EV charging infrastructures

EV Development Test System for the Evaluation of Electric Power Trains

SUGAWA Masashi

Abstract

EV development test systems are used to test the performance of motors and inverters for hybrid and electric vehicles by simulating the behaviors of the component parts of an electric power train. They are compatible with HILS systems, which simulate an entire vehicle by combining an EV power emulator and a vehicle control simulator. This paper outlines the recent technological advances in EV development test systems and introduces a battery charge-discharge test system.

Keywords

electric power train, inverter emulator, motor emulator, hybrid vehicle
electric vehicle, vector control, secondary battery, charge-discharge, ripple superposition

1. Introduction

The global rise in environmental consciousness under global warming and increased requirements for vehicle fuel consumption are promoting the active development of hybrid vehicles and electric vehicles (EVs). In the development of an electric power train (secondary battery, inverter and motor) (**Fig. 1**), the mainstream methodology is to develop components using software simulators and evaluate the developed components using a test system that simulates the input and output conditions electrically. At Takasago, Ltd. we have been developing an EV development test system since 2005 and have developed an EV power emulator that simulates the behavior of a battery, inverter and motor using advanced power supply technology, DSP firmware technology and hardware architecture technology (**Photo**). We have also developed a charge-discharge test system that can reproduce inverter current waveform patterns similar to those during driving, without using an actual vehicle, for use in the evaluation testing of the secondary battery. In this paper we will introduce the key technologies of the EV development test system.

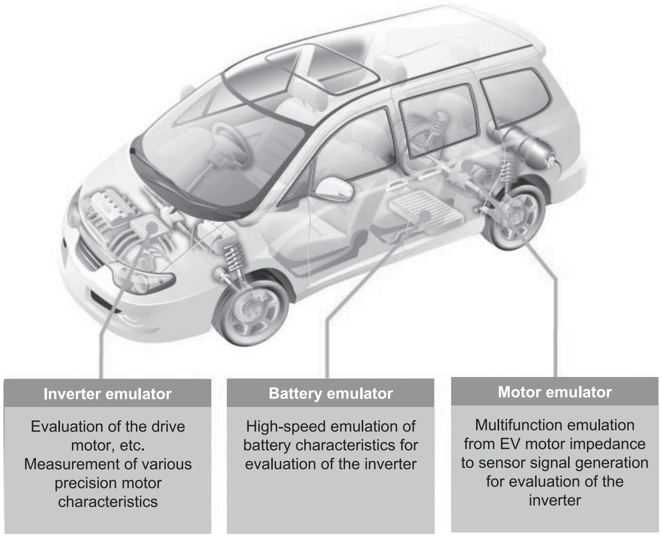

Fig. 1 Electric power train configuration.

Photo External view of the EV power emulator (300 kW total system).

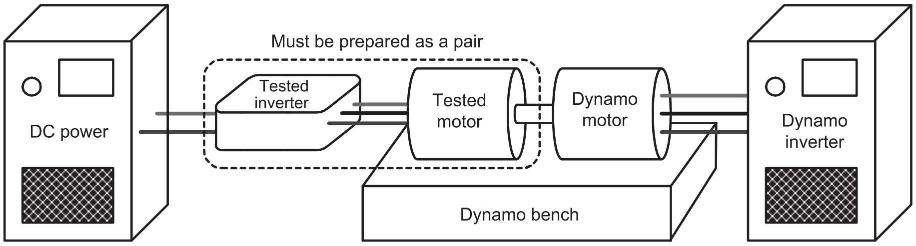

Fig. 2 Traditional motor evaluation system.

2. Outline

2.1 Inverter Emulator

Traditionally, the evaluation of a motor required the evaluation of the inverter and the motor as a pair. This meant that the evaluation testing of the motor was not possible until the development of the inverter was complete, posing an obstacle preventing the reduction of the development period (**Fig. 2**).

To meet the need to evaluate a motor without waiting for the completion of inverter development, we developed an inverter emulator that simulates inverter operations. We also developed a bidirectional class D amplifier of the constant current drive type with industry-first sine-wave current operation capability for use as the inverter emulator's AC power source. This AC power supply feeds a sine-wave current to the motor using a DSP-based vector controller for real-time computations of the magnetization component current (Id) and torque component current (Iq). This makes it possible to obtain characteristic data similar to the design values of the motor and to perform ideal evaluation testing efficiently.

