ISSN 2032-6653

R&D of the Advanced Electric Vehicle at CATARC

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The breakthrough of key technology on battery electric vehicles is critical to of hybrid and fuel cell electric vehicles. This paper introduces the technical configuration of the new advanced electric vehicle and design of lightweight vehicle and integrated assembly. The Electric Vehicle developed at CATARC acquires many creative results, such as control strategy of vehicle, CAN Bus technology, heat management system of lithium-ion battery pack, fault diagnosis, safety management for high-voltage system and body comfort control. Also, this paper evaluates the vehicle performance and defines the technical scheme by using simulation tools. Simulation results are also validated by vehicle test. At last, the test results on the performance of electric vehicle are systematically introduced.

Keywords: Battery Electric Vehicles; Distribution Control System; Double Bus; High-Voltage Safety; Integrated Assembly; Battery Thermal Management

1. INTRODUCTION

Electric vehicles contain electric motor and drive, traction battery and its management system, etc. Many technologies of battery electric vehicles are the basics of hybrid and fuel cell electric vehicles. Successful experiences indicate that the companies such as TOYOTA and GM which have the most advanced technology on hybrid and fuel cell electric vehicles have advanced technology on battery electric vehicles. The key technologies on battery electric vehicles are critical to hybrid and fuel cell electric vehicles.

At the goal of innovation of science and technology and industrialization, comprehensive and systematic R&D of the advanced battery electric vehicle was carried on at CATARC. The emphases are design of weight reduction, integrated assembly, distribution control system based on double bus, battery heat management, fault diagnosis, high-voltage safety management, recording and analysis of the data of fleet vehicles, and supervising management system based on wireless telecommunication technology, etc.[1].

2. VEHICLE CONFIGURATIONS [2]

The technical configuration of the advanced electric vehicle is described in Fig. 1.

It can be seen that research of new type battery electric vehicles is system engineering on complete vehicle development [3]. It emphasizes on sustaining constructing on platform supporting research and development as well as focuses on the field of advanced automotive electronic technology. It not only carried out technology innovation of complete vehicle design, but also developed intelligent supervising management system based on wireless long-distance communication technology.

2.1 Design for Weight Reduction

Weight Reduction is always an important research content of auto technology, and the problem stands out. Through analyzing vehicle using condition and requirement, we can optimize the parameter of the voltage and capacity of battery, requirement of power , speed and torque of motor, complete vehicle performance, traction battery and motor were chosen accordingly.

We reduce the weight of electric drive assembly and on-board energy storage system for configuration optimization that includes integration and modularization design among motor, motor drive, powertrain, cooling system, air condition, brake vacuum system, and also includes integration on on-board energy system which is composed of battery module, management system and on-board charger. The electric vehicle used lightweight material, for instance, in frame of battery pack, plates of pack, and wheel hub. Fig. 2 is the integrated electric drive assembly.

CAD techniques are used to perform finite element analysis on body bearing frame pieces, achieve optimization of configuration by combining calculation and test.

