IMPLEMENTATION AND PERFORMANCE EVALUATION OF ENERGY STORAGE PACK SYSTEM BASED ON C-RATE

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Abstract—In this paper, energy storage system (ESS) pack of lithium battery is implemented and performance of system based on C-rate is evaluated. Structure, usability and functions of ESS pack system are described. In our scheme, 80 cell lithium battery is used. The result shows that by reducing c-rate more energy can be stored in ESS pack.

Index Terms—Energy, Storage System, C-rate.

I. INTRODUCTION

ESS (Energy Storage System) is the production of electrical energy to improve the storage energy, utilize renewable energy and stabilize power supply system. The development of ESS technology is highly interested in global and in domestic energy issue [1]. The main function of ESS is to maximize energy efficiency through the use of power leveling. In power plant system, more amounts of energy is needed during the day as compare to night time. In that case, energy is poor during the day while at night time the energy requirement is more. In technical terms, by using the ESS, system efficiency can be increased while in the economic aspect, it reduces the cost of investment in the power plant. In addition, by combining the ESS system with solar system more advantage can be utilized. In day time, energy is generated by solar system, stored in ESS and the same energy from ESS system can be used during the night time.

The ESS has become a key technology and markets around the United States for the smart grid and has expanded rapidly since 2010 as shown in Fig. 1a. The ESS is used for (long term storage) 80% power system ancillary services showed (short term storage) about 20%, especially if the ESSs prevailing market accounts, and the United States about 78% of the situations, which forms the largest market.

Accordingly, ESS in the world market is expected to increase in power demand due to the global expansion of renewable energy and electric vehicles. In addition, global electricity demand is expected to increase, its share of renewable energy generation is expected to grow by 7.8%, from 1.205 MW storage demand in 2011 to 20.105MW in 2020 which is expected to grow about 16 times as plotted in Fig. 1b. Major industrialized countries such as Japan and the United States actively promote the research, development and demonstration relating to the ESS, including some entered the stage for successful commercialization. Japan’s renewable energy power plants, and household, such as promoting technology development in various fields, sodium-sulphur battery, holds an advanced lithium-ion battery technology. In the empirical status but promote demonstration case is still in the early stages of the ESS. In Korea, the budget of the energy storage sector has continued to increase from 2005 to 2011 up to 53 billion won in the last five years. The government contributions in 2011 has invested 19.1 billion won. The government is also planning to promote industrialization through another
energy storage. The demonstration of a lithium-ion battery technology, such as the installation immediately, plans to lead the international standards to ensure the ESS management skills. Another large volumes in coast area, the development of wind farm and EES is designed to generate a large-scale renewable energy sources. The trends in development and commercialization of ESS is referred to as an important task. Furthermore, in this paper, 14kWh class ESS is implemented and C-rate [2] performance evaluation is investigated. The Battery Management System (BSM) is utilized to examine the system [3]. The rest of paper is organized as follow. In Section II, the ESS structure and function is discussed. The experimental methods and the results is described in Section III. Furthermore, in section IV the conclusion and future works are presented.

II. ESS Structure and Function

A. EES Configuration

The implementation of 14kWh ESS system is configured to the five modules in series, the configuration module is connected to the 16 lithium battery cells in series. In Fig. 2, there are 80 cell of lithium ion pouch battery [4]. The system specification are listed in Table 1 while the characteristic of each cell is arranged in Table 2. The reason for the difference is the individual cells and the entire system capacity and operating voltage, when the individual cells is blocked by the system, a difference is generated in the internal resistance, and cell voltage due to a slight difference between the cells, such as self-discharge. So, if a certain cell is charged and discharged when a voltage difference is greater than other cells, there is a risk of over-discharge and overcharge. To avoid this risk, the capacity to use an operating voltage lower than the maximum use value is relatively small. Fig. 3 and Fig. 4 is represents the 3 KWh ESS pack module and the 50Ah lithium-ion battery cell, respectively.

**TABLE 1 THE BATTERY PACK SYSTEM SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Content</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage (V)</td>
<td>264-326</td>
</tr>
<tr>
<td>Nominal Voltage (V)</td>
<td>296</td>
</tr>
<tr>
<td>Energy (KWh)</td>
<td>14</td>
</tr>
</tbody>
</table>

**TABLE 2 THE BATTERY PACK SYSTEM SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Content</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving Voltage (V)</td>
<td>3.0-4.2</td>
</tr>
<tr>
<td>Nominal Voltage (V)</td>
<td>3.7</td>
</tr>
<tr>
<td>Capacity (Ah)</td>
<td>50</td>
</tr>
</tbody>
</table>

Fig. 2 The 14KWh ESS pack system and the laptop to monitor the system

Fig. 3 The 3KWh ESS pack module.