Fig. 3 shows a block diagram of the inverter emulator.

2.2 Battery Emulator

Inverter evaluation testing was traditionally performed by connecting an actual battery as the DC input source. But this method was unable to provide evaluation testing with high reproducibility and stability because battery characteristics vary depending on charge status and temperature (**Fig. 4**). In addition, since a battery's energy is limited, the labor of using a charger and adjusting the charge rate was also necessary.

To solve this problem, we developed a battery emulator that can perform highly reproducible evaluation tests emulating the characteristics of a battery (I-V characteristics) using a DSP. **Fig. 5** shows a block diagram of this battery emulator.

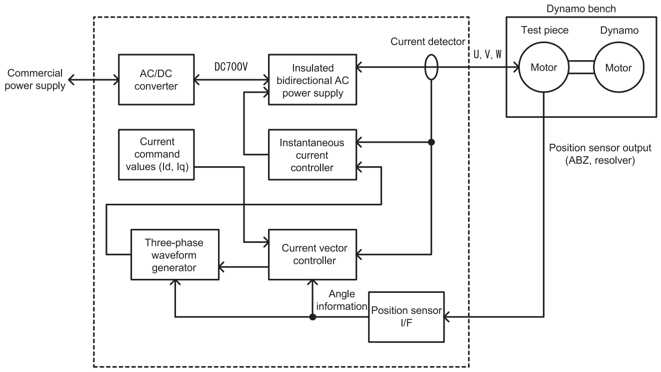

Fig. 3 Block diagram of the inverter emulator.

An insulated bidirectional DC/DC converter is used as a constant voltage output. It refers to an I-V characteristics table based on the measured current and outputs a voltage corresponding to it.

To allow emulations to be conducted under conditions close to a battery's charge-discharge characteristics, it is also possible to set emulation conditions such as charge rate, battery temperature, open voltage and remaining capacity status (**Fig. 6**).

As a result, this battery emulator is capable of emulating a wide range of energy storage devices, from secondary batteries based on nickel-metal hydride and lithium-ion cells to capacitors.

2.3 Motor Emulator

Developed inverters were previously evaluated by installing an actual motor on the dynamo bench for use as the load

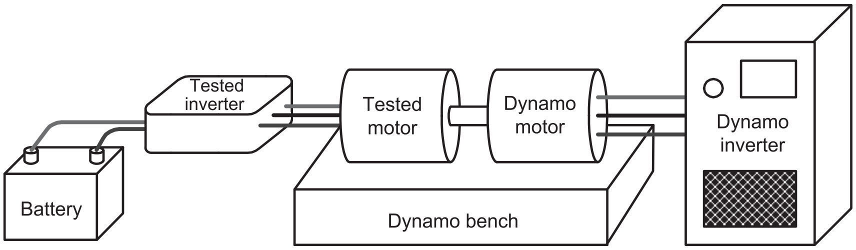

Fig. 4 Traditional inverter evaluation system.

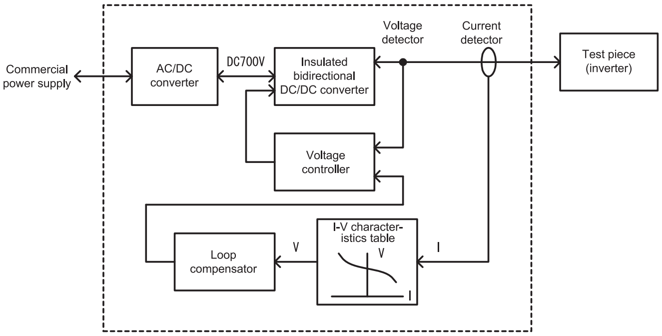

Fig. 5 Block diagram of the battery emulator.

