Development of Nickel Metal Hydride Batteries and Its Management System for Electric Vehicles

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Abstract

Beijing general research institute for nonferrous metals (GRINM) has focused on developing nickel metal hydride (Ni/MH) batteries for electric vehicles (EVs) and related key materials since 1990. Some kinds of batteries has already used in electric vehicles and finished a good demonstration driving to and fro between Beijing and Tianjing city in china 1999. And more, in order to meet to the requirement of a fuel cell hybrid electric bus, a 100Ah/384V Ni/MH high power batteries and its battery management system (BMS) has been developed in 2002, the specific power of the 100Ah battery has reach 300 W/kg and specific energy reach 60Wh/kg, 1/3C to 3C bench tests of the 100Ah/384V battery system show excellent power performance. At the same time in order to meet the requirement of a oil-electricity hybrid electric car, a D-size 8Ah/336V Ni/MH high power battery and its BMS also has been developed in 2002, the 8Ah batteries can discharge with 10C to 30C rate, shows its specific power 800W/kg and specific energy 50Wh/kg. It appeared that those two batteries system all has excellent performance for Evs application.

Keywords

nickel metal hydride batteries, battery management system, electric vehicles

1. INTRODUCTION

Compared with conventional electrochemical power sources (such as lead acid battery, nickel cadmium), nickel metal hydride (Ni/MH) batteries have superior characteristics with high energy density, high rate capability, tolerance to overcharge and overdischarge, and freedom from poisonous heavy metals, and so on, so they have been developed and commercialized to electric vehicles (EVs). Of all the battery systems, Ni/MH battery is regarded worldwide as the most technically advanced, and it is said that 2/3 market of secondary batteries for EVs would be occupied by Ni/MH battery before 2005 (14th International electric vehicles Symposium). Therefore, Ni/MH batteries can be considered as the most realistic secondary battery for EVs.

Beijing General Research Institute for Non-ferrous Metals (GRINM) has maintained a continuous effort of research and development in the field of nickel metal hydride (Ni/MH) battery materials and the batteries for electric vehicles during the last 15 years. Some kinds of Ni/MH batteries such as EV-150, EV-110, EV-80, EV-100, EV-45, EV-20, EV8 etc have been developed by GRINM, while the Ni/MH batteries is now ready in mass production, and a production line for the hydrogen storage material with capability of 200 ton/year and a production line for Ni $(OH)_2$ active material with capability of 60 ton/year have been built during 1996 one after the other. Ni/MH battery packs are already on the road. One of the electric vehicles equipped with Ni/MH battery of 24kwh class produced by GRINM, with a driving range of 225km per charge, and finished a journey to and fro between Beijing and Tianjin City by a single charge in 2000.

Furthermore, supported by the program of "Special Momentous Project for Electric Vehicles" of The National High Technology Research and Development Program (863 Program), GRINM has developed a 100Ah/

384V Ni/MH battery system and its battery management system (BMS) for the project of the "fuel cell hybrid electric urban bus", and developed a 8Ah/336V Ni/MH battery system and its BMS for the "EQ7200 hybrid electric car". Therefore, in this paper we will give some research results of the 100Ah/384V and D-size 8Ah/336V systems, and some performance of the two BMS.

2. MAIN TECHNOLOGY TOPICS

Batteries for EVs should meet the demand of supporting and feedback high power, which is requirement during the EVs startup, accelerating, making the grade and regenerating brake etc. the state of charge (SOC) is usually during 0.2-0.8, according to the working condition for EVs, in general, the EVs, especially hybrid electric vehicles (HEVs) battery is required many characteristics as follows:

(1) Higher output power and regenerative power acceptance, High specific energy
(2) High durability and reliability including its capacity, internal-resistance, thermal characteristic, efficiency etc.
(3) Long service life (equal to HEV)
(4) Superior performance over a wide temperature range
(5) Small and light battery pack
(6) Low cost

Especially, it is demand that a high voltage battery pack system should be characteristic with hi-rate capability and hi-efficiency, and frequency pulse charge and discharge, and tolerance to abuse use etc., also there should be a hi-efficiency thermal management, and electric circuit protected and controlled BMS, battery should adequately consider its current density distributing and collecting current in its electrode.

According to consideration above, we have developed 30-100Ah series high power prismatic Ni/MH batteries by the technology of a slurry negative electrode and a foamed nickel electrode for the "fuel cell hybrid electric city bus", and have developed 6.5Ah-8Ah (D-size) and 11Ah (F-size) high power Ni/MH batteries by the dry-preparation electrode technology for "EQ7200 hybrid electric car".

