Environmental testing for reliable battery management system in electric vehicle

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Abstract. The Battery management system (BMS) is a main component in the battery pack system for electric vehicles (EV). The function of BMS is to monitor battery cells such as; cell voltage, cell temperature, and current in the battery pack. Moreover BMS also able to balance the voltage of the cells so the difference in voltage of the cells can be minimized. By having many of these functions, BMS can identify battery health based on these parameters. With such an important function, in this paper, BMS was tested to determine its reliability. The standard testing for BMS reliability is the Environment test. In the environment test, some things that are conducted in the environment test are initial temperature cycling. From the environment, the test can be generated information to assess the quality of the BMS following its function. Furthermore, it can reduce the cost to inspect every battery cells in the packs. With the environment test as a basis for BMS reliability tester, hopefully, good quality is obtained. Future development in BMS reliability testing can also be conducted to improve reliability.

1. Introduction

A lithium-ion battery is a technology that develops rapidly. This battery is the most popular rechargeable battery with advantages such as the best energy density compared to other batteries, better life cycles performance, low self-discharge, and no memory effect. But battery also required maintenance to increase the life cycles, a stable voltage, and performing at the best condition for electric \cite{1}, \cite{2}.

The battery provides an energy source to drive an electric vehicle. The use of batteries in electric vehicles can reduce dependence on fossil fuels and eco-friendly. Therefore, monitoring the condition of the battery is necessary so that the voltage of each battery cell, temperature, and other parameters is stable and safe \cite{1}, \cite{3}. The Battery management system (BMS) is an integral part of the battery in electric vehicles. BMS function is monitoring the battery condition from the battery voltage of each cell or State of Health (SOH), State of Charge (SOC), temperature, delta cell voltage, average voltage, and charging settings \cite{4}–\cite{7}. It is compulsory to do a resistance test at BMS so it can function under various conditions. The BMS used in this test is developed and manufactured by The Centre of Excellence – Automotive and Control System ITS.
This paper will discuss environmental testing in BMS according to the criteria set by the International Organization for Standardization (ISO). The standard we refer is ISO 16750 (Road vehicles — Environmental conditions and testing for electrical and electronic equipment). The objective of ISO 16750 as a whole is to assist the user in systematically defining and or applying a set of internationally accepted environmental conditions, tests and operating requirements, based on the anticipated actual environment in which the equipment will be operated and to which it will be exposed during its life cycle. There are 5 sections or parts in ISO 16750 but we focus only on ISO 16750 – 2 and ISO 16750 – 4 for this project. ISO 16750 – 2 applies to electric and electronic systems/components for road vehicles. Describing the potential environmental stresses and specifies tests and requirements recommended for the specific mounting location on/in the road vehicle. While ISO 16750 – 4 describes the climatic loads that can effect of electric and electronic systems and components in respect of their mounting location directly on or in road vehicles and specifies the corresponding tests and requirements [8]–[11]. Sections of this paper are composed of the methods used for environmental setup and testing contained in section II. Carry out analysis of methodology in Section III. The results of environmental testing are in Section IV and the final sections discussing the conclusions of this paper.

2. Experimental Setup

Environmental testing is using the High Low Temp Chamber OTS engine model XB-OTS-80. This machine is suitable for testing high and low temperature reliability of industrial products. The machine is used to test the performance of electronic components and materials, electrical engineering, electric vehicles, and other related products. This machine can also do temperature and humidity control testing with a temperature range of -70°C ~ + 150°C and has a program settings feature that can be adjusted to the needs according to user. Moreover, this machine is equipped with an adiabatic process that controls heat transfer unaffected from outside the environment.
Function testing equipment for BMS is a 24 series battery pack, CANTOUSB, 12V Supply and a computer that has been equipped with BMS applications, can be seen in Figure 3 and Figure 4. Function testing is carried out for 15-20 minutes to ensure the BMS is functioning or not. The testing mechanism used for environmental testing is Initial temperature cycling. The test is based on standards and testing regulations that focus on electric vehicle battery management systems. This testing standard has been used for guidance and testing by several laboratories[11]. For the mechanism of environmental test on the BMS can be seen in Figure 5 and testing the BMS after completing environmental test temperature can be seen in Figure 6.