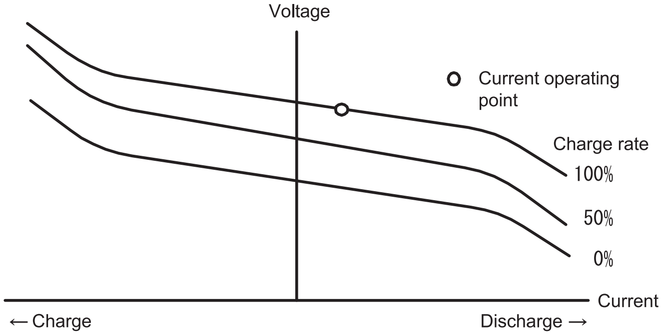

Fig. 6 Emulation by adjusting the I-V characteristics table according to charge rate.

of the tested inverter, so the evaluation was accompanied by mechanical noise and the risks of rotary parts. In addition, a motor matching the inverter had to be prepared every time an inverter of a different type was evaluated. This led to a long time required for preparation and resulted in a deterioration of development efficiency.

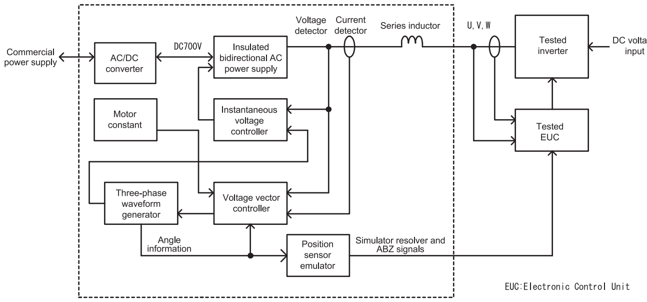

Fig. 7 Block diagram of the motor emulator evaluation system.

To solve this problem, we developed a stationary motor emulator that is capable of safe evaluation testing by arbitrarily setting the motor constant. This motor model emulates the permanent magnet-type sync motors used in EVs and hybrid vehicles.

Fig. 7 shows a block diagram of the motor emulator. It is composed of an insulated bidirectional three-phase AC power supply, a series inductor and control circuitry. The insulated bidirectional three-phase AC power supply is operated with constant voltage output and outputs the motor inductor voltage, which is set proportionally to the set frequency according to a preset inductor voltage constant. The system measures the load current from the tested inverter and generates the impedance and inductor components of the motor with vector control to emulate the motor. A dynamo bench is unnecessary, allowing the installation area to be reduced considerably.

2.4 Charge–discharge Test System

In the development of a secondary battery, a charge-discharge system capable of controlling various charge-discharge modes is necessary to evaluate the reliability, lifespan

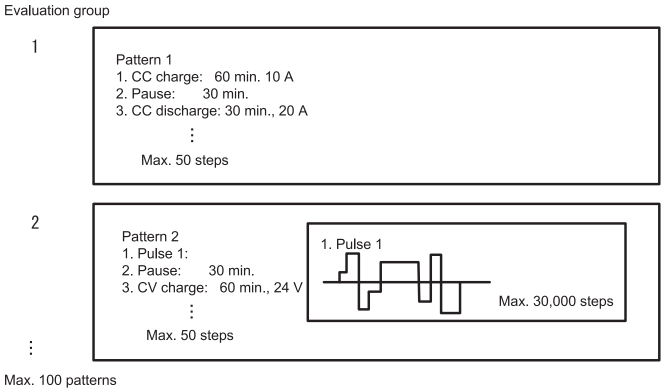

Fig. 8 Outline of a test pattern based on a hierarchical structure.

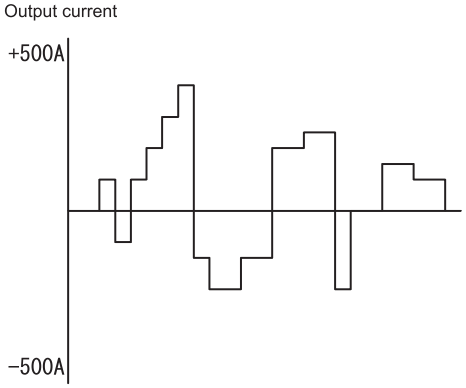

Fig. 9 Current waveform simulating inverter current during actual driving.

