Designing Framework for Standardization Case Study: Lithium-Ion Battery Module in Electric Vehicle Application

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ABSTRACT
Standardization is one of the important things before to deploy a product. Regulation such as national standard has important roles in industry. The roles of standard such as ensuring safety for consumer and producer, increasing product competitiveness, and reducing trade berries. Indonesia is currently in the stage of developing industry of electric vehicle, so that standard which is related to electric vehicle, one of it is standard for the electric vehicle battery. Besides that, Indonesia does not have a relevant standard to regulate. This study is intended to make a framework for standardization of lithium-ion battery module product using A Framework for Analysis, Comparison, and Testing of Standard (FACTS) approach. There are three stages in FACTS approach, they are analysis, comparison, and testing. Based on the result of this research, the framework of lithium-ion battery module product standard consists of 8 parameters.

1. INTRODUCTION
Global warming is one of the newest issues which are related to environmental damage. One of the causes of global warming is increasing amount of CO2 emissions which are produced by fossil fuel. Therefore, most of people switch fossil fuel to green energy sources such as solar, wind, etc. Battery is one of green energy embodiments that can reduce the using of fossil fuels. It can efficiently store electricity in chemicals and release it according to demand [1], [2]. Electric vehicle is one of technologies that utilize battery as energy source and usually the battery which is used is rechargeable battery. The battery has huge effect for electric vehicle performance [3], [4]. Battery storages energy chemically, and convert chemical energy into electrical energy by electrochemical reaction [5], [6]. Battery is currently developed in various types, such as lead-acid battery, nickel metal hydride, nickel cadmium, lithium-ion battery etc. Each type of batteries has different performance and characteristic [6].

Currently, rechargeable lithium-ion batteries are under the consideration of an electrical vehicle because they have been showing good characteristic such as high energy density, long cycle life, high power density, stable voltage, no memory effect and environmental friendliness [7-9]. Countries which are recently excel in developing lithium-ion rechargeable battery for electric vehicle are US, China, Germany, Japan, and Korea [10]. The countries also dominate battery manufacture industry in Indonesia. They can be market leader easily in Indonesia because unavailability of lithium-ion rechargeable battery regulation or standard in Indonesia which can be used as reference to regulate all of things which are involved in battery industry.
Regulation such as national standard has important roles in industry, the roles such as:

a. Ensuring safety for consumer and producer
b. Increasing product competitiveness
c. Reducing trade berries

Process to establish a standard is called as standardization. Standardization is defined as process of formulating, defining, applying, maintaining, imposing, and supervising standard which is done orderly and involves roles of relevant stakeholders [11]. Standardization is done by government through a national standardization organization. In Indonesia, government regulates standard product through by national organization which is called National Standard Agency (BSN) [12].

Given the important roles standard and unavailability of lithium-ion battery standard for electric vehicle application, this research tried to figure out how to make a framework for standard of lithium-ion battery in electric vehicle by using FACTS approach. Standardization for lithium-ion battery in electric vehicle is done gradually, that means the standard is made for the smallest part to the whole battery system in electric vehicle. The whole battery system in electric vehicle consists of battery cell, battery module, battery pack, and battery management system. Figure 1 shows the detail of battery system of electric vehicle.

Case of this research is how to make a framework for product standard of lithium-ion battery in electric vehicle especially in module level. According to IEC 62620, module battery is group of cells connected together either in a series and/or parallel configuration with or without protective devices (e.g. fuse or PTC) and monitoring circuitry [13], [14]. Every battery module in assembly process consists of battery cells, the cell to cell interconnection, and the battery cell insulation, sensors, the cooling components, the Battery Module Controller (BMC) and the housing [15]. Figure 2 shows the battery module product. The framework for standard of lithium-ion battery module is done by using FACTS approach (A Framework for Analysis, Comparison, and Testing of Standard). FACTS approach analyzes, compares, and tests standard [16]. This approach is partially based on the Zachman Framework, which is used to bridge the perceived gap between standards as developed by domain expert and those standards as understood by stakeholders [16].

Figure 1. Battery system of electric vehicle [10]

Figure 2. Module battery product [17]
FACTS concept considers stakeholder requirements when designing standard framework, it is in line with BSN’s consensus principle which considers relevant stakeholder opinions or requirements and does not side with a certain party or stakeholder to get the decision. Based on these, one of stages in FACTS namely, verification test is done by focus group discussion. In this research, the FGD involved the relevant stakeholders as participant.

