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EV R&D Activities in Korea Electrotechnology Research Institute (KERI)

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Abstract

This paper introduces electric vehicle (EV) R&D activities in Korea Electrotechnology Research Institute (KERI) such as EV monitoring, charging infrastructure, charger, secondary batteries, power train, traction motor/drive and charging equipment test system.

Keywords: monitoring, charger, secondary battery, power train, traction motor/drive

1 Introduction

Korea Electrotechnology Research Institute (KERI), which is being sponsored by the Korean Ministry of Knowledge Economy (MKE), has been researching in the field of EV since 1993. KERI had developed the first EV in Korea for Dae-Jeon EXPO 93 in 1993.

This paper introduces activities of EV R&D in KERI such as EV monitoring for EV key parts, charging infrastructure with charger/IMS4EVC /BMS, fast/rapid charging system with CAN based communication, lithium secondary battery with high power density, electrical power train to analyse the characteristic of the main components (batteries, battery monitoring system, inverters, decelerators, and motors), induction motor/PM synchronous motor/its drive with high power density and charging equipment test system.

2 EV Monitoring

Recent battery technology makes EV as one of the hottest issues in automotive industry. However, the lack of information of the EV key parts such as electric propulsion motors, batteries, HVAC and drivers' charging patterns slow down the EV market growing [1]. Hence, Korean government is trying to push as fast as possible by launching EV pilot projects in JeJu island and in Chang Won city. The former one is dealing with the issues related with smart grid, and the other is for the issues of the EV monitoring with viewpoints of the followings.

- Energy efficiency of the main components such as batteries, inverters, and motors
- Drivers' charging pattern and operating behaviors
- Impacts of the electric energy charging on utilities
- Optimizations of charging infrastructures.

In the project 5 types of EVs are used with more than 60 charging spots including 11 rapid charging systems in the operating range of 35km.

EV monitoring system is shown in Figure 1. It is composed of driving behaviour monitoring system to monitor the vehicle's location and driving route and parts operation monitoring device to monitor the status of parts.

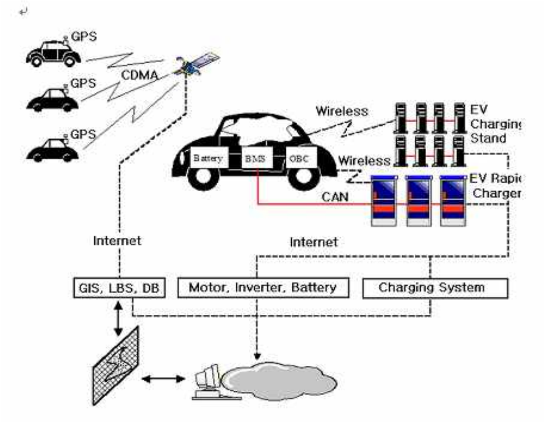

Figure 1: EV monitoring system

The sensor system is shown in Figure 2. It is monitoring the operating status of the inverter, motor, and auxiliary power.

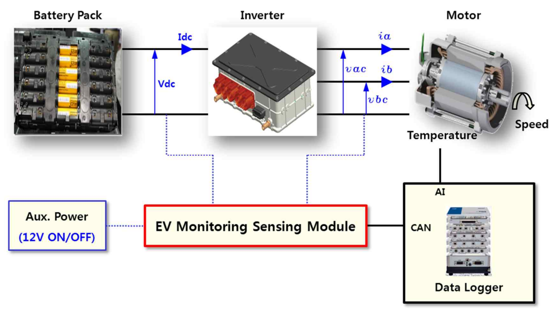

Figure 2: Data logger and sensor system

The developed analysis tool is illustrated as below Figure 3. For track of EV's movements, the analysis tool displays the path for the selected EV. Also the collected module status information data is drawn as a graph.