2.2 Distribution Control System Based on Double Bus

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ISSN 2032-6653

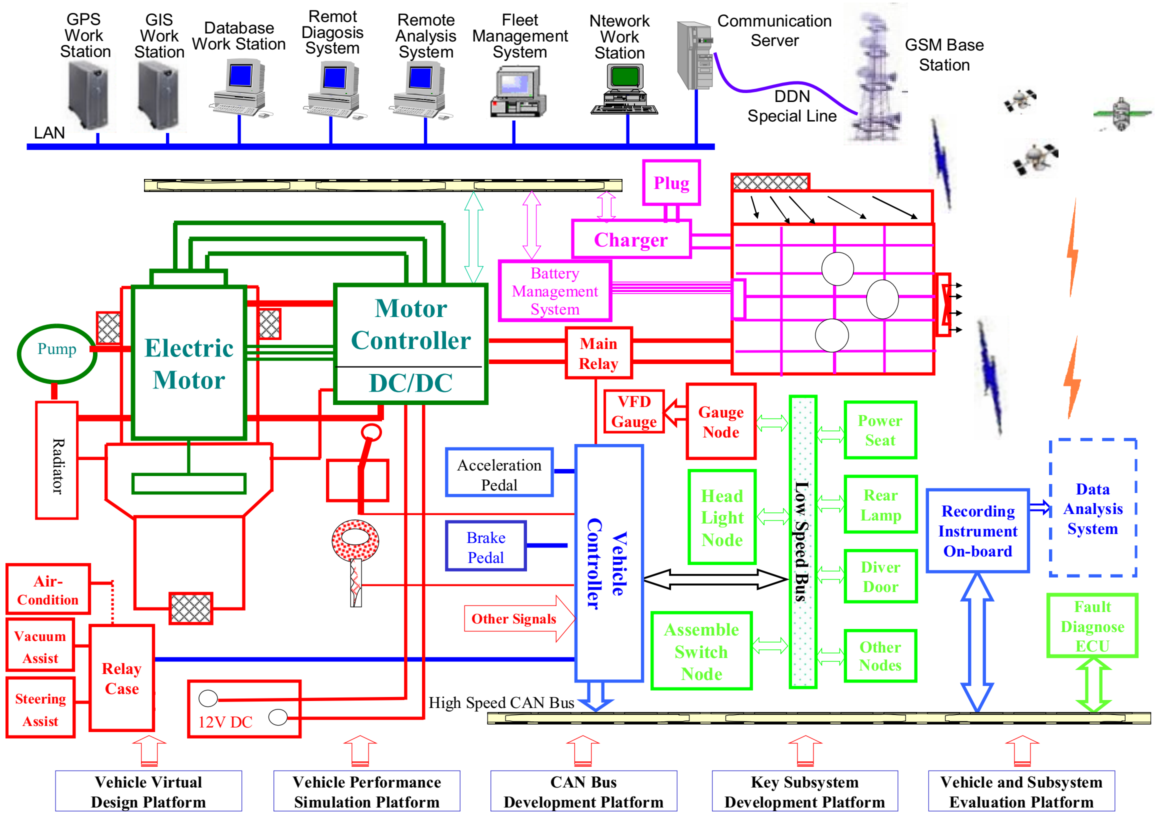

Fig. 1 Technical Configuration of advanced electric vehicle

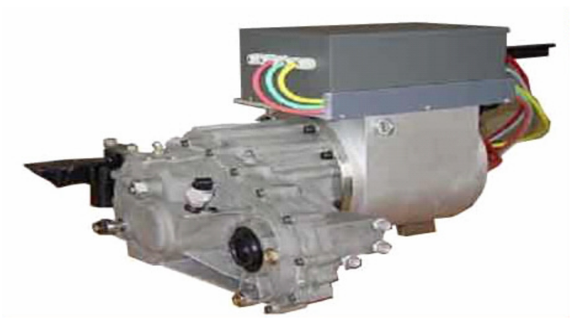

Fig. 2 Integrated Electric Dive Assembly

Vehicle control system of the advanced electric vehicle is network configuration that have two buses, which are high speed CAN bus in powertrain and low speed bus in body system. Each node in high speed CAN bus is the ECU of each subsystem. Low speed bus sets node according to physical position. The principle is area autonomy based on space position. Electric components were linked nearby to ECU on one node, and communicated with the bus through ECU. Low-speed bus had two choices, one is low speed CAN bus, the other is LIN bus.

In the former one, the configurations of both high-speed CAN bus and low-speed CAN bus are independently controlled. We can build high speed CAN bus according to ISO11898 and J1939 and J2284 [4], and build low speed fault tolerant CAN according ISO 11519-2 [5]. Node control unit controls local executing components according to local sensors and signals from CAN bus, while transmitting the signals that needs to be shared with other nodes to CAN bus.

Fig. 3 is the vehicle control net configuration used in advanced electric vehicle, and control system is double bus net configuration, i.e. high speed CAN bus in driving system and low speed bus in body system. Fig. 4 is the network topology in body comfortable system.

