PCS for Lithium Ion Batteries

Manabu Teramoto
Takahiro Murai

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Abstract

Lithium-ion Batteries (LiB) have already been commercialized for vehicle on-board application and are expected to widely penetrate the market in the future. They are also noted as devices for application in energy storage systems.

Recently, particularly after the Great East Japan Earthquake in 2011, demands for grid stabilization have increased due to facts such as penetration and expansion of renewable energy resources, optimization of energy through the promotion of electrification, the "no nuke" movement, and readiness for emergency power supply. In this, the use of energy storage systems is expected to be applied to demand-supply adjustment in the grid system through the energy storage system, and also frequency control.

1 Preface

According to various applications, batteries for energy storage systems, lead batteries, sodium and sulfur batteries, and nickel-hydrogen batteries have been used. Recently, Lithium-ion Batteries (LiB) are receiving high attention as devices for on-board vehicles application because it features high energy density and are widely used in cars. These batteries are also noted as the energy storage batteries and its research is actively promoted worldwide.

This paper introduces a comparison of characteristics among various energy storage batteries as well as features our newly developed Power Conversion System (PCS) for the LiB.

2 Energy Storage Batteries

2.1 Comparison of Characteristics among Various Electric Energy Storage Batteries

In the energy storage system to be introduced for load leveling with due consideration of demand-load curves, it calls for high energy density and high charge/discharge efficiency.

Table 1 shows a comparison of characteristics among various batteries used for energy storage systems. Compared with other batteries, the LiB provides a high energy density. In addition, the charge/discharge efficiency of the battery unit alone is outstanding compared with others.

2.2 Outline of LiB Specifications

The LiB is a battery of which the anode is a compound of lithium metal oxide with a major com-

Table 1 Comparison of Battery Characteristics

This comparison table has been established based on our unique investigation. Compared with other batteries, the LiB offers an outstanding efficiency.

Characteristic item	Lead battery	Sodium and sulfur battery	Nickel-hydrogen battery	LiB
Self-discharge rate (%/day)	0.5	0	0.7～1.0	0.3～0.6
Cycle life	500～3000	4500	500～5000	500～5000
Energy density (Wh/kg) Values in the parentheses ( ) denote the theoretical energy densities.	40 (167)	100 (786)	60～90 (125)	130 (392～585)
Charge/discharge efficiency	0.87	0.85	0.6	0.95
Cell voltage	2.0	2.1	1.2	3.8

Table 2 Example of LiB Specifications

An example of LiB specifications is shown. There are differences in battery manufacturers.

Battery type	Lithium ion battery
Reaction formula	$Li_{1-x}M_yO_{2y}+Li_xC_6 \longleftrightarrow LiM_yO_{2y}+6C$
Anode material	Compound of lithium metal oxide
Cathode material	Carbon
Electrolyte	Organic solvent
Theoretical energy density (wh/kg)	392~585
Open line voltage/cell (V)	3.6~3.8
Working temperature (℃)	0~40
Major auxiliary equipment	Nil in particular

M: Metalic element (Co, Mn, Ni, etc.)

Table 3 BMU Functions

General BMU functions are shown. While the battery protective function is in action, the PCS also stops the charge/discharge operation for security.

Item	Contents
Protective function	Overcharge, over-discharge, overvoltage, overcurrent, thermal errors, etc.
Status monitoring	Measurement of voltage, current, electric energy, charge/discharge limit management, state of charge management, etc.

Table 4 PCS Specifications

The inverter capacities are standardized according to the number of PCS parallel connections.

Item			Rating or performance
Capacity			0.25~2MVA (250kVA × 8 in parallel connections)
Inverting system			Voltage type self-excited PWM current control system
Type of rating			A0 (100% continuous)
AC I/O	Rated voltage		400V class
	Voltage deviation permissible range		−12~+10%
	Rated frequency		50Hz or 60Hz
	Frequency deviation permissible range		±6%
	Phases		3-phase, 3-wire
	Rated I/O capacity		0.25~2MVA (250kVA × 8 in parallel connections)
	Constant-power control accuracy	Active power	±1%
		Reactive power	±1%
	Power control deviation range	Active power	0~100%
		Reactive power	0~100%
	Current harmonics content rate		Each order 3%, total 5% or less
DC I/O	Voltage range		240~420V
Efficiency			95% or above

ponent of cobalt, manganese, or nickel. Its cathode is carbon and the electrolyte is an organic solvent. Table 2 shows an example of LiB specifications.