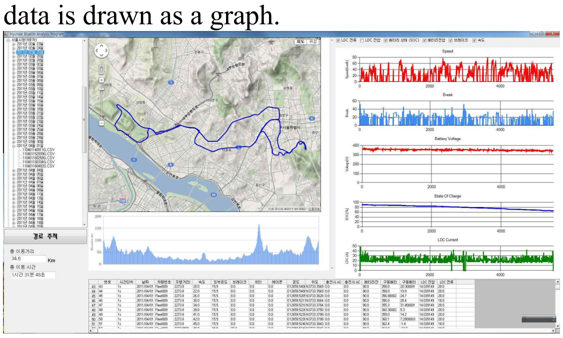

Figure 3: Developed analysis tool of monitoring data.

3 Charging Infrastructure

For implementation of the efficient charging infrastructure, KERI is continuing to develop the AC normal charger and integrated management system for EV charging stations. The charging infrastructure is divided into 3 components: Chargers, EV and Integrated Management System (IMS).

Chargers supply electric power directly to the electric vehicles. The developed AC normal charger is offering the following features [2], [3].

- Various methods to control the charger
- Bi-directional communications
- Compatible with IEC 61851
- Application of the power line communication
- Easy to apply for the other charging system

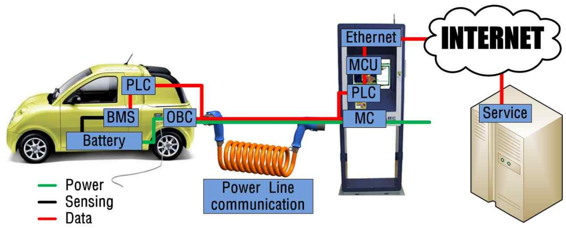

Figure 4: PLC communication between EV and charging stand.

Integrated management system gathers and manages all message transferred by AC normal chargers through internet. This system has following features:

- XML based-on protocol
- Real-time remote control
- Ubiquitous user interface

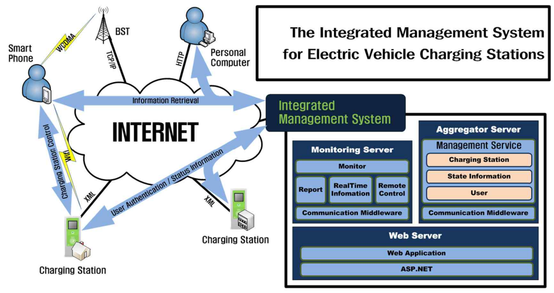

Figure 5: Integrated management system for EV charging infrastructure

To efficiently manage chargers, we defined five XML messages between chargers and BMS, as following.

- Periodic: This message delivers the charger status information to the IMS: i.e., the measured charger temperature, current, and voltage.
- Authentication: this message delivers the user's RFID tag information to IMS
- Start Charging: the message to inform the charging start
- Finish Charging: the message to inform the Charging finish
- Demand Response: after completing a

challenge received from IMS, charging stand reports the process results via the response message.

Figure 6 shows the screen that displays the real-time temperature data received from a charging stand. Also, we developed the IMS Program providing the easy charging stand control button.

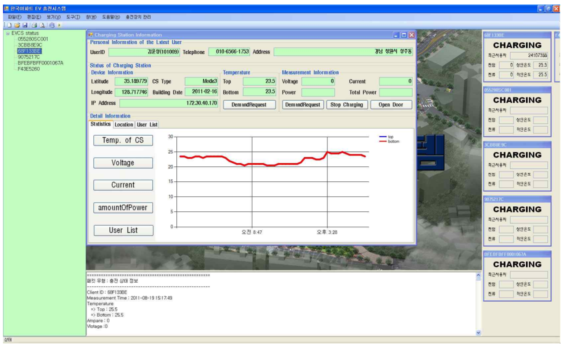

Figure 6: An example of IMS display

KERI is developing a system which is monitoring and controlling a charger on a development kit, instead of a smart phone, based on Windows Embedded CE 6.0, as shown in Figure 7.

Figure 7: Display screen of a charging status

4 Charger

KERI is focusing on high efficient fast off board charger for EV. For the charging high density Li based battery safely and fast, rapid charging system is using CAN based communication with vehicle controller.

It is achieved 94% of efficiency by applying KERI's high efficient converter technology and total size is greatly reduced.[4] [5].

Figure 8 shows the developed rapid charging system.