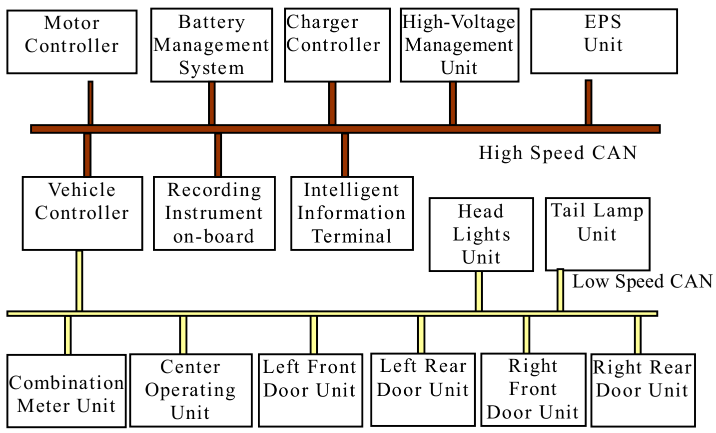

Fig. 3 Vehicle Control System Configuration

ISSN 2032-6653

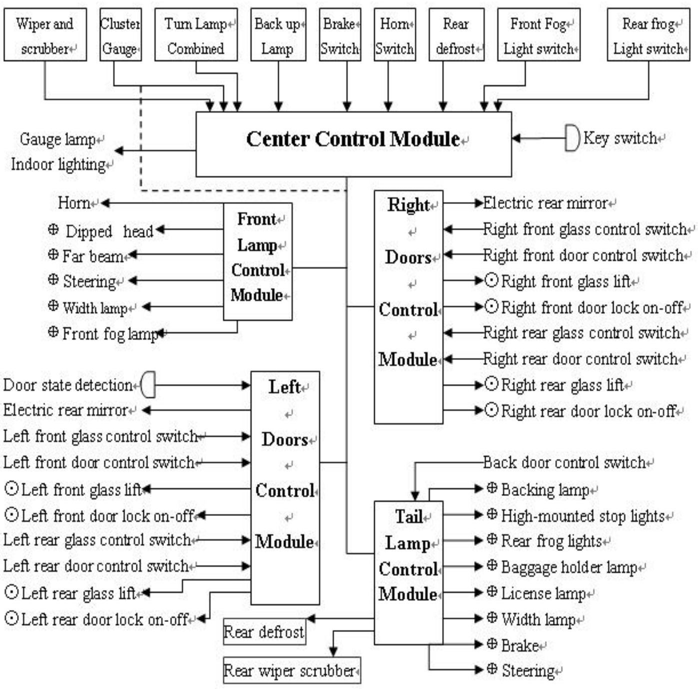

Fig. 4 Network Topology of Body Comfortable System

Distribution control system based on double bus not only solved the problems such as complex circuitry and wiring harness, but also improved communication and resources sharing ability, at the same time, it supports X-By-Wire technology further.

2.3 Fault Diagnosis and Safety Management Technique for High-Voltage System [6]

An important character of battery electric vehicles is high voltage and large current. Electric vehicles, with similar performance as traditional vehicles, have higher voltage than safe voltage, while the impedance is very small. The current may achieve even hundreds amperes, and instantaneous short circuit current can increase several times. For these reasons, design of high voltage power system must consider the safety of people and vehicle.

In the development of new type electric vehicle, we studied safety control of high voltage and protection strategy, including condition analysis before switching on high-voltage system, prevention while instantaneous crash, high-voltage system real-time supervising in operation, management strategy considering kinetics safety and electric safety. The advanced electric vehicle was equipped with the Diagnosis and Safety Unit (DSU) specially designed. The unit's major function is state inspect and malfunction diagnosis for each tache of electric car drive chain, then start correspond function of strategy in invalidation and safe prevention to insure the safety and reliability [7]. Fig. 5 shows the structure of Diagnosis and Safety Unit.

