Intelligent Battery Health Monitoring System

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Intelligent Battery Health Monitoring

• Agenda

1. • Introduction

2. • Problem Statement

3. • Approach

4. • Results

5. • Conclusion
• Introduction

➢ As the electrical vehicle market is growing, research on battery management system has got more attention.

➢ SOH (state of health) of battery is most crucial factor which decides the driving mileage and also the replacement time of the battery.
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• Problem statement
  ➢ Battery failure can cause loss in operation, reduce the capacity and in vehicle it can cause the fatal accident.
  ➢ To ensure that battery operate within design limits and storage life time, effective battery health monitoring is required.
  ➢ Monitoring evaluation can also provide the remaining charge information and warn when the limits exceeds.
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• Approach
  ➢ The proposed system will automatically predict the battery health based on the SOH calculated from battery time capacity.
  ➢ Multiscale entropy (MSE) and SOH are used as data input and target vector for learning algorithm.
  ➢ The neuro fuzzy classifier (ANFC), an adaptive network based system in which antecedent parameters are adapted with neural network, is used as a learning algorithm.
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• Approach

Battery Data → Feature Extraction (MSE) → ANFC Testing

Battery Capacity → ANFC Training

Estimated SOH → Perform. → Battery Prognostics
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- Experimental setup

  - dataset provided by the data repository of NASA Ames Prognostic center of Excellence (PCoE) is used here for the validation of the proposed system.

  - In the experiment Li-ion batteries go through three different profiles (charge, discharge and impedance) at room temperature.

  - The charge and discharge cycle increase the aging of batteries. While the impedance measurement present the insight into the battery internal parameters that change as aging accelerate.

  - The EOL (end of life criteria) is 30% fade in rated capacity (2Ahr to 1.4 Ahr) for these batteries.
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• Experimental setup
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• Experimental setup
  - discharge voltage shows that cells will not have the same end of discharge at the same cycle index because of variation in depth of discharge and rest period.
  - This ambiguity shall represent the actual usage.
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• Multiscale Entropy
  ➢ Multi scale entropy provides the way to measure complexity over the range of scale.
  ➢ MSE method incorporate two procedure
  1. Construct coarse-grain series
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• Multiscale Entropy

1. Calculate sample Entropy

\[
SE = -\ln \left[ \frac{x^m(r)}{y^m(r)} \right]
\]

Here \(x^m(r)\) & \(y^m(r)\) represent two sequence will match for \(m\) points and \(m+1\) points

➢ MSE is implemented using the MATLAB.
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- During the discharge process the sample entropy value reduce with increase in the cycle.
- This relation can indicate the battery degradation.
- At cycle number 46 sample entropy value is higher than the previous cycle, because of variant in depth of discharge in which voltage and rest period is high.
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• State of health (SOH) estimation

➤ SOH is calculated based on the capacity method, that is ratio between nominal capacity of the present time to the initial time.

➤ \[ \text{SOH} = \frac{\text{Capacity at present time}}{\text{Capacity at initial time}} \]
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- State of health (SOH) estimation
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• Adaptive Neuro Fuzzy classifier

➢ It is the combined system with fuzzy system qualitative approach and artificial NN adaptive capabilities.

➢ The ANFC explicates a zero order surgeon fuzzy inference model into the framework of a multilayer artificial neural network (ANN) with adaptive and non-adaptive nodes.

➢ MATLAB ANFIS toolbox is used to implement fuzzy inference system with scaled conjugate gradient algorithm.
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• MATLAB ANFIS toolbox
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• Results

![Performance evaluation graphs]

- [Graph 1: Performance evaluation plot showing RMSE value vs Epochs]
- [Graph 2: Performance evaluation plot showing RMSE value vs Epochs]
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• Results

➢ Accuracy prediction comparison for battery no. 28 and 18

<table>
<thead>
<tr>
<th>Battery No</th>
<th>Performance measure</th>
<th>SVM*</th>
<th>RVM*</th>
<th>ANFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>RMSE</td>
<td>0.47</td>
<td>5.96*10-5</td>
<td>0.069</td>
</tr>
<tr>
<td>18</td>
<td>RMSE</td>
<td>1.43</td>
<td>0.54</td>
<td>4.93 *10-33</td>
</tr>
</tbody>
</table>

* A. Widodo et al. Intelligent prognostics for battery health monitoring based on sample entropy. 2011 (expert system with applications).
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• Results

Accuray prediction comparison for battery no. 28 and 18

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<tr>
<td>28</td>
<td>Accuracy</td>
<td>&gt;95%</td>
<td>95%</td>
<td>96%</td>
</tr>
<tr>
<td>18</td>
<td>Accuracy</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
<td>100%</td>
</tr>
</tbody>
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• Conclusion

➤ MSE provides rich source of feature from the raw battery data, which has the relation with SOH of battery.

➤ Proposed system is applied successfully to use this relation to automatically predict the life of the battery.

➤ This system based on the MSE and ANFC method is plausible and can be used for Li-ion remaining battery life prediction.