Also BMS simulator was developed in order to perform battery charging test with battery without any interface with vehicle charging controller. BMS simulator simulates exactly same function of vehicle controller for safe charging.

Figure 9 shows the battery charging procedure using 20kWh Li-FeO4 battery. It was measured 17 minutes from SOC 10% to 90% charging. The display of BMS simulator is shown in Figure 10.

Detail specification of developed rapid charging system is summarized as follows.

- Input: 3 phase 380Vac
- Charging power: 60kW
- Output voltage: 50Vdc~500Vdc
- Output current: 0A~150A
- Charging mode: CCC, CVC and combined
- Communication: CAN
- Charging inverter: modified resonant converter
- Charging time: 17 minutes for 20kWh battery/14 minutes for 16kWh battery

Figure 8: Rapid charging system (60kW)

Figure 9: Battery voltage variation during rapid charging

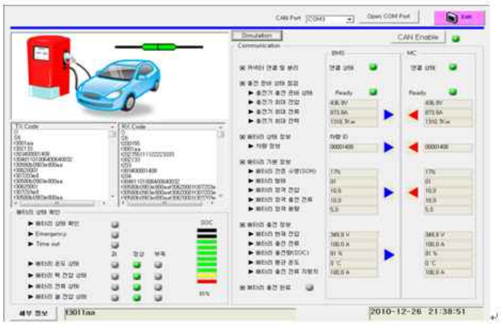

Figure 10: BMS simulator

5 Secondary Batteries

KERI is developing the core technologies of lithium secondary battery of new type electrode materials and electrolyte composition, and lithium air batteries etc. [6] [7].

For the battery of electric vehicle new electrode materials of high specific capacity and high density is researching to increase energy density of battery. Large capacity cylindrical type lithium secondary battery of 3.7 V 100 Ah for pure electric vehicle was developed together with a battery company(Suttong Co., Ltd.). Battery module of 8 unit cell of 3.7 V 100 Ah and BMS (battery management system) was fabricated and served a battery pack of electric vehicle of passenger car. 12 modules (96 unit cells) was used for a battery pack.

Performance evaluation and development of standardization of battery are also very important area of KERI. For the performance evaluation of battery the test facilities was developed and is using for the public service to give test results of electrical, mechanical and environmental performances. For the evaluation of properties of thermal runaway accelerated rate calorimeter (ARC) is using.

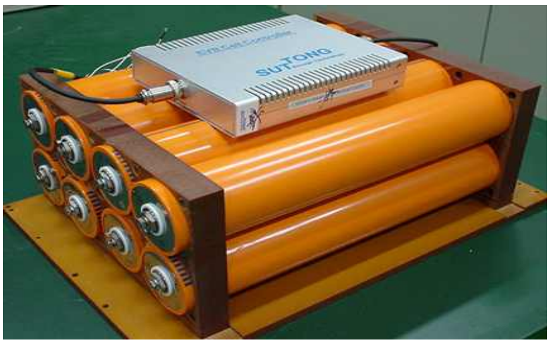

Figure 11: Lithium secondary battery module.

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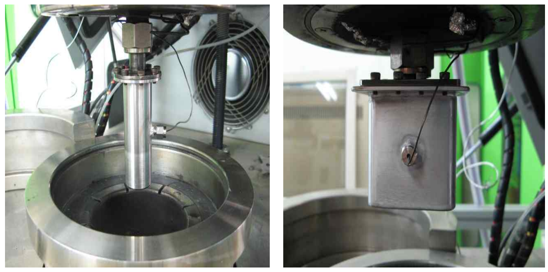


(a) Cylindrical (b) Prismatic

Figure 12: Battery holder for ARC experiment.

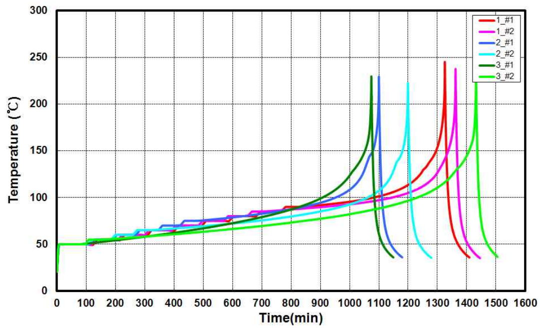


Figure 13: Typical experiment results of ARC experiment for charges batteries as the function of cell temperature and passed time.