3. PERFORMANCE OF THE BATTERIES AND BMS

3.1 Cells and battery packs

Tested by the China National 863 EVs Battery Test Center, all performances of the prismatic Ni/MH batteries (100Ah) have meet the requirements of the contract and the requirements of the "Test Criterion for High Power Battery". The test results shown that the specific energy of 100Ah/12V module can reach 55Wh/kg, and the specific power can reach 300W/kg. Bench tests by the department of automotive engine of the Tsinghua University has shown that the 384V batteries system characterizes excellent Charge and discharge performance, the efficiency of 1C charge/discharge can attain to 96% at room temperature, and the temperature of the all cells of the 384V battery pack are all under28℃ during the course of the charge and discharge. The Figure 1 to Figure 9 given a outline of the characteristics of the 384V/100Ah battery pack.

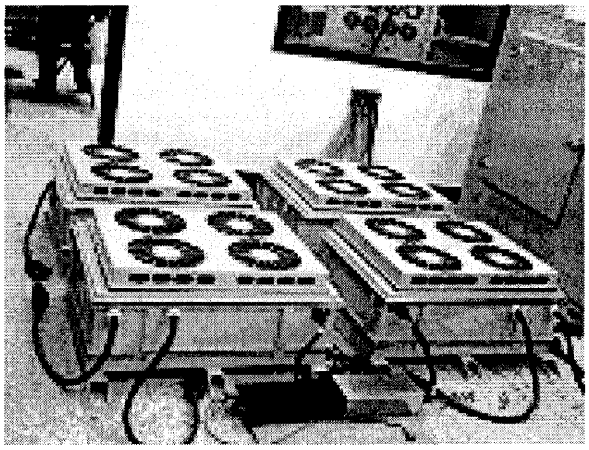

Fig. 1 Thermal management trunk for 384V Ni/MH battery pack

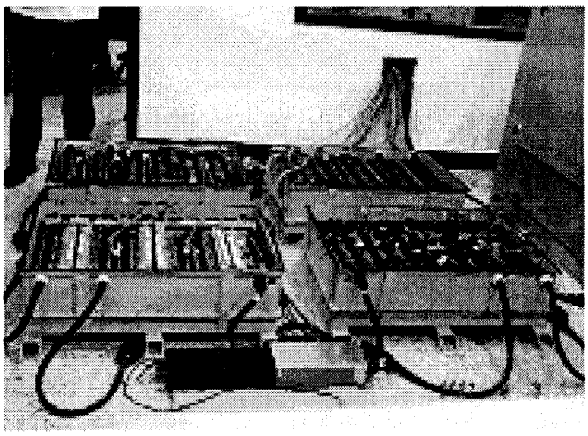

Fig. 2 384V Ni/MH battery pack

Fig. 3 384V Ni/MH battery pack assembled on the chassis of the bus

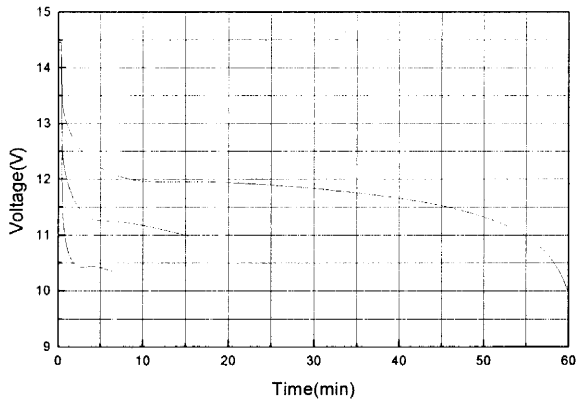