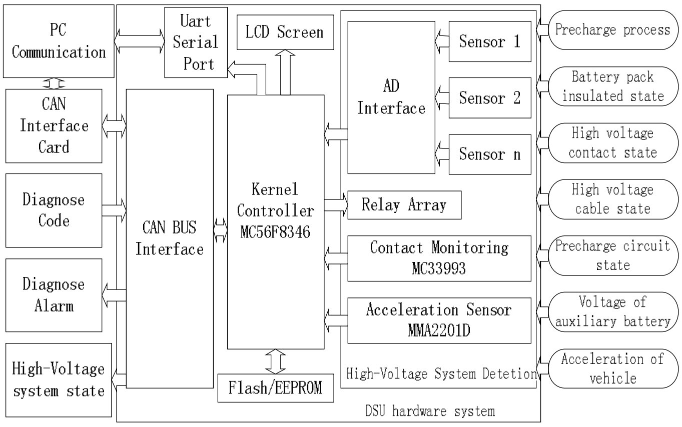

Fig. 5 Diagnosis and Safety Unit

2.4 Battery Thermal Management System

Condition of battery pack directly influenced the performance such as acceleration characteristics, cruising range, regenerative braking, etc. The cost and cycle life of battery influence the cost and reliability of vehicle. Battery got heat during charging and discharging because of battery ohm polarization, electrochemistry polarization, electrochemistry reaction and overcharge oxygen complex. The heat can do harm to electrode and septum materiel, which can influence electrode performance and life, and then cycle life, efficiency characteristics, capacity, safety and reliability[8]. Thus it is very important to control overheat of modules in pursuit of normal use of great capacity battery. Another problem, which influences the module that is composed of many cells, is that batteries in the pack differ from each other on temperature, which will lead different state of charge, and then it leads imbalance among cells, which reduces the capacity and life of the modules. We designed Battery Thermal Management System (BTMS), by the system battery working in the best temperature range, and keeping temperature balanced. BMTS had some functions, such as cooling the battery when the ambient temperature is high, and heating when cold to keep the battery in the best condition, even BTMS can exhaust automatically the dangerous gas from battery pack.

Fluid analysis software -FLUENT and general finite element analysis software -ANSYS are used to analyze gas flow condition in the pack, such as distribution of gas speed and temperature, in the meantime lots of research tests are performed. Many parameters are optimized based on influence factors, such as battery pack size, battery layout in battery pack, pack material, structure of cooling system, and control strategy of actuator for forcing ventilation. For ensure the design of battery thermal managements, the hardware-in-loop simulation test was performed. At the temperature of －20℃、20℃、

ISSN 2032-6653

35℃, the battery performs charging and discharging in simulating vehicle ECE city drive cycle ,and temperature in the pack stayed in the best range. Temperature difference among all the cells is less than 3℃.

2.5 On-line Supervising and Calibration Technology

On-board recording instrument based on multi communication ports is very important to vehicle powertrain system matching and operation analysis. On-board recording instrument should record the information of vehicle operation, motor state, battery state, etc. Data analysis software related to electric vehicle carried out data rerunning and analysis, including statistic analysis.

For the convenience of matching and optimization, the ECU of each subsystem supervised and calibrated data on-line. Controlled objects and management strategy were parameterized, and could be supervised and calibrated on-line through communication ports.

2.6 Vehicle Intelligent Management System

During calibration, testing and demonstration, we introduced GPS, GSM/GPRS and GIS to intelligent management such as communication and dispatching and tracking. Through vehicle intelligent monitoring platform, on-board terminal transmits vehicle information to the central monitor management center, which makes it easy to manage the fleet. In the meantime wireless remote testing, calibration and analysis can also be achieved. Developing further can achieve remote diagnosis and assistance.

3. SIMULATION AND TESTING RESEARCH

3.1 Simulation and Validation

Power performance, economic performance and cost of battery electric vehicle can be influenced by many factors, such as nominal power and peak power of motor, rated speed and highest speed of motor, high-efficiency area distribution of motor, battery capacity and quantity. Vehicle performance was evaluated by simulation software–CRUISE. Combining the design goal of complete vehicle, the basis technology and the requirement of main capability index are decided, such as high-efficiency area distribution of motor, peak power of battery, and so on. Fig. 6 shows the process of some parameters in Tianjin city drive cycle. We can get some key data such as maximum discharge current and variation of SOC, and then we can work out the cruising range after a complete charge in Tianjin city drive cycle (Table 1 shows the result). Fig. 7 shows the operating point distribution in Tianjin city drive cycle, and we can get the energy consumption distribution. In the meantime, it can give the special requirement of high-efficiency area distribution of motor and optimize index of vehicle economic performance.

Table 1 is the comparison between test results and simulation results. It can be seen that power performance simulation result is similar with test one, but cruising range in real city cycle is less than simulation result by 7%. The main cause is that cells in the pack are not balance, and it is difficult to model exactly in simulation.