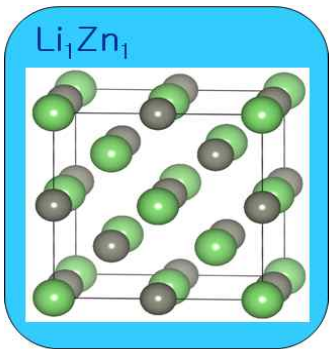


Figure 14: Known crystal structure of lithium-zinc intermetallic alloy.

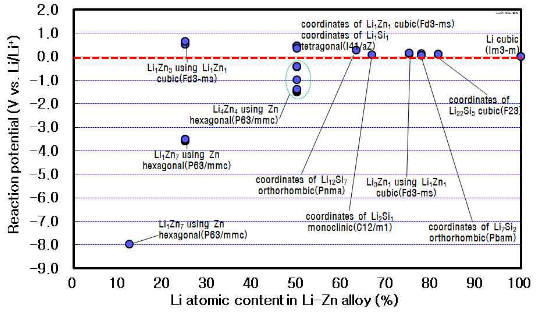


Figure 15: VASP based calculated electrochemical potentials of lithium-zinc intermetallics based on various crystal structural models.

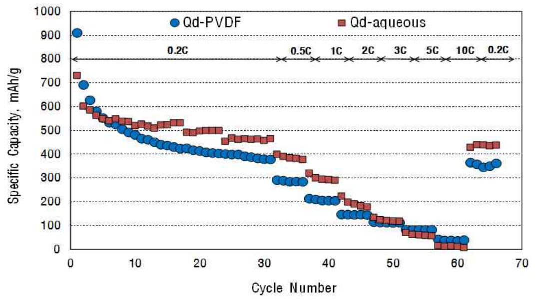


Figure 16: Specific capacities of Zn:In:Ni=90:7.5:2.5 (HTT 550℃)/Li secondary batteries with PVDF and CMC-SBR binders.

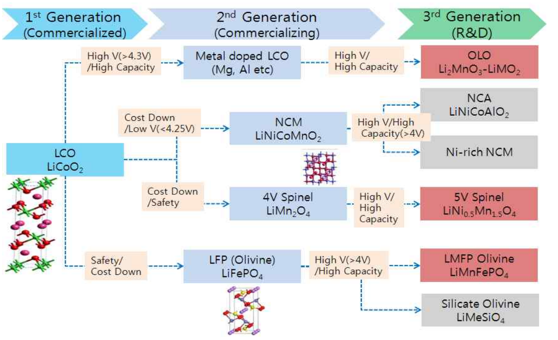


Figure 17: Performance advancement of cathode materials for lithium ion secondary batteries

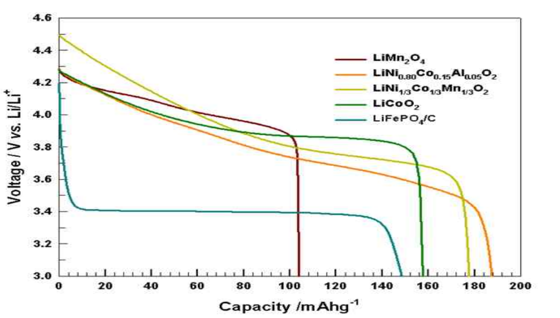


Figure 18: Typical potential behaviours of major cathode active materials for lithium ion secondary batteries

6 Power Train

In KERI, the test bed of electrical power train developed to analyze the characteristic of the main components (batteries, battery monitoring system, inverters, decelerators, and motors) in EV.

Figure 19 shows the test bed in constructing. Also turning ICE (internal-combustion engine) into EV is going to investigate the running characteristic of electrical power train and the regeneration braking characteristic. This is going to take a point as follows [8].