Fig. 4 Discharge curves of 12V/100Ah at 1C, 2C and 3C

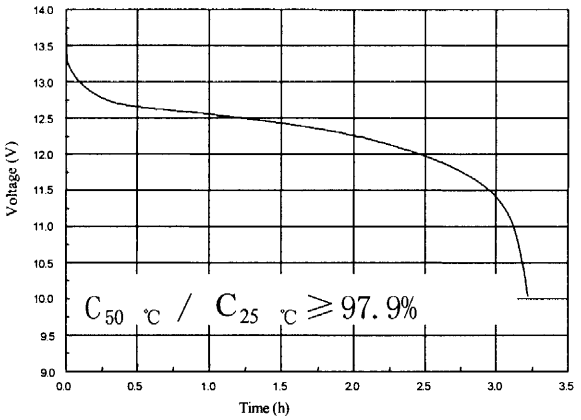

Fig. 5 Discharge curve of 12V/100Ah at 50℃, 1/3C

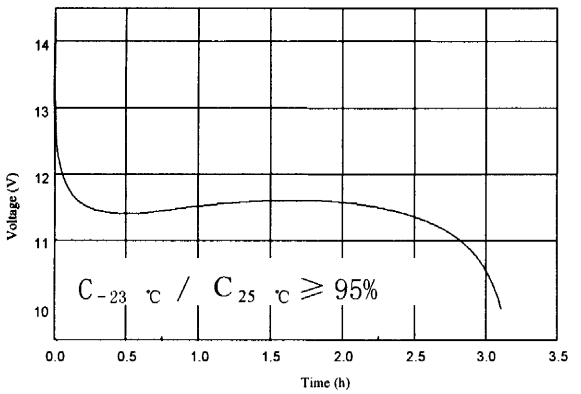

Fig. 6 Discharge curve of 12V/100Ah at -23℃, 1/3C

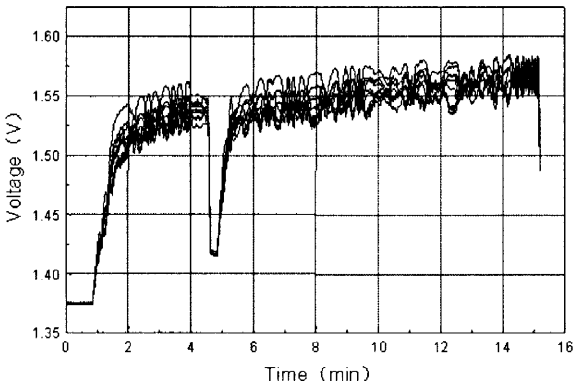

Fig. 7 120A charge curves of 12V/100Ah at 0.75SOC

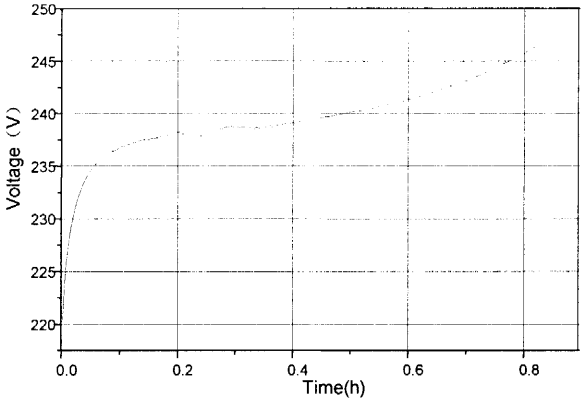

Fig. 8 1C charge curves of 192V/100Ah

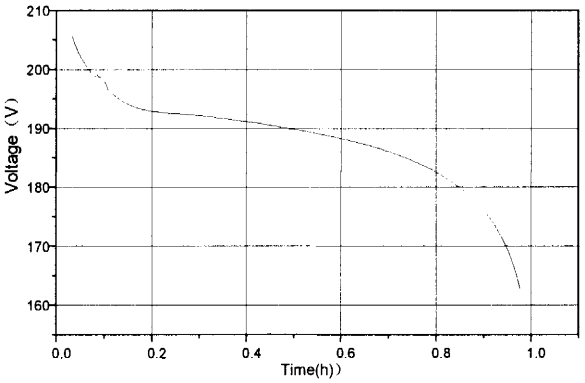

Fig. 9 1C discharge curves of 192V/100Ah

At the same time, 336V/8Ah (D-size) cylindrical high power Ni/MH battery pack for the "EQ7200 hybrid electric car" has also finished by GRINM, and its performance, which is tested by China National 863 EVS Battery Test Center (Tianjin City), are shown that the results meet the requirements of the contract and the requirements of the "Test Criterion for High Power Battery" of the "Special Momentous Project for Electric Vehicles". The test results shown that the specific energy of 12V/8Ah module can reach 50Wh/kg, and the specific power can reach 800W/kg. Some of the characteristics of the 8Ah (D-size) high power battery may be shown as the Figure 10 to Figure 18 as follows.

