteristic and having a discharge characteristic including either or both characteristics of a characteristic in which the third voltage rises with a rise in the charging rate and a characteristic in which the fourth voltage rises with a rise in the charging rate, and a charge characteristic including either or both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate in a sectional range of a charging rate where this discharge characteristic is set.

5. The power storage device according to claim 1, wherein

the control characteristic has:

between the second discharge characteristic and the first discharge characteristic,

a second charge characteristic including either of both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate;

first charge/discharge characteristics having a discharge characteristic including either or both characteristics of a characteristic in which the third voltage rises with a rise in the charging rate and a characteristic in which the fourth voltage rises with a rise in the charging rate, and a charge characteristic in which either or both voltages of the first voltage and the second voltage become constant voltage regardless of the charging rate in a sectional range of a charging rate where this discharge characteristic is set; and

second charge/discharge characteristics having a discharge characteristic including either or both characteristics of a characteristic in which the third voltage rises

with a rise in the charging rate and a characteristic in which the fourth voltage rises with a rise in the charging rate, and a charge characteristic including either or both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate in a sectional range of a charging rate where this discharge characteristic is set, wherein

from a low side toward a high side of the charging rate, an arrangement is made in order of the second charge/discharge characteristics, the first charge/discharge characteristics, and the second charge characteristic.

6. The power storage device according to claim 1, wherein

the control characteristic comprises one or more characteristics of,

between the second discharge characteristic and the first discharge characteristic,

a second charge characteristic including either of both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate,

first charge/discharge characteristics having a discharge characteristic including either or both characteristics of a characteristic in which the third voltage rises with a rise in the charging rate and a characteristic in which the fourth voltage rises with a rise in the charging rate, and a charge characteristic in which either or both voltages of the first voltage and the second voltage become constant voltage regardless of the charging rate in a sectional range of a charging rate where this discharge characteristic is set, and

second charge/discharge characteristics having a discharge characteristic including either or both characteristics of a characteristic in which the third voltage rises with a rise in the charging rate and a characteristic in which the fourth voltage rises with a rise in the charging rate, and a charge characteristic including either or both characteristics of a characteristic in which the first voltage rises with a rise in the charging rate and a characteristic in which the second voltage rises with a rise in the charging rate in a sectional range of a charging rate where this discharge characteristic is set.