Large Capacity and High Precision Charging/Discharging Battery Test System – JH40

Sho Shibata,
Jun Mitsuta,
Keiichi Kodachi

Keywords Charging/discharging battery test system, Multilevel converter, Battery evaluation

Abstract

Currently, Electric Vehicles (EVs) are being released by various automobile manufacturers and they are about to become popular in earnest. One of the key components for the spread of EVs is the battery. In a battery evaluation system, there is a system that charges and discharges a connected battery using arbitrary voltage and current.

In the charging/discharging battery test system, the JH40 achieves large capacity and high accuracy by using a flying capacitor multilevel converter that multiplexes our proprietary units for the power conversion circuit in the output section. This allows it to support batteries of a wide range of capacities. Additionally, by increasing the equivalent carrier frequency of the circuit, the output filter was made smaller, thereby reducing the size of the system.

1 Preface

In recent years, environmental issues such as the Sustainable Development Goals (SDGs) and carbon neutrality have attracted attention. At the same time, Electric Vehicles (EVs) are becoming more popular worldwide. Batteries are one of the key components for the spread of EVs. Battery research and evaluation are being actively conducted.

The capacity of an in-vehicle battery is directly linked to the driving distance of an EV, and increasing battery capacity is being considered. Accurately understanding the battery's charging/discharging conditions is also important in preventing the risk of overcharging or overdischarging, as is selecting a battery with an appropriate capacity. This also leads to cost reduction. Therefore, evaluation equipment is also required to be highly accurate.

This article introduces the JH40, a large capacity and high precision charging/discharging battery test system, that meets these requirements. JH40 has a capacity of 540 kW, the largest in Japan (at the time of JH40 release). Additionally, to ensure accuracy within a wide range of capacity operation, the JH40 uses three ranges depending on the size of the output current. As a result, it achieved the current output accuracy of ±0.3% F.S. at each rated output.

2 Features of JH40

2.1 Main Circuit Configuration

Fig. 1 shows the system configuration. The JH40 consists of a rectifier section that converts input Alternating Current (AC) to Direct Current (DC), and a chopper section that outputs the desired DC. In particular, the power conversion circuit in the chopper section uses a Flying Capacitor (FC)

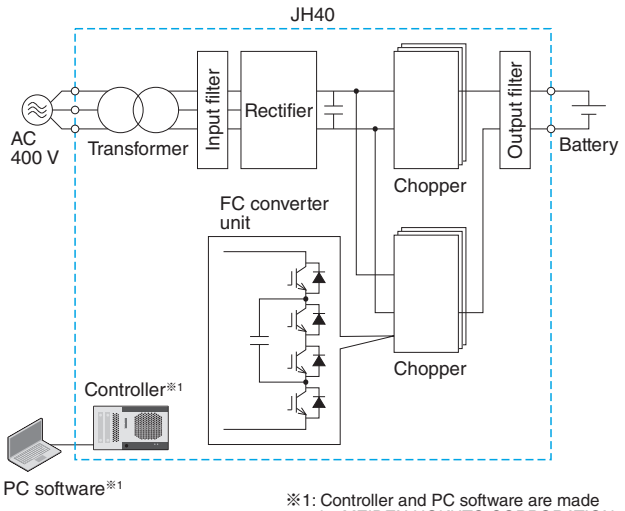


Fig. 1 System Configuration

The JH40 is composed of the rectifier section and the chopper section. To realize large-capacity and high-accuracy control performance, the chopper section adopts the FC multilevel converters.

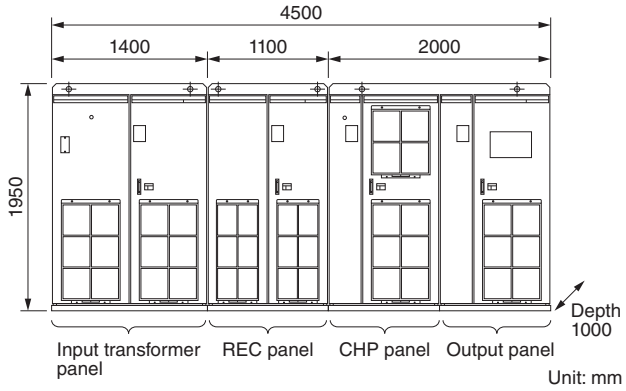


Fig. 2 External Dimensions

The JH40 comes in a panel array configuration.

multilevel converter that multiplexes our proprietary units.

The JH40 is divided into three ranges depending on the size of the output current, with the highest range being the High Range, Middle Range, and Low Range. By using these three ranges depending on the output, a single device can ensure high accuracy over a wide range from high current to low current.