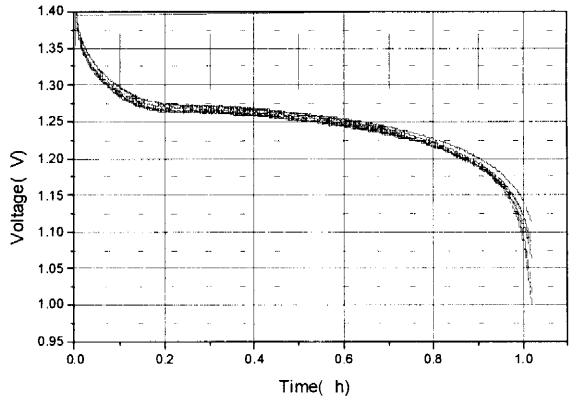

Fig. 10 Charge curves of 12V/8Ah at 1C

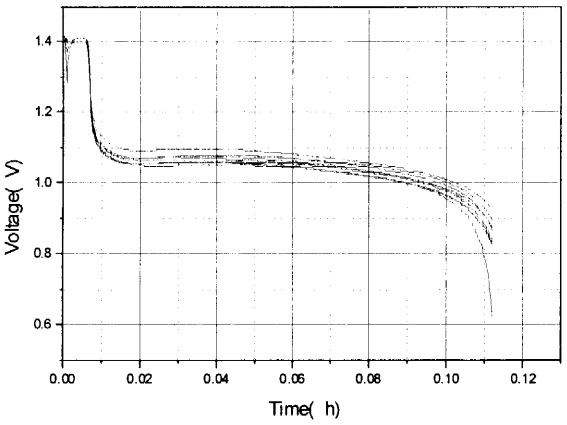

Fig. 11 Charge curves of 12V/8Ah at 10C

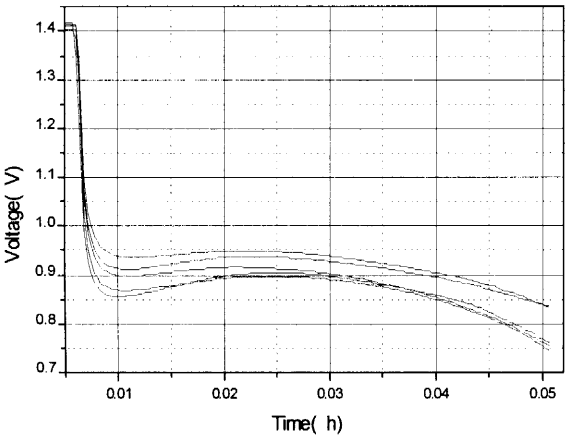

Fig. 12 Charge curves of 12V/8Ah at 20C

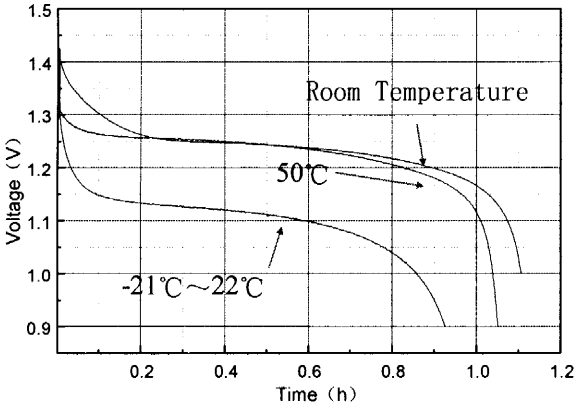

Fig. 13 Temperature characteristics of the 8Ah battery at 1C discharge

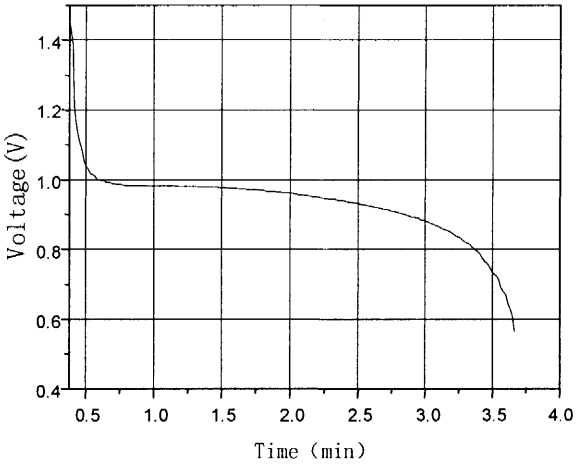

Fig. 14 20C discharge curve of the D-size 7Ah battery