2. RESEARCH METHOD

The object of this study is lithium-ion rechargeable battery which is used in electrical vehicle especially in module level. There are 3 stages in FACTS approach, they are analysis, comparison, and testing. The detail stages in FACTS can be seen in Figure 3. The analysis consists of a stakeholder and technical analysis [16]. The stakeholder analysis must be done to get stakeholder’s requirements. Each stakeholder may also have multiple perspectives, for examples a manufacturing company can be either a buyer or a producer [16]. After doing stakeholder analysis, the next step which is done in stage of analysis is technical analysis. The technical analysis is intended to convert stakeholder’s requirements into technical requirements by using Zachman framework which is used 6 based questions and they are What, How, When, Where, Who and Why (5W1H) [16].

![Figure 3. Stages of FACTS Approach](image)

The Comparison is intended to do identification of gaps and overlaps between two or more analysis results [14]. The last stage of FACTS is testing. Testing is done by doing verification and validation. Verification is done through Focus Group Discussion (FGD) and interview by using questionnaire. Validation is done by testing the product (Lithium-ion rechargeable battery) in accordance with the tests which have been decided.

3. RESULTS AND DISCUSSION

3.1. Analysis

Stakeholder analysis was intended to define stakeholder requirements. In this research, the stakeholders which involved are government, battery tester laboratory, battery manufacture, the relevant experts, electric vehicle manufacture, and consumer. Table 1 shows the requirements of each stakeholder.

Technical analysis was intended to convert each stakeholder requirements into technical requirements. It help to define tests which needed for lithium-ion rechargeable battery in electric vehicle application. Technical analysis was done by using Zachman framework which used 6 basics questions (what, how, when, who, where, and why). Table 2 shows technical requirements of each stakeholder.

| FACTS (Framework for Analysis, Comparison, and Testing of Standard) |
|---|
| 1. Stakeholder analysis |
| 2. Technical analysis |
| 3. Comparison |
| 4. Testing |
| 1. Determining the relevant stakeholders |
| 2. Identifying every needs/requirements of each stakeholders |
| Zachman framework: (What, How, When, Who, Where, Why) |
| Identification of gaps between standards |
| 1. Verification |
| 2. Validation |
### Table 1. Stakeholder Requirements

| No | Stakeholder Requirements | Stakeholder Requirements |
|----|--------------------------|--------------------------|
| 1  | Government               | high energy, small size, environmental friendliness, low emission, electric car can reach long distance (300 km), fast charging and safe |
| 2  | Battery testing laboratory | Low emission level, high safety, high power density, fast charging, high energy density, high safety, heat/thermal resistance, good capacity, environmental friendliness |
| 3  | Battery manufacture       | high energy density, high safety, heat/thermal resistance, no over heated, long life cycle |
| 4  | The relevant experts      | small size, light weight, fast charging, heat resistance, good capacity, long life cycle, save energy, good energy density |
| 5  | Electric vehicle manufacture | supporting to reach long distance (120 km/hour), high power, supporting in fast speed, fast charging, water resistance (can be operated when the rain and flood are coming) |
| 6  | Consumer                  | environmental friendliness, supporting to reach long distance, low cost electric vehicle |

### Table 2. Technical requirements and comparison references standard

| No | Stakeholder Requirements | Technical requirements | Comparison of referenced standard |
|----|--------------------------|------------------------|----------------------------------|
|    |                          | ISO 12405-1 | ISO12405-2 | ISO 12405-3 |
| 1  | High energy, good capacity: (government), high energy density: (Battery testing laboratory, Battery manufacture, The relevant experts) | Energy density (Wh/kg) measurement through a test is needed | sub-section 7.1 and 7.2 (energy and capacity test at different temperature and different discharge rate) | sub-section 7.1 and 7.2 (energy and capacity test at different temperature and different discharge rate) |
| 2  | High power density: (Battery testing laboratory), high power: (Electric vehicle manufacture) | Power (Watt) measurement through a test is needed | sub-section 7.3 (power and internal resistant test) | sub-section 7.3 (power and internal resistant test) |
| 3  | Save energy: (The relevant experts) | Energy efficiency test is needed | sub-section 7.8 (energy efficiency test only for system) | sub-section 7.4 (energy efficiency test at fast charging only for system) |
| 4  | Long life cycle: (Battery manufacture, The relevant experts) | Cycle life test is needed | sub-section 7.9 (cycle life test only for system) | sub-section 7.7 (cycle life test only for system) |
| 5  | High safety: (Battery testing laboratory, Battery manufacture) | Vibration test is needed | sub-section 8.3 (vibration test for high power applications) | sub-section 8.2 (vibration test for high energy applications) |
|    |                          | Mechanical shock test is needed | sub-section 10.4 (mechanical shock test for high power applications) | sub-section 9.4 (mechanical shock test for high energy applications) |
|    |                          | Electrical test and abuse test | sub-section 9.2 (short circuit protection) | sub-section 9.2 (short circuit protection) |
|    |                          |                          | sub-section 9.3 (overcharge protection only for system) | sub-section 9.3 (overcharge protection only for system) |
|    |                          |                          | sub-section 9.4 (overdischarge protection only for system) | sub-section 9.4 (overdischarge protection only for system) |
| 7  | Fast charging: (Battery testing laboratory, Battery manufacture) | energy efficiency test at fast is needed | sub-section 7.4 (energy efficiency test at fast charging only for system) | sub-section 7.4 (energy efficiency test at fast charging only for system) |
3.2. Comparison