2.2 Specifications

Fig. 2 shows the external dimensions of JH40. The JH40 has an input transformer panel, a Rectifier (REC) panel, a Chopper (CHP) panel, and an output panel. The input transformer panel houses a transformer for insulation and to meet REC input specifications. The REC panel and CHP panel contain power conversion circuits for the rectifier section and chopper section, respectively. The output panel houses the output filter and the system controller.

Table 1 shows the main specifications of JH40. Since the system capacity is 540 kW, the output current is reduced according to the output voltage to ensure that the power does not exceed 540 kW. Fig. 3 shows the output range of JH40. It has constant output characteristics in the range where the output voltage exceeds 600 V.

Fig. 4 shows a screen of the Personal Computer (PC) software (produced by MEIDEN HOKUTO CORPORATION) that sends JH40 operation commands for charging and discharging operations, voltage, current, and time. Commands can be set in detail and the settings can be displayed graphically. It is also possible to display output voltage and output current during operation.

Table 1 Main Specifications

The JH40 assures large-capacity and high-accuracy control performance.

Items		Specifications
System capacity		540 kW※1
Output voltage		0～750 V※1
Rated current		High range : 900 A※1 Middle range: 450 A Low range : 20 A
Input voltage range		3-phase 400～440 V
Main circuit rating class		Class A0 (100%) continuous
Control performance※2	Current output accuracy	±0.3%F.S.
	Current conversion width	±0.1%rmsF.S.
	Current response performance	Convergence into ±0.1%rmsF.S. in 10 ms Overshooting: within 1%
	Output voltage accuracy	±0.1%F.S.
	Output power accuracy	±0.5%F.S.
Functions	Constant current mode	Current-constant control
	Constant voltage mode	Current control so that voltage does not exceed the specified control level
	Constant power mode	Current control so that output power does not exceed the specified control level
Protective construction		IP20
Setting		Indoor self-standing type
Cooling system		Forced air cooled
Maintainability		Panel-front maintenance system
Maintenance space		Door width: +600 mm or more
Cable entry		Lead-in: Upper part Lead-out: Lower section
Vibration resistance		During transportation: 4.9 m/s^2 (10～50 Hz) or below
Environmental conditions for use	Installation place	Indoors
	Ambient temperature	0～40℃, annual average 25℃ or below
	Humidity	85% or below (Freedom from dew condensation)
	Altitude	1000 m or below
	Atmosphere	Freedom from corrosive or explosive gases, metallic powder, vapor, dust, oil mist, cotton flies, etc.
Options	FINEMET for input section	Suppression of common mode noise flowing into AC the input section
	FINEMET for DC section	Suppression of common mode noise passing through this equipment
	FINEMET for output section	Suppression of common mode noise flowing out of the output section

Notes:
※1. When the output voltage is within the range of 600 V to 750 V, the equipment is operated by reducing the output current so that power does not exceed 540 kW.
※2: Based on our testing environment.

2.3 Larger Capacity

The JH40 uses an FC multilevel converter in the chopper section to achieve both high response speed and reduced output ripple. The FC can easily

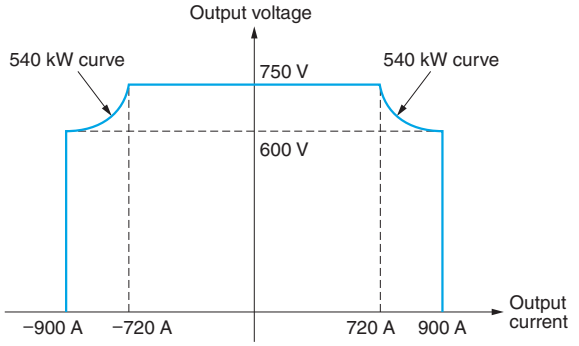


Fig. 3 Output Range

The capacity of the JH40 is 540 kW. The output current should be controlled not to exceed 540 kW possibly caused by the effect of output voltage.

※ The display screen may change according to software versions.

Fig. 4 Screen of PC Software

For the JH40, operation commands and other data are transmitted from the PC software. For (a), commands for charge and discharge can be set up. For (b), various setup commands can be graphically displayed.

avoid the nonlinear region of Pulse Width Modulation (PWM) by superimposing a zero-phase voltage. Therefore, output ripple can be reduced even at low output voltages. Since FC charges and discharges depending on the switching frequency, the FC capacity required to withstand voltage fluctuations can be reduced by increasing the switching frequency. The FC multilevel converter uses a power conversion circuit composed of FC and Insulated Gate Bipolar Transistor (IGBT) as one unit, and by connecting the units in parallel, it achieved large power output. Furthermore, multiplexing the units also contributes in making the compact chopper output smoothing reactor. In order to ensure output current response performance, it is necessary to reduce the inductance of the output filter. By multiplexing units, the JH40 increases the equivalent carrier frequency of the circuit and achieves a smaller output filter. Increasing the carrier frequency also leads to an increase in switching loss. However, by using multi-level, the voltage applied to one IGBT is reduced. This reduces output voltage ripple and switching loss, and decreases heat loss.