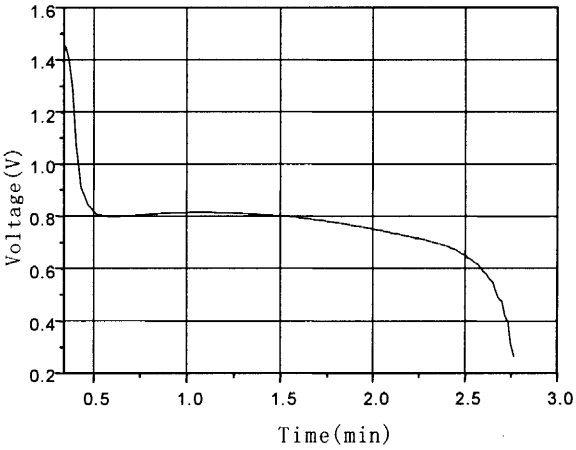

Fig. 15 30C discharge curve of the D-size 7Ah battery

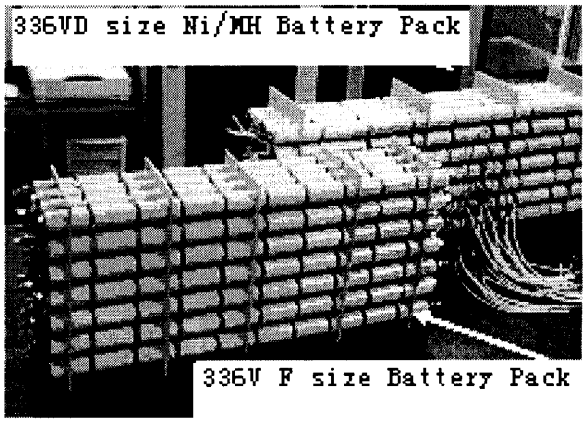

Fig. 16 336V Ni/MH battery pack (D-size and F-size)

Fig. 17 Bench test for the 336V/8Ah Ni/MH battery pack

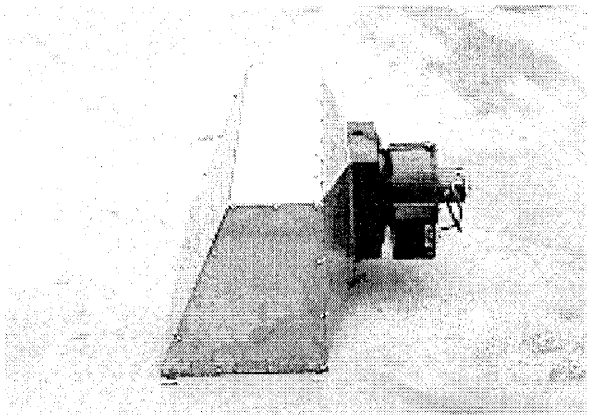

Fig. 18 Thermal management trunk for the 336V/8Ah Ni/MH battery pack

Some other batteries, which developed by the similar technology, are shown as Figure 19 and Figure 20 as follows.