**Figure 5.** Flowchart mechanism environmental test on machine  
**Figure 6.** Flowchart monitoring and charging testing
BMS has specifications regarding the minimum and maximum temperature limits when operating and using electric vehicles. So, in this temperature and humidity test using the same temperature parameters as the operational standards that have been carried out on BMS by several researchers at Centre Of Excellence – Automotive and Control System ITS.

**Table 1. Temperature Standard Minimum and Maximum for BMS**

| Value          | Definition                                      |
|----------------|-------------------------------------------------|
| TemperatureBMS_min | Minimum operational temperature of BMS is 10°C |
| TemperatureBMS_max | Maximum operational temperature of BMS is 50°C |
| TemperaruteRoom  | Room temperature 30°C                           |

**Figure 6.** (Continued) Flowchart monitoring and charging testing
This environmental testing is carried out with temperature settings that are repeated up to three times. This test does not use wire installation on BMS, only BMS hardware. The following are the testing steps:

1. Lower the environmental temperature to Temperature\(_{\text{BMS}\_\text{min}}\) at a rate of 1 k/\(\text{min}\)
2. Hold the environmental temperature at Temperature\(_{\text{BMS}\_\text{min}}\) up to 2 hours
3. Raise the environmental temperature to Temperature\(_{\text{BMS}\_\text{max}}\) at a rate of 1 k/\(\text{min}\)
4. Hold the environmental temperature at Temperature\(_{\text{BMS}\_\text{max}}\) up to 2 hours
5. Lower the environmental temperature to Temperature\(_{\text{Room}}\) at a rate of 1 k/\(\text{min}\)

![Test setup no wiring connected](image)

**Figure 7.** Test setup no wiring connected

3. **Analysis of Methodology**

Temperature Setting Point (SP) is reference value of a manic variable. Temperature Present Value (PV) is the current temperature value. Then for the axis (X) represents time (sec) and the axis (Y) represents the temperature (°C). Based on Figure 6, SP is always stable value following with the parameter values used. Meanwhile, for PV there is a difference in temperature reading when SP decreases and raises the temperature to reach the reference point. When the SP is stable at a certain temperature, the PV reading also matches the temperature value used by the SP.

![Graphic environmental from chamber](image)

**Figure 8.** Graphic environmental from chamber
4. Result
Environmental testing on BMS using OTS high low temperature chamber machines with various temperature differences has validated the BMS function after the test. The function test is obtained by BMS performance which can function reliably with a battery pack. Thus, BMS can be used on electric vehicles to monitor battery conditions and provide a longer battery health condition on electric vehicles. The Table below is the result of a functional test on the BMS that has been tested three times.

| Value     | Definition                                                                 |
|-----------|-----------------------------------------------------------------------------|
| Monitoring| Can monitor the condition of the battery directly                             |
| Temperature| Temperature sensor is working                                                |
| Current   | Current sensor functions when there is an incoming current such as charging or discharge |
| Charging  | Can control when charging                                                    |

Based on the BMS function that can work with high reliable, the Figure 12 is a user interface display of the battery management system application that manufactured by Centre Of Excellence – Automotive and Control System ITS that provides information about battery condition directly such as, voltage of each cell, highest and lowest voltage, temperature, and total voltage.

![Figure 9. Main picture of system when operating](image1)

![Figure 10. Machine when operating](image2)

![Figure 11. User interface application BMS](image3)
5. Conclusion

Based on environmental testing methods and function test results on BMS after environmental testing, obtained BMS which is reliable and has resistance to temperature under any conditions. Also, successfully achieved from our target of rapid changing temperature testing which is at 10°C to 50°C for three cycles of changing temperature rapidly. Therefore, with this environmental testing process, the feasibility of BMS is obtained, so that it can use in electric vehicles. Moreover, BMS can maintain and care for batteries in electric vehicles safely and reliably.

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