2.4 Higher Precision

The JH40's FC multilevel converter achieves both improved output response speed and reduced current ripple by multiplexing units.

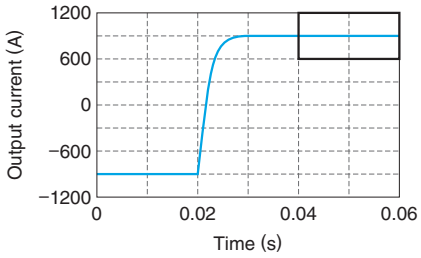
Unbalanced FC voltages cause current ripples, so multiple multiplexed FC voltages must be controlled to a constant level. Charging and discharging of the FC voltage is determined by the polarity of the output current. The FC voltage can be controlled by appropriately switching between the two charging and discharging patterns depending on the direction of the output current. However, in the low current range, the direction of the output current may be incorrectly detected due to the effects of current sensor offset and delay, resulting in incorrect charging and discharging patterns of the FC voltage.

The JH40 also uses a method that determines the charging and discharging pattern of the FC voltage by detecting changes in the FC voltage at a certain time. This method allows the FC voltage to be constant regardless of the amount of output current. This enables highly accurate control over a wide output range from high current to low current.

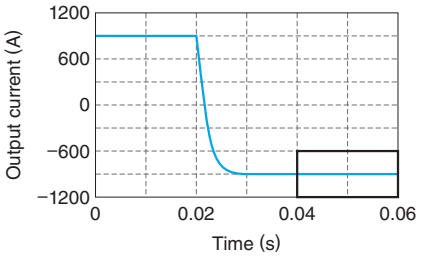
The JH40 detects two currents: (1) the current before the output filter (filter current), which is the output of the FC multilevel converter in the chopper section, and (2) the current after the output filter (battery current) that actually flows into and out of the battery. In Proportional-Integral (PI) control, which is a type of current control, the filter current is input to P control, which requires response speed, and battery current is input to I control, which has small ripple. By doing this, ripples at high frequencies such as integral multiples of the carrier frequency are reduced. Additionally, ripples caused by disturbances are suppressed by adding a battery current feedback term to the P control current command value.

3 Output Current Response Waveforms

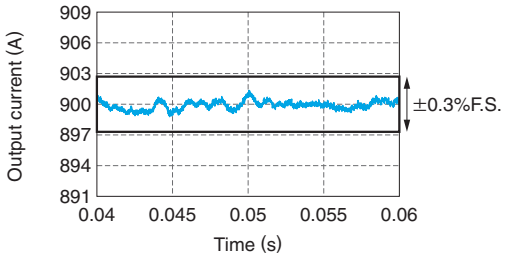
Fig. 5 shows the output current response waveforms of JH40 in the High Range. During measurement, the output of JH40 was short-circuited. (a) shows the output current waveform when switching



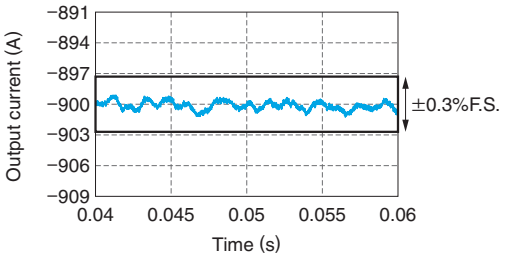
(a) Output current response waveform (−900→900 A)



(c) Output current response waveform (900→−900 A)



(b) Enlarged waveform of (a)



(d) Enlarged waveform of (c)

Fig. 5 **Output Current Response Waveforms**

For the JH40, the situation of switching from discharge to charge or from charge to discharge is supported by the aid of high response performance.

from −900 A discharging to 900 A charging, and (c) shows the output current waveform when switching from 900 A charging to −900 A discharging. (b) is the expanded waveform of (a) after convergence, and (d) is the expanded waveform of (c) after convergence. From (a) and (c), the response time is 10 ms when the overshoot amount is within 0.1% in both cases.

Within this range, the response performance is high. After convergence, the output accuracy for both is within ±0.3% F.S., achieving highly accurate control with suppressed current ripple.

4 Postscript

We introduced the JH40 charging/discharging battery test system, which is a system for evaluating batteries. The main circuit configuration features an FC multilevel converter with multiplexed units, achieving large capacity and high accuracy. The output capacity of the JH40 is 540 kW, the largest in Japan. It is applicable to a wide range of battery capacities and will greatly contribute to market expansion as EVs become more widespread. It is expected that this will also contribute in mitigating the global environmental issues.

In the future, we will continue to release products that meet the needs of society, including expanding our capacity series.