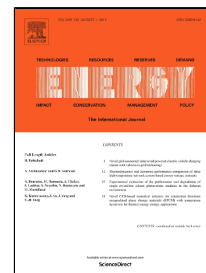


# Accepted Manuscript

A Unified Modeling Framework for Lithium-ion Batteries: An Artificial Neural Network Based Thermal Coupled Equivalent Circuit Model Approach

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2 Neural Network Based Thermal Coupled Equivalent Circuit Model  
3 Approach

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10 **Abstract**

11 The thermal coupled equivalent circuit model provides a vital role not only in accurate and  
12 reliable state monitoring, but also in effective thermal management of lithium-ion batteries.  
13 However, it lacks appropriate modeling strategies for including both the temperature and state of  
14 charge effects into the thermal coupled equivalent circuit model. In this study, a unified artificial  
15 neural network based thermal coupled equivalent circuit model approach is proposed to  
16 accurately and reliably capture the electrical and thermal dynamics of lithium-ion batteries. Both  
17 reversible and irreversible heat generation mechanisms are introduced in the thermal model. The  
18 quantitative relationship between circuit parameters and temperature/state of charge in equivalent  
19 circuit model is modeled by artificial neural network. Both electrical and thermal related  
20 parameters are simultaneously identified by means of least square strategy with  $l_1$ -norm penalty  
21 on output weights in artificial neural network and positive constraints on circuit parameters. The  
22 effectiveness of the proposed artificial neural network based thermal coupled equivalent circuit  
23 model approach is validated by the experimental constant current discharge, pulse current  
24 discharge test and hybrid pulse power characterization test of a commercial large-format pouch-  
25 type lithium-ion battery. It implies that the proposed hybrid modeling strategy can provide a  
26 general framework for the inclusion of other effects such as health state and current into battery  
27 models and can be easily extended to more complicated models such as first-principle  
28 electrochemical-thermal model.

29 **Keywords:** lithium-ion batteries, equivalent circuit model, thermal model, artificial neural  
30 network, state of charge, temperature

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