- To reduce the weight by applying the high density battery.
- To reduce the rebuilding cost.
- To increase the efficiency of the traction motor.
- To apply the transmission to improve the running characteristic or not.
- To apply the battery and super-capacitor hybrid system to improve the braking and the efficiency of energy in EV
- To analyze the main components in EV and recommend the requirements of the main component in order to run EV efficiently.
- To analyze the influence of the noise by the high voltage switching.

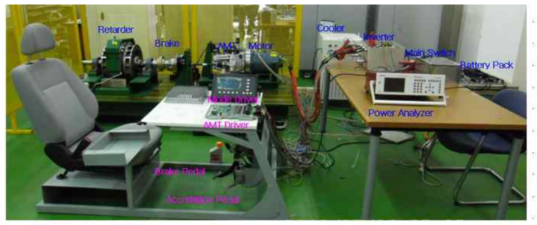
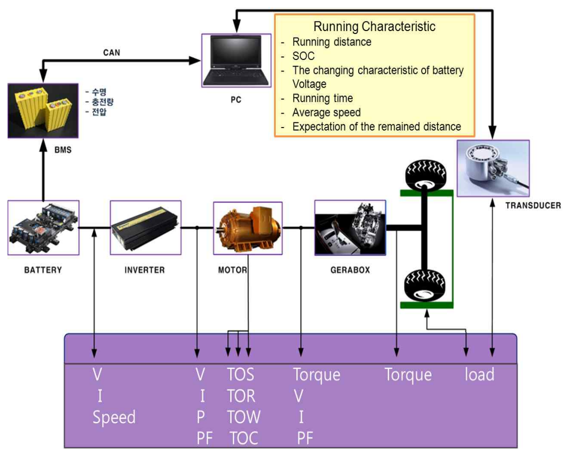
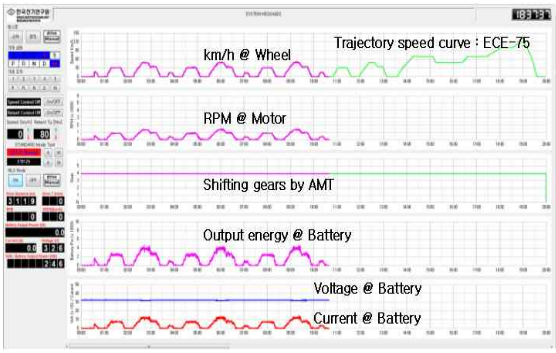


Figure 19: The configuration of test bed of electrical power train



(a) The configuration of test bed



(b) Measurement of ECE-75 mode test drive
Figure 20: Test bed of electrical power train

Figure 20 shows that the power train follows the speed curve of mode test ECE-75(Economic Commission for Europe) or FTP-75(Federal Test Procedure) while driving. The speed was automatically traced by PID control. At this point, the battery and the inverter's output energy was measured and compared with the mechanical energy at wheel. In addition, the hilling climbing force that is needed to drive the vehicle up a slope was applied to the train. It can be achieved by using the eddy retarder system with maximum braking torque 1650 Nm at DC 12V. And also, the optimal gear ratio could be known as the shifting gears of the train were controlled variously by the AMT (Automated Manual Transmission) with DC motors. With the electric vehicles, the prediction of performance is important. Therefore, the test bed of the power train was developed and allowed to do this reasonably easily.

7 Traction Motor/Drive

Figure 21: Induction motor, PM synchronous motor and its drive

The traction motor and drive (included inverter and converter) for EV have been developing as shown in Figure 21. The advantage and output capacity of the motors are as follows.

- Intermittent Power: 90kW 9,000rpm
- Continuous Power: 45kW 9,000rpm
- Stator end winding moulding in order to increase cooling capacity
- Copper bar for lower rotor loss
- Common stator core (IM & IPM motor)
- Induction motor with copper bar

Figure 22 shows the comparison results between the design and the test of induction motor. In the low speed region, the efficiency and the current are a little bit differences, because of the voltage drop of stator impedance. The test has considered the voltage drop of stator impedance. However, in the high speed region, the efficiency and the current are well matched between the design curve and test curve.