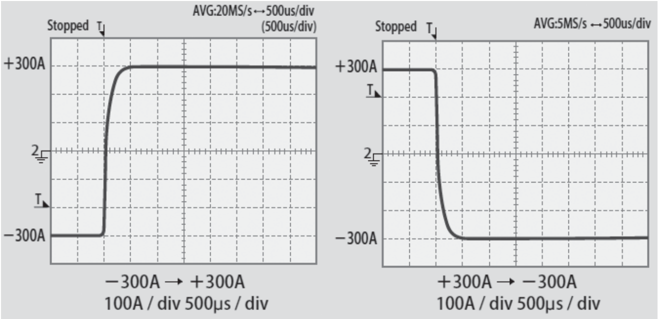

Fig. 10 Current waveforms during switching from discharge to charge and from charge to discharge.

and other characteristics of the developed battery. Charge-discharge test software adopts a technique capable of compiling testing patterns in hierarchical structures and programming repeat tests efficiently. The set testing patterns position the evaluation group in the top level of the hierarchy and can register up to 30,000 steps of pulse waveforms, including patterns in which the charge-discharge mode setting, time transitions and transition conditions can be registered in up to 50 steps and the driving patterns of actual vehicles (**Fig. 8**).

A variety of charge-discharge modes are available to program any kind of charge-discharge testing.

1) Constant current charge-discharge

This mode charges or discharges electricity at the set current value.

2) Constant current/constant voltage charge-discharge

This mode charges or discharges electricity at a constant voltage while charging or discharging electricity at a constant current value.

3) Constant power charge-discharge

This mode performs charge or discharge at a constant wattage.

4) Pulse charge-discharge

This mode performs charge and discharge using the same current waveform as that used during the driving of an actual vehicle.

This system's hardware has the following features:

1) The charge-discharge test system employs a high-precision, high-resolution 16-bit D/A converter for charge and discharge at high precision, high resolution and high setting accuracy.
2) To evaluate the secondary battery by reproducing the same inverter current waveform as the waveform during the driving of an actual vehicle (**Fig. 9**), this system employs bidirectional converter technology to implement performance that can smoothly switch the cross-points between charge and discharge and prevent overshooting or undershooting of the current waveform (**Fig. 10**).
3) A function for superposing AC current in the charge-discharge current is required to evaluate the performance degradation of the inverter due to high-frequency ripple current (a few to a few tens of kilohertz). A charge-discharge system of the 60 V type is capable of supplying a sine wave without zero-cross distortion up to 10 kHz as well as a flat response without gain deviation from DC to 10 kHz (**Fig. 11**).
4) The system also features environmental considerations thanks to its capability for the high-efficiency electrical power generation of discharge energy to the primary side

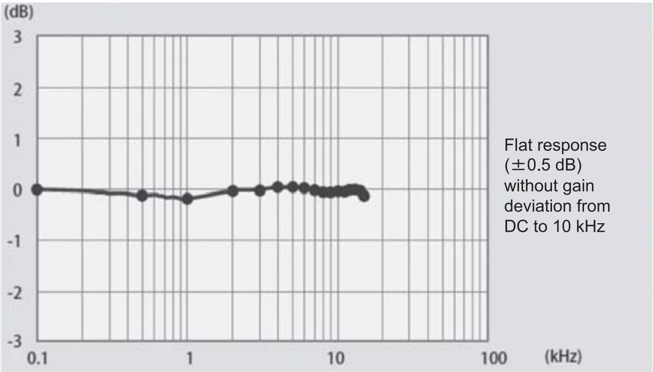

Fig. 11 Frequency vs. gain of ripple superposition.

of the power supply system.

3. Conclusion

Environmentally-friendly EVs are expected to be widely popularized more than ever in the future. We will develop more test system products by applying full digital design, reducing analog control circuitry and reducing price so that our systems can be the standards of the vehicle industry.

Author's Profile

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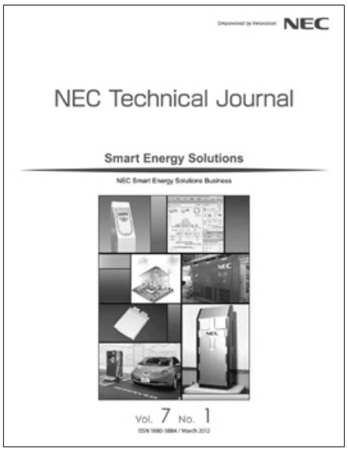

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