Application Constant Temperature Charging Technique for Charging Time Reduction of Lithium Ion Battery

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Abstract- Existing battery charging techniques such as Constant Current-Constant Voltage (CC-CV) method, Multistage Constant Current (MCC) method, Pulse Charging, Sinusoidal Ripple Approach (SRA), etc., are time consuming open loop approach which uses the fixed cell parameters and does not consider temperature variation while charging. The proposed Constant Temperature – Constant Voltage (CT-CV) charging technique suggests the closed loop scheme using instantaneous cell voltage and temperature changes with the charging current magnitude and maintaining the temperature rise at the set value as CC-CV. Charging current is controlled using PID controller added by feed forward current. This method is inexpensive as compared to the other optimization techniques which involve high quality and high cost sensors. Results shows that the proposed technique reduces the battery charging time by 24% when compared with CC-CV technique. As per the results Requirement of fast charging can be achieved through higher ambient temperature limits. The scheme can be expanded to pack level by integrating the cells.

Index Terms- Battery charging, lithium Ion battery, PID Controller, temperature control.

I. INTRODUCTION

In today’s world, laptops, smart phones and many automobiles are becoming basic needs due to their portable and rechargeable behavior and these devices can be powered by the energy storage system. Batteries can be classified into primary and secondary batteries. Primary batteries once discharged cannot be charged again. Secondary batteries can be charged again and again. Lithium-Ion batteries are more popular in the areas of portable and mobile applications due to high efficiency, high life cycle, high energy density and no memory effect. Currently many chargers are in use namely microcontroller controlled battery charger, Current pumped battery charger, grey prediction battery charger etc [1]-[4]. Lithium Ion battery also many some drawbacks such as aging increases the impedance which reduces the energy density [5]-[7], overheating and over voltage reduces the life cycle of the battery [8]-[10]. State of health (SOH) [11] and state of charger (SOC) [12]-[14] are the two important parameters of the battery. Lithium Ion battery can be modeled electrically, to analyze its behavior, [13], [15] by the large capacitor which charge and discharge gives or absorbs the electrical energy. Charging techniques for Lithium Ion battery are CC-CV[16],[17], Pulse charging method [18]-[20], MCC [21]-[28] i.e. ant colony, taguchi, particle swarm optimization etc. But all these techniques do not take rise in cell temperature into consideration. So in the proposed technique a closed loop approach is used which maintains the cell temperature at the specified limit using PID controller and also reduce the charging time of the Lithium Ion battery.

II. PROPOSED CHARGING TECHNIQUE

Temperature plays a very important role in battery charging and evaluating its performance. In the proposed closed loop technique, as shown in Fig. 1, the cell voltage and temperature are utilized to maintain the charging current magnitude keeping the temperature rise within the limits. PID controller provides path to the charging current while maintaining the battery temperature within the specified limit. Feed forward current, which is exponentially decreasing from 2C to 1C (C is the charge capacity), is added to PID signal to reduce its gain. The higher charging current, as shown in Fig. 2, is given at the start of the CT (Constant Temperature) phase maintaining the temperature within the limit, and the current decreases exponentially till the end of
CT phase. Once the nominal voltage is achieved, the battery will charge using CV mode where the current is decreases to 0.1C.

\[ I_{FF} = \begin{cases} 2C ; & 0 \leq t < t_{pk} \\ C \left( 1 + e^{-\left( t - t_{pk} \right)/\tau} \right) ; & t_{pk} \leq t < t_{CV} \end{cases} \]

Where \( t_{pk} \) is the time when the current is at its peak value, \( t_{CV} \) is the time at which CV mode is reached, \( \tau \) is time constant of exponential delay. The technique can be improved further by evaluating feed forward term using the electrical and thermal model of the battery.

\[ C_{i} \frac{dT_i}{dt} = P_L - \frac{T - T_{am}}{R_{is}} \]  
\[ C_s \frac{dT_s}{dt} = \frac{T - T_{am}}{R_{sa}} \]  

Where \( C_i \) is the cell internal heat capacity, \( C_s \) is the cell surface heat capacity, \( T \) is the cell temperature, \( T_{am} \) is the cell ambient temperature, \( R_{is} \) is the thermal resistance of cell between internal to surface, \( R_{sa} \) is cell surface to ambient thermal resistance. The flow chart of the proposed technique is shown in Fig. 4.

### III. RESULT

This section shows the comparative experimental results of the proposed technique and the conventional CC-CV technique. The test is performed on the 4.2V Lithium Ion battery whose rated capacity is 2.3A and nominal voltage is 3.6V. TABLE II shows reduction in the charging time when proposed CT-CV technique is used. Fig 5 shows and TABLE II shows that the battery is charged 24.33% faster by giving the exponentially decreasing current signal from 2C to 1C during constant temperature mode.
Fig. 4. Flowchart of proposed CT-CV method
decreasing signal, maintaining the reference
temperature at 28.5°C and the room temperature is
21°C.

TABLE II REDUCTION IN CHARGING TIME

<table>
<thead>
<tr>
<th>S.no.</th>
<th>SOC (%)</th>
<th>Time Taken in CC-CV (min)</th>
<th>Time Taken in CT-CV (min)</th>
<th>% Reduction in Charge time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>6.38</td>
<td>3.17</td>
<td>50.29</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>12.34</td>
<td>6.15</td>
<td>50.15</td>
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<td>3</td>
<td>50</td>
<td>18.21</td>
<td>9.13</td>
<td>50.10</td>
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<td>4</td>
<td>70</td>
<td>24.27</td>
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<td>5</td>
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<td>30.24</td>
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<td>54.10</td>
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<tr>
<td>10</td>
<td>100</td>
<td>60.44</td>
<td>43.73</td>
<td>24.33</td>
</tr>
</tbody>
</table>

Fig. 5. Experimental results comparing proposed CT-CV and CC-CV charging

IV. CONCLUSION

This section concludes the presented study in the
field of battery charging system. This work has
proposed an improved charging technique namely
CT-CV to improve the performance and reduce the
charging time of the battery. The proposed method reduces the charging time by 24.33% maintaining the rise in battery temperature same as CC-CV charging which improves battery life. The Li-Ion battery charging time for 4.2V battery using CC-CV method is 60.44 minutes and charging time using CT-CV method is 45.73 minutes. For faster charging requirements the cell temperature limit can be raised in expense of cycle life. This method can be expanded to pack level by integrating the cells.

REFERENCES