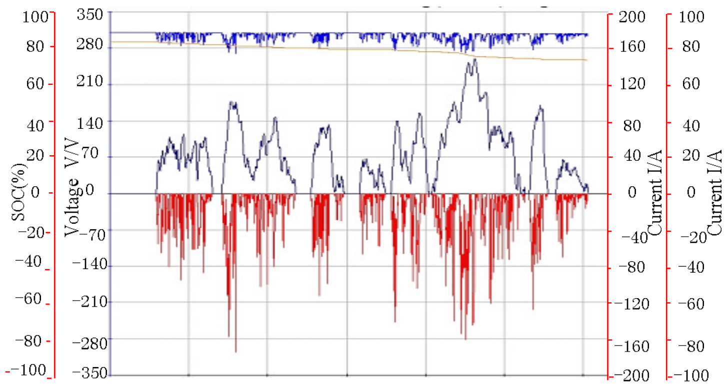

Fig. 6 Running Parameter in Tianjin City Drive Cycle

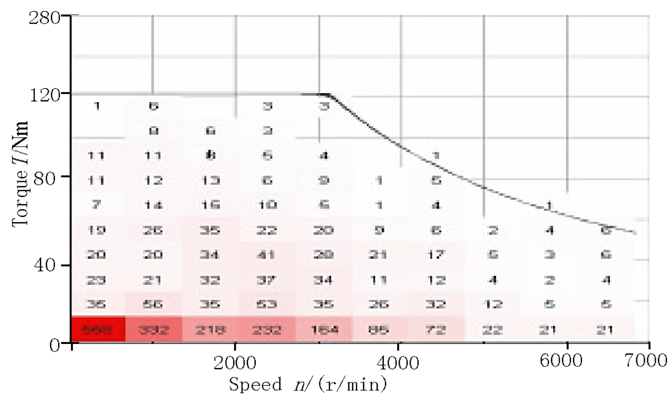

Fig. 7 Distribution of Motor Operation Point

Table 1 Comparison between Test and Simulation Results

Performance index		Test Result	Simulation Result
Top Speed (km/h)		123.6	125
Acceleration (s)	0-50	6.3	6.8
	50-80	7.4	6.8
	0-100	17.8	17.8
Rang(km)	40km/h constant speed	252.9	255
	City cycle in Tianjin	172	185

3.2 Test Evaluation

3.2.1 Power Performance Test

ISSN 2032-6653

The specifications for the battery electric car and its prototype gasoline car are shown in table 2.

Table 2 The specifications for BEV and Prototype vehicle

	BEV	Prototype Vehicle
Vehicle Type	Sedan	
Curb vehicle weight	1200 kg	980 kg
Gasoline ICE	--	1.3 liter
Power(ICE/Motor)	45 kW @3600~9500rpm	63kW@6000rpm
Battery type	Lithium-ion	--
Voltage / Capacity	288 V / 80Ah	--

Table 3 shows the comparison between the battery electric car and its prototype gasoline car. We can see that acceleration performance dropped in 0~50 km/h and 0~100km/h test, but other performance index meets technique requirement of prototype car, and the direct gear acceleration is much better than prototype.

Table 3 Power Performance Comparison between Electric Car and Prototype

Testing item	Requirement of Prototype	Testing result of electric vehicle
Top speed after 30 min. (km/h)	——	100
Starting accelerating time from 0 to 50 km/h (s)	5.3	6.3
Accelerating time from 50 to 80 km/h (s)	——	7.42
Starting and gear shift from 0 to 100 km/h (s)	≤17	17.8
Direct gear Accelerating time from 50 km/h to 100km/h (s)	≤21	16.1
Maximum gradeability	≥30%	>30%

3.2.2 Economic Performance

Table 4 shows comparisons on energy consumption and economic performance between electric vehicles and gasoline vehicles at speed of 40 km/h and in city drive cycle. It is evident that economic performance of electric vehicle is much better than of traditional gasoline vehicle.

Table 4 Comparisons on Economic Performance

Testing Items		Results	Total Expenditure (RMB yuan)
40km/h Constant Velocity	Energy Consumption of Prototype Vehicle (L/100km)	5	21.00 Gasoline: 4.2 RMB / L
	Energy Consumption Of BEV (kWh/100km)	9.28	3.71 electricity: 0.4 RMB / kWh
Comparisons Result			Save 17.29 RMB /100km
Running in City Drive Cycle	Energy Consumption of Prototype Vehicle (L/100km)	7.43	31.20 gasoline:4.2 RMB/ L
	Energy Consumption Of BEV (kWh/100km)	16.29	6.52 Electricity: 0.4 RMB / kWh
Comparisons Result			Save 24.68 RMB /100km

3.2.3 Other Tests Required By Standard

According to test standard, we tested for safety, noise, braking (fully loaded), and smoothness (fully loaded) and so on, Table 5 and 6 show part of results, and the index meet the integral vehicle requirement.