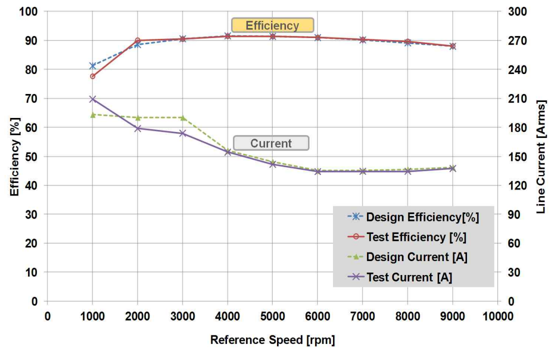


Figure 22: The comparison between design and test of induction motor with its drive

Figure 23 shows the allowable vibration velocity of the dynamo system combined with EV induction motor. The reference standard is ISO 10816-3. This standard present that the allowable vibration speed is 2.8mm/s. At the speed 6000 rpm, the allowable speed is over, because the test bench except motor has its own resonance at the 6000rpm. At most of the speed region, the vibration velocity of the induction motor is satisfied with ISO 10816-3.

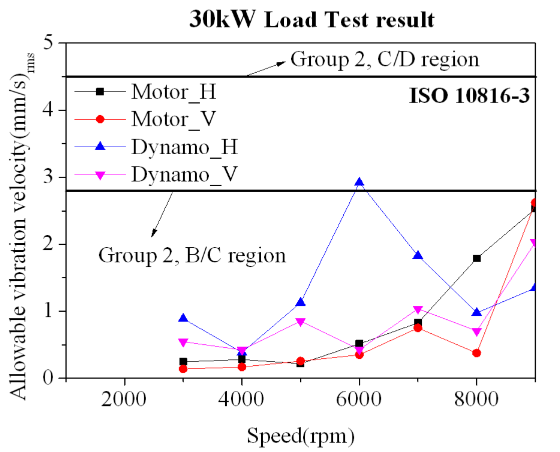


Figure 23: The vibration test results of induction motor

Figure 24 shows the no-load back-emf of the PM synchronous motor. The difference of no-load voltage between the analysis and test is 0.92%. The condition of analysis is 20°C at 3000rpm, and the condition of test is 9.6°C at 3000rpm. The temperature makes the difference of no-load voltage. This means the analysis results is well matched the test results.

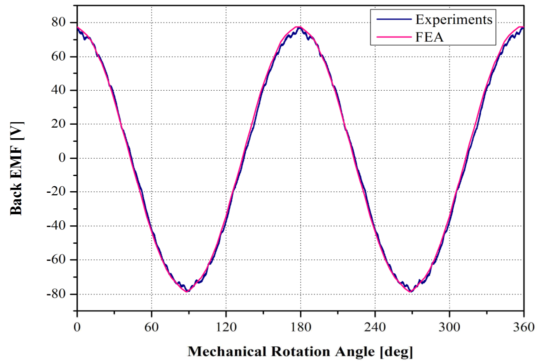
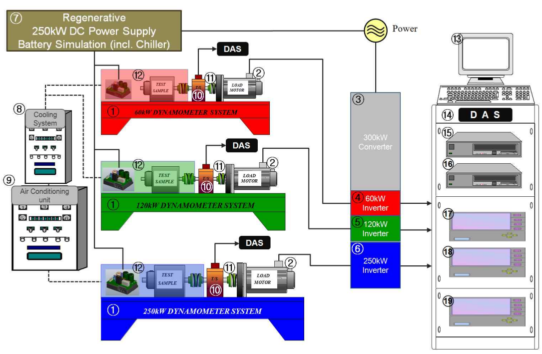


Figure 24: The no-load back-emf test results of PM Synchronous motor

EV test equipment from 60 kW to 250 kW will be installed from 2012 to 2013 at KERI. These test equipment can be operated by international Standard IEC 60034-1, IEC 60349-2, and IEC 60034-2-3 [9]. The EV motor and drive can be tested in temperature and humidity environment condition with battery simulation function.