Comparison was intended to know the gap between each standard which was used as reference. The standards which were used in this research is ISO 12405 series 1, 2 and 3. ISO 12405-1 provides specific test procedures for lithium-ion battery packs and systems specially developed for propulsion of road vehicles especially for high-power applications [40]. There are 4 main tests, namely general test, performance test, reliability test and abuse test. ISO 12405-2 provides specific test procedures for lithium-ion battery packs and systems specially developed for propulsion of road vehicles especially for high-energy applications [41]. ISO 12405-3 provides specific test procedures and related requirements to ensure an appropriate and acceptable level of safety of lithium-ion battery systems specifically developed for propulsion of road vehicles [42]. The other test is consisting of 5 steps, namely mechanical test, climatic tests, simulated vehicle accidents, electrical tests and system functionality tests. Subsequently, the comparison result between each test in the reference standards was associated to the result of technical analysis. Table 2 shows the result of technical analysis and comparison of standards.

3.3. Testing

There are two primary phases to test, first is verification and second is validation. Verification was done by Focus Group Discussion (FGD) with the stakeholders and interviewing the stakeholders using questionnaire. Verification was intended to know whether the standard had captured all the stakeholder requirements or not [16]. The verification through by FGD was done twice. The first is internal FGD which is done by drafters who consisted of battery testing laboratory, battery manufacture and the relevant experts. First FGD gave result that there were only 2 tests which were relevant to module battery lithium-ion, they were energy & capacity test and power and internal test which reference on ISO 12405-1 and ISO 12405-2.

There were only 2 tests because the cost of module battery is expensive so the participants of FGD agreed that tests which have destructive character such as vibration, mechanical shock and short circuit were only to be done in cell level.

The second verification is external FGD, which was attended by all of the stakeholders in Indonesia. The FGD gave result that the national standard of lithium-ion battery module for electric vehicle still needed other tests which is intended to test the connection between cells in module form (assembled cell), ability of battery module in water environment, and the function of cooling system in battery module. Besides that, the stakeholders agreed that the cells which are used in module should be tested in accordance with cell standard. Besides doing FGD, the verification tests also have done by interviewing stakeholders by using questionnaire. Table 3 shows the questionnaire result.

Based on FGD and questionnaire, the new frameworks for module test have been done. The result is there are 8 parameters in standard. They related to battery cell performance, density energy of battery module, power of battery module, vibration, mechanical shock, water immersion, loss of thermal control/cooling, and short circuit. Figure 4 shows the detail of new framework for lithium-ion battery module in electric vehicle application.

The next steps after verification test is validation test. Validation test is going to be done by testing the module battery accordance with parameters in standard which have been agreed by all of the stakeholders.
Table 3. Recapitulation of questionare result

| Framework of Module Battery Standard | Stakeholders |
|--------------------------------------|--------------|
|                                       | 1 2 3 4 5 6  |
| The standard regulates the current value of energy density (Wh/kg) | * Yes No Yes * * |
| The standard regulates the current value of power (Watt) | * Yes No Yes * * |
| Vibration test | * Yes Yes Yes * * |
| Mechanical shock test | * Yes No Yes * * |
| Thermal shock cycling test | * Yes No No * * |
| Short circuit test | * Yes No Yes * * |

Note:
1. Government
2. Battery testing laboratory
3. Battery manufacture
4. The relevant experts (R&D battery)
5. Electric vehicle manufacture
6. Consumer
*still under discussion

Figure 4. Framework of standard for lithium-ion battery module in electric vehicle application

4. CONCLUSION

This research used FACTS model to approach and make a framework for national standard of lithium-ion battery module in electric vehicle application. The content of standard shall consider the requirement of stakeholder. There are 6 stakeholders which are involved in standardization. Namely are government, battery testing laboratory, battery manufacture, the relevant experts, electric vehicle manufacture, and consumer. Based on the last FGD there are 8 parameters which must be fulfilled by lithium-ion battery module standardization.

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Title of manuscript is short and clear, implies research results (First Author)
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