2.3 Battery Management Unit (BMU)

Since the LiB uses organic materials that involve risk, the BMU is incorporated for battery safety management. This unit offers a protective function and a status monitoring function. Cell voltage, current, temperature, and other essential factors inside the battery are continuously monitored. Table 3 shows these functions.

3 PCS for the LiB

The features of the Meiden PCS developed for the LiB application are introduced below.

3.1 Unit Specifications

Table 4 shows PCS specifications.

3.2 System Configuration

Fig. 1 shows a configuration diagram of a power storage system. The PCS is composed of a power-incoming switch, interconnection switch, protection relays belonging to the power incoming block, inverters, and input filter which belong to the power conversion block, and the PCS monitoring and control sequencer, and operator panel which then reside in the supervisory control block.

3.2.1 Power Conversion Unit

The PCS is used to convert the AC power into the DC power to charge the LiB. The power stored in the LiB is inverted into the AC power that is then fed to the grid system. The PCS is composed of eight 250kVA inverter units connected in parallel. The maximum system capacity is scheduled to be 2MVA.

3.3 System Functions

The outline of the PCS function features is introduced below.

(1) Manual operation

At the operator panel for this system, it is possible to perform operation in an arbitrary power setting, such as start-stop and charge-discharge. Also at the operator panel, equipment status, fault display, and various telemetry values can be monitored.

(2) Remote operation

When the supervisory unit installed in a remote supervisory room and the PCS are connected with