① Test bed (60kW) : install in 2011
Test bed(120kW) : install in 2012
Test bed(250kW) : install in 2013
② Load motor (60kW, 120kW, 250kW)
③ 300kW AC-DC converter
④ 60kW inverter(4Q) : install in 2011
⑤ 120kW inverter(4Q) : install in 2012
⑥ 250kW inverter(4Q) : install in 2013
⑦ 250kW Battery simulator
⑧ Cooling system
⑨ Air conditioning unit
⑩ Torque sensor
⑪ Coupling & Burst protector
⑫ Environment camber
⑬ Monitor, keyboard
⑭ Data acquisition system
⑮ Torque/speed amplifier
⑯ Resistance meas. Unit
⑰ Power analyzer
⑱ Temperature meas. device
⑲ Vibration meas. device

Figure 25: The test equipment for EV traction motor

8 Charging Equipment Test System

KERI is the international testing laboratory accredited by KOLAS (Korea Laboratory Accreditation Scheme), KAS(Korea Accreditation System) and IECEE CB scheme. KERI has the various outstanding testing facilities as following

- EMC test system : IEC 61000-4 series
- Temperature-humidity test chamber : IEC 60068-2 series
- IP test system : IEC 60529
- BMS simulator : IEC 61851-24
- Dielectric test system : IEC 60255-1
- DC electronic load : DC 500V 150A 60kW
- Material test system: Solar radiation, Saline mist etc.

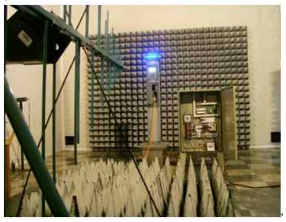


Figure 26: EMC Test Chamber

9 Conclusion

Korea Electrotechnology Research Institute (KERI) has been researching for EV since 1993 to response to new industry demands, to reduce CO2 emission and to save energy.

For getting the information of the EV key parts such as electric propulsion motors, batteries, HVAC and drivers' charging patterns, Korea launched EV pilot projects in JeJu island and in Chang Won city.

For efficient charging infrastructure (CI), KERI is continuing to develop the AC Normal Charger (ACNC) and Integrated Management System for Electric Vehicle Charger (IMS4EVC) and BMS. The charging time is 17 minutes for 20kWh battery and 14 minutes for 16kWh battery from SOC 10% to 90%.

KERI is developing the core technologies of lithium secondary battery of new type electrode materials and electrolyte composition, and lithium air batteries etc.

The test bed and simulator of electrical power train developed to analyse the characteristic of the main components (batteries, battery monitoring system, inverters, decelerators, and motors) in EV.

To save installation volume and weight, the induction motor and PM synchronous motor including inverter and converter with instant power 90kW and continuous power 45kW at 9,000rpm had been developed.

As the financial support for EV from the industries and the Korean Ministry increases, it is expected that the EV R&D activities at KERI will be increasing as well. KERI will play a pivotal roll in the standardization of EV test method and growing the EV market in Korea and all over the world.

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Geun Hie Rim received the B.S. degree from Seoul National University, Seoul, Korea, in 1978 and the M.S. and Ph.D. degrees from Virginia Polytechnic Institute and State University, Blacksburg, Virginia, in 1988 and 1992, both in electrical engineering.
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His specialized research areas include power electronics, motor drives, high power energy conversions, power quality and high-voltage-pulsed power generation for plasma applications. He has published about 100 technical papers and obtained 15 Korean and international patents on these subjects.

In testimony to his esteemed status, the ministry of Science and technology of Korea chose him as one of nationally recognized researchers in 1997. He was granted the National Research Laboratory Fund for pulsed power technology development by the Ministry of Science and Technology of Korea in 1999.

He is a member of various professional organizations including IEEE, KIEE and KITE. He is also a member of Phi Kappa Phi.

Hong Kwan Sohn received M.S degree in electrical engineering from HanYang University and Ph.D in electrical engineering from Chung Nam University. He is working to principal researcher of

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He is the national secretary of IEC TC 95(Protection Relay) and IEC TC SC 37(Surge Protective Device) and also a member of IEC TC 57(Power systems management and associated information exchange) and IEC TC 22(Power electronic systems and equipment) as a representative of Korea. In addition, He is a member of "Working group of standardization for Smart Grid Device" in Korean Agency for Technology and Standards and also a technical member of Korea Smart Grid Association.