Fig. 4 The 50Ah lithium-ion Battery Cell

Fig. 5 The result of battery explosion

Fig. 6 Passive Cell Balancing
B. Roles and Functions of the BMS

The BMS is used for the battery state monitoring, protection, and cells balancing. Fig. 5 shows the example of battery explosion. The explosion of battery can be reduced and even avoided by utilizing the BMS system [6]. The following list describes the detailed function of BMS.

1) Monitoring
   BMS monitors the voltage, temperature and current of individual cells. This information is based on information to protect and cell-balancing of the BMS. The information are collected and transmitted to the monitoring unit via a CAN communication.

2) Protection
   The warning and protection is activated, such as on the basis of the sensed voltage and temperature information by the BMS [7].
   - Cell OVP (Over Voltage Protection): The protection is turn on when a particular cell is charged more than the specified voltage.
   - Cell UVP (Under Voltage Protection): The protective function is activated when the cell voltage falls below a specified voltage.
   - Pack OVP (Over Voltage Protection): The protection is activated when the voltage of battery is more than a certain voltage threshold.
   - Pack UVP (Under Voltage Protection): The protection is activated when the cell voltage below a certain voltage.
   - OTP (Over Temperature Protection) / UTP (Under Temperature Protection): The temperature protection is activated when the cell temperature more or less than temperature threshold.
   - C_OCP (Charge over Current Protection): The protection is activated when charging current flows over a certain current.
   - D_UCP (Discharge under Current Protection): The protective function is activated when the discharge current is lower than a certain current relay.

3) Cell Balancing
   BMS of the ESS is implemented in this paper is a passive cell balancing system as shown in Fig. 6. In [8], the article clarify that passive cell balancing has the advantage of easy and inexpensive to implement compared to other balancing methods.

4) BMS Structure and Functions
   The structure and functions of BMS of proposed scheme is shows in Fig. 7. By sensing the voltage and temperature of each cell, it sends information to the MCU. The MCU determines whether to use the protection and balancing function on the basis of the supplied information. For example, when the voltage of any cell exceeds the operating voltage sensing as 4.21V MCU sends a warning label to the monitoring program, send a blocking signal to block the relay to prevent overcharging. The information generated by the monitoring program is transferred from the MCU through the CAN communication. The detail of BMS specification is listed in Table 3.

III. EXPERIMENTAL

C. Experimental Method

The experiment procedure is to charge and discharge the batteries and measure the performance based on C-rate test. The room temperature is set for a time sufficient to proceed in order to reduce the difference between the temperature and the ambient temperature around the battery. When the temperature of the battery pack is equal to the ambient temperature and the test is started and switch to rest for one hour between each charge and discharge. The following is the list of experimental algorithm in ESS pack with system test shown in Fig. 8.

a) Soaking the battery system at room temperature.

b) Charge the battery with proposed scheme parameters. CCCV mode, 0.3C - rate (15A), end condition: 328V/2A.
c) Idle for 1 hour.

**Discharge to the proposed discharge conditions**

CC mode, 0.2C – rate (10A), end condition: 264V.

e) Idle for 1 hour.

**Filled with a given charge parameter. CCCV mode, 0.5C – rate (25A), end condition:**

328V/2A.

g) Idle for 1 hour.

**Filled with a given charge parameter. CCCV mode, 0.5C – rate (25A), end condition:**

328V/2A.

h) Last, discharge into the proposed discharge parameter and end the experiment test. CC mode, electric current: 1C-rate (50A), end condition: 264V.

**D. Results**

The experiment results is summarized in Table 4 and Fig. 9. The 50Ah battery pack with the energy of 14kWh class is investigated. Energy also came out lower, when the C-rate becomes greater. This is because the C-rate increases due to the voltage difference is greater than the cell internal resistance.

<table>
<thead>
<tr>
<th>C-rate (Charge/Discharge)</th>
<th>Capacity (Ah)</th>
<th>Energy (kWh)</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3C charge</td>
<td>46.956</td>
<td>14.271</td>
<td>11.817</td>
</tr>
<tr>
<td>0.2C discharge</td>
<td>48.247</td>
<td>14.335</td>
<td>17.371</td>
</tr>
<tr>
<td>0.5C charge</td>
<td>47.110</td>
<td>14.332</td>
<td>7.411</td>
</tr>
<tr>
<td>1C discharge</td>
<td>47.072</td>
<td>13.799</td>
<td>8.391</td>
</tr>
</tbody>
</table>

**TABLE 4 EXPERIMENTAL RESULTS**

**CONCLUSION AND FUTURE WORKS**

In this paper, the performance of 14kWh ESS pack system is investigated. The drawback of the current implementation of the ESS system may not be able to use full capacity of the individual cell. Utilizing a cell balancing algorithm to overcome this point. The result shown by reducing c-rate more energy can be stored in ESS pack. The implementation of ESS cell balancing method of a larger capacity is targeted for future works. Therefore, implementation using active approach such as utilizing the redistribution is considered as future work.

**REFERENCES**