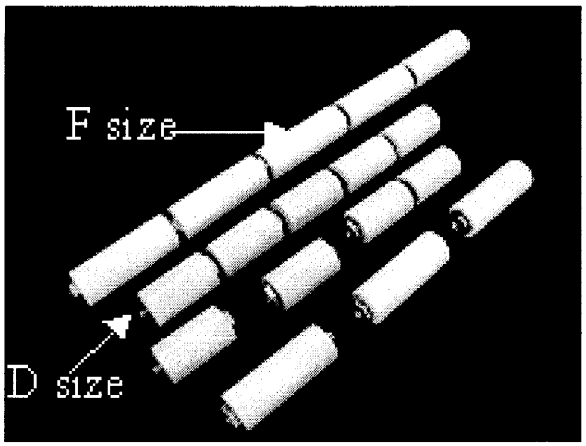

Fig. 19 11Ah and 8Ah Ni/MH cells

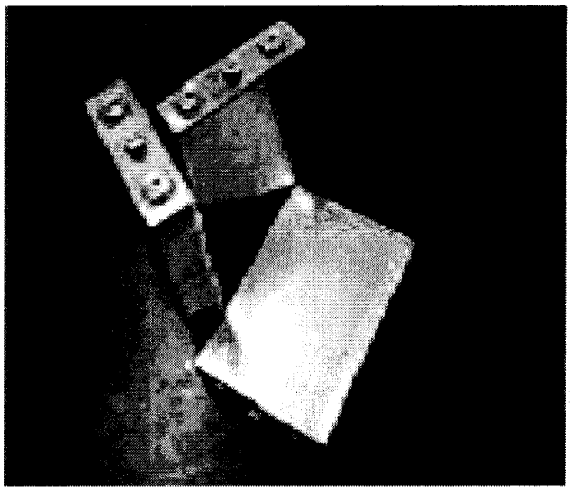

Fig. 20 The prismatic Ni/MH batteries developed by GRINM

3.2 Battery management system (BMS)

As battery performance depends on temperature, battery state-of-charge (SOC) and state-of-health (SOH), it is essential to measure or estimate these properties to guarantee full functionality of electrically powered components, for triggering means to keep the battery in its best operational condition, and for early detection of limited battery functionality. Battery monitoring allows for best use of the capability of a battery of given size, to guarantee power supply for high-reliability devices, and for replacement strategies [Meissner et al., 2001], further, the BMS should automatically limit battery discharge below a predetermined minimum level. The charger system should include equipment to maintain each module in the battery pack at equal temperature and within the allowed temperature range of the battery throughout each charge-discharge cycle.

In the work of this paper, the BMS has fabricated by a type of a configuration of the toy bricks, and its main features are:

(1) The BMS is composed of main controlled box, assistant controlled box, double CAN, and a LCD display box

(2) The measure error for the current and voltage are less then 0.2%, the measure error of the SOC is less then 8%.

(3) Easy to expansive to meet the requirements of all kinds of batteries for its configuration of the toy bricks type

(4) Function of evaluation of battery temperature, battery performance on charge and discharge, battery system voltages, and the evaluation of telltales, and diagnosis for trouble of the battery.

(5) Tolerance to electromagnetic wave disturbing by the environment of the EVs reliably.

(6) Protection the battery system from troubles

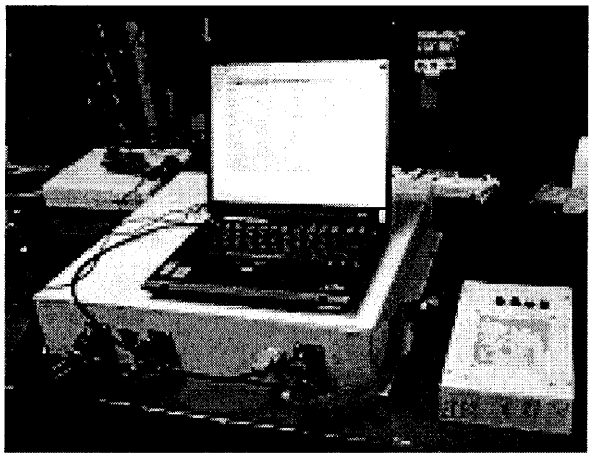

Fig. 21 Monitoring box and main controlled box of the BMS

Fig. 22 Voltage, temperature, SOC and SOH measured by BMS

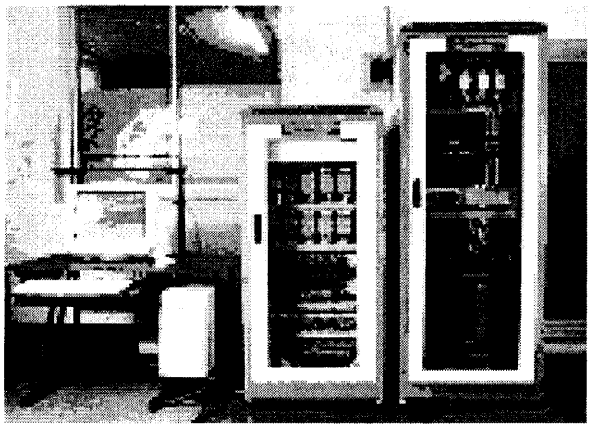

Fig. 23 Simulation equipment for the test of the battery pack

Fig. 24 Simulation equipment for the test of the battery pack

Fig. 25 EQ7200 hybrid electric car

4. CONCLUSION

(1) 6Ah, 8Ah, 11Ah, 30Ah, 50Ah, 70Ah, 100Ah Ni/MH batteries for EVs have been developed by GRINM, the test results by the National 863 Test Center shown the batteries excellent performance.

(2) The specific power of cylindrical Ni/MH battery (example: D-SIZE 8Ah/12module, specific energy of 50Wh/kg) reaches 800w/kg, and the specific power of the prismatic Ni/MH batteries (example: 100Ah/12 module, specific energy of 55Wh/kg) reaches 300W/kg.

(3) 384V/100Ah Ni/MH batteries system and its BMS has been tested for the fuel cell hybrid bus. And 336V/8Ah batteries system and its BMS also has been tested for the EQ7200 hybrid electric car, those two batteries systems and related BMS are all shown excellent performance.

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