Table 5 Noise

Testing items	Technical requirement	Result
outside car when acceleration dB(A)	74	68.9
inside car when constant drive dB(A)	----	62.2

Table 6 Braking

Testing items		Technical requirement	Result
50km/h, fully loaded	Distance (m)	≤20	13.8
	Braking stability	Less than 30 meters	Less than 30meters
Parking braking (Grade ratio %)		20%	Check out

3.2.4 Electromagnetic Compatibility Test

We tested electromagnetic compatibility according to national standard of China-GB/T 17619-1998 "Motor Vehicle Electric Apparatus Electro-magnetic Radiation Anti-interference Limit and Measurement". The results show that main control units such as vehicle controller and battery management system meet the requirement of national standard at electro-magnetic radiation anti-interference. Controller still work well when we built a 24V/m interference field among 27MHz~900MHz frequency band by free field method. Test object still worked well when the interference field was 50 V/m and 70 V/m among 27MHz~900MHz, and we can see the excellent

ISSN 2032-6653

anti-interference ability. Complete vehicle was tested according to GB/T 18387-2001-"Electric Vehicle Electro -magnetic Radiant Intensity Limit and Measurement Band 9kHz~30Hz" and GB/T 14023-2000-"Engine Light by Spark Radiation Interference Characteristic Limit and Measurement ", and radiation interference characteristic meet the requirement among the bandwidth 9kHz~1GHz. Fig. 9 is plane polarization peak scan process at vehicle left side. We can see that measure data is much lower than standard limit.

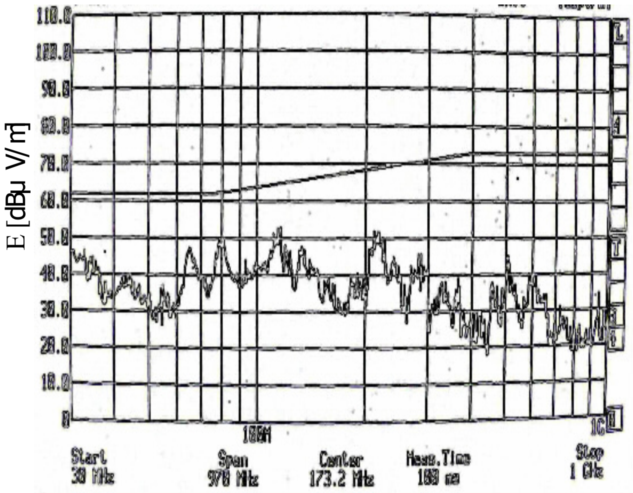

Fig. 9 Plane Polarization Peak Scan Chart

4. CONCLUSION

Research and development of the advanced electric vehicle at CATARC embodied innovation of science and technology, and gained several creative achievements, such as lightweight design and integrated assembly, battery heat management system, and fault diagnosis and safety management for high-voltage system, body comfort control, etc.

The key technologies involved in battery electric vehicles are common issues that hybrid vehicles and fuel cell vehicles must confront. The breakthrough of key technology on battery electric vehicles is critical to hybrid and fuel cell vehicles. Because of environmental protection characteristics and universality of energy sources, battery electric vehicles will become of mainstream in future of transportation.

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BIOGRAPHIES

Chunming Zhao was born in 1972, and received the M.S. degree in mechanical engineering from Tianjin University in 1997. He is a senior engineer at China Automotive Technology and Research Center, and Vice Chief Engineer of Electric Vehicle Research Center, CATARC. Main research is R&D on EV and HEV, evaluation method research on EV and HEV, and standards establishment on EV and HEV of China. Chunming Zhao is a member of National Electric Vehicle Standardization Technical Committee in China

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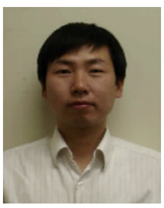

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ISSN 2032-6653

The World Electric Vehicle Association Journal, Vol. 1, 2007

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