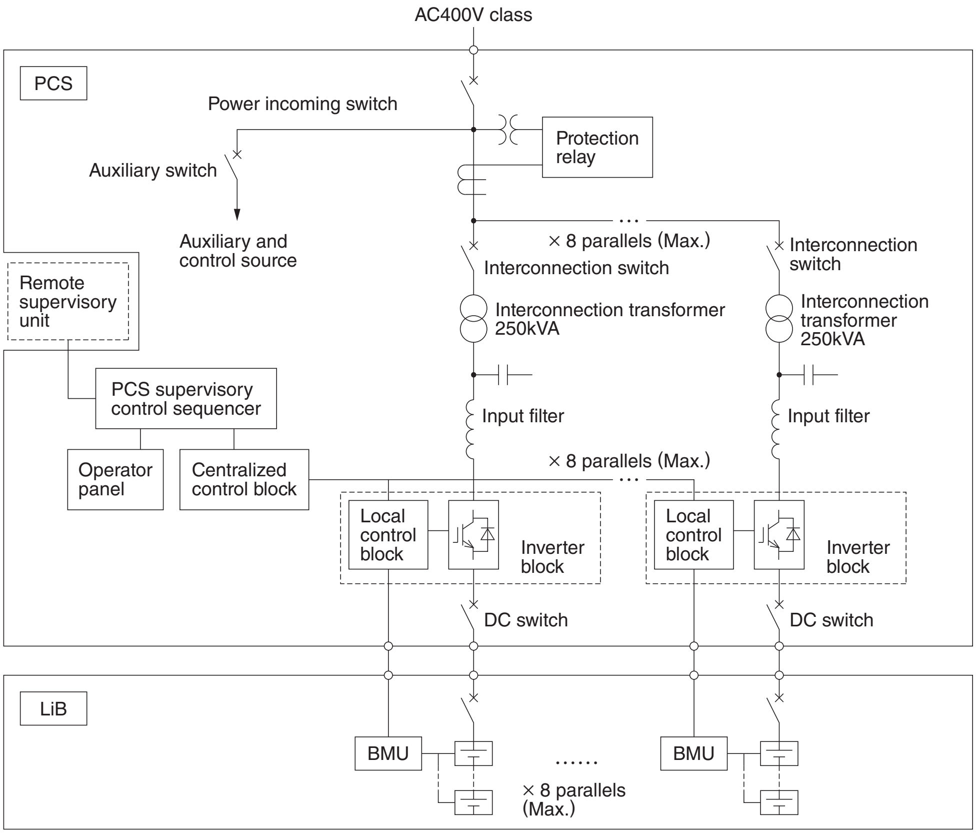

Fig. 1 **Configuration Diagram of Power Storage System**

Eight units of 250kVA inverter systems are connected in parallel. The configuration shown is for a 2MVA system. The number of parallel connections is changeable arbitrarily from one to eight parallels.

an Ethernet or other like communication line, the same operation as described above can be performed.

(3) Inrush current preventive function needed at the time of grid interconnection

When the PCS is interconnected with the power grid system, there may be equipment deterioration due to the effect of inrush current in the interconnection transformer, or due to system disturbance in some cases. To avoid this, this function is used to generate a voltage from the PCS side so that grid-connection can be accomplished smoothly after being synchronized with the system voltage.

(4) Active power control

According to the power command value, this function controls the active power at end of the AC terminal in order to be kept constant.

(5) Reactive power control

According to the power command value, this function controls the reactive power at the AC terminal end in order to be kept constant.

(6) Islanding operation function (emergency power supply)

In the event of a service interruption in the utility system, as a backup power supply, this function is used to convert the DC power of the battery system into an AC power (constant voltage and frequency) so that the converted power can be fed to the load as an emergency power supply.

(7) Frequency control function

This function is used to monitor the AC terminal voltage and frequency, to calculate the amount of active power control comparable to changes in frequency, and to take automatic control in order to adjust the PCS output.

(8) Fault Ride Through (FRT) function

In order to prevent unusual stoppage of the PCS during abnormality in system voltage, this function is used to maintain favorable operation within the range of the specified rate and duration of a voltage drop.

(9) Constant-voltage charging function

For the prevention of battery breakage and deterioration due to overvoltage at the time of constant-power charging to the LiB, this function is used to change-over the present charging mode to constant-voltage charging when the specified voltage (around the charge limit) is attained.

Table 5 Example of Energy Storage System Applications

The energy storage system can be used for a variety of applications. It can be used for peak-shaving and peak-shifting operation in factories and large buildings, or used as a power supply in cases of an emergency. It is applicable to demand-supply control and frequency adjustment in the power grid.

Application	Outlined explanation
Load leveling	Batteries are charged up during the nighttime when demand for electricity is low and they discharge in the time zone when power demand peaked in the daytime. This performance contributes to the reduction of contract power rates.
Emergency power supply	In the case of a service interruption occurring in facilities, electric power is kept supplied to significant loads. This feature contributes to the Business Continuity Plan (BCP).
Regulation restraint	This feature is effective in avoiding turbulence in the utility system by relieving voltage regulations predicted to occur when a PV power source or other renewable energy source is interconnected with the power grid.
Peak shift	Batteries are charged in the time zone when power generation at the PV generation system is large, and discharged in the time zone when power demand is large. This feature contributes to the effective utilization of energy.
Demand-supply control	Based on the plan in regard to power generation by means of generators, utilization of renewable energy, and demand-supply prediction, measures with the use of charge/discharge capabilities are taken for power balancing in the case of deviation from the range planned.
Frequency control	Batteries are discharged when voltage and frequency are lowered in the utility system, and then are charged when their values are recovered. This feature is effective in controlling frequency regulations.

3.4 Example of Application

This energy power storage system is used for a variety of applications such parallel grid-connection operation with a renewable energy system or as an emergency power supply operation. **Table 5** shows an example of energy storage system applications.

4 Postscript

The LiB energy storage system offers outstanding features in terms of economy, long operational life, and smaller footprint space. Since the system is rich in applications, it is expected to be widely used in the near future. We will continue to promote development of key products that are indispensable for the LiB energy storage systems.