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ANN approach to SOC estimation of Lithium-Ion Battery

***Abstract**. State-of-charge, or SOC, is an electric vehicle's battery pack's analogue of a gasoline gauge. It becomes crucial to ascertain the status of charge in all battery applications, including electric cars (EVs). This paper's goal is to use an artificial neural network (ANN) to estimate the state of charge (SOC) of a high capacity lithium-ion battery (LIB). This is necessary since SOC cannot be measured directly; instead, it must be calculated using measurable battery metrics like temperature, voltage, and current. It is possible to obtain an accurate predictive model that can predict the SOC in the near future. The simulated data set and the ANN model agreed, indicating the model's strong performance.*

***Streszczenie.** Stan naładowania, czyli SOC, to odpowiednik wskaźnika benzyny w zestawie akumulatorów pojazdu elektrycznego. Ustalenie stanu naładowania akumulatorów staje się niezwykle istotne we wszystkich zastosowaniach, w tym w samochodach elektrycznych (EV). Celem tego artykułu jest wykorzystanie sztucznej sieci neuronowej (ANN) do oszacowania stanu naładowania (SOC) akumulatora litowo-jonowego o dużej pojemności (LIB). Jest to konieczne, ponieważ SOC nie można zmierzyć bezpośrednio; zamiast tego należy go obliczyć na podstawie mierzalnych parametrów akumulatora, takich jak temperatura, napięcie i prąd. Możliwe jest uzyskanie dokładnego modelu predykcyjnego, który będzie w stanie przewidzieć SOC w najbliższej przyszłości. Symulowany zbiór danych i model SSN były zgodne, co wskazuje na wysoką wydajność modelu. (**Podejście ANN do szacowania SOC baterii litowo-jonowej**)*

Keywords: Electric Vehicle, State of Charge, Open Circuit Voltage, ANN
Słowa kluczowe: Pojazd elektryczny, stan naładowania, napięcie obwodu otwartego, SSN

I. Introduction

The transportation sector is moving quickly toward electric vehicles (EVs), which are thought to be more dependable and efficient and are already starting to compete on the market. Depending on the degree of electrification, EVs include all AEVs, more MEVs, PHEVs (Plug-in Hybrid Electric Vehicles), and HEVs (Hybrid Electric Vehicles). Significant funding for EV research and development, production, and commercialization has come from government agencies, academic institutions, business, and the general public in an effort to fulfill the growing demand for EVs. The range of specs for EVs is quite extensive. Numerous technologies are suitable since every application has distinct demands on the motor [1].

The term "energy storage system" (ESS) refers to a group of devices that store surplus electrical energy generated by various sources using mechanical, chemical, electrochemical, and electrical approaches. While each technique has advantages and disadvantages of its own, the environment, independent system operators, equipment manufacturers, end users, regulators, and energy service providers all benefit from these techniques.

Two pieces of information need to be understood in order to plan energy storage systems as efficiently as possible. With the application of the ANN approach, our contribution seeks to:

First, precisely forecast the load profile over the timeframe that the ESS will operate.

Second, use state-of-charge (SOC) estimate to ascertain the system's energy availability at the scheduling time

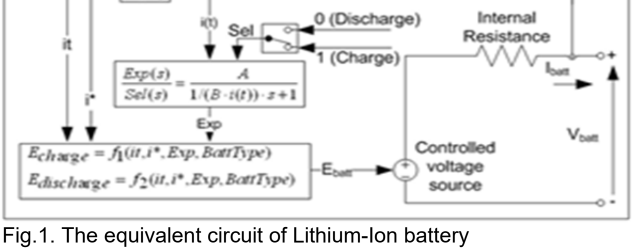

Fig.1. The equivalent circuit of Lithium-Ion battery

.II. LITHIUM-ION BATTERY (LIB) MODELING

In recent years, a large number of battery models with various goals and levels of complexity have been published in technical literature [2–8]. The battery's equivalent circuit is displayed below.[9]:

Discharge Model (i*>0)

$$f_1(it,i^*,i) = E_0 - k\frac{Q}{Q-it}i^* - K\frac{Q}{Q-it}it + Aexp(-B\,it) \quad (1)$$

Charge Model (i*<0)

$$f_2(it,i^*,i) = E_0 - k\frac{Q}{it+0.1Q}i^* - K\frac{Q}{Q-it}it + Aexp(-B\,it) \quad (2)$$

Where: EBatt= Nonlinear voltage (V); E0= Constant voltage (V); Exp(s) = Exponential zone dynamics (V); Sel(s) = Battery mode; Sel(s) = 0 while battery discharge, Sel(s) = 1 while battery charging; K = Constant of polarization (Ah−1) or Polarization resistance (Ω); i* = Low frequency current dynamics (A); i = Battery current (A); it = Extracted capacity (Ah); Q = Maximum battery capacity (Ah)

A = Exponential voltage (V); B = Exponential capacity (Ah)−1

III. SOC estimation in liyhium-ion battery using ANN

An ANN models complicated patterns and prediction issues by using neural network processing as a foundation for creating algorithms. The basic principle below is used to model the simple neuron:

To create the product w.p, the scalar input p is supplied across a link and multiplied by the scalar weight w. According to the summing junction, the bias can be understood as either increasing the product w.p. or shifting the function f to the left by an amount b. Except that its input is always 1, the bias is similar to a weight. The transfer function net input (n), which is also a scalar, is the product of the weighted input (wp) and the bias (b). This sum is the parameter of the transfer function f. [9]. One of the most well-known benefits of an artificial neural network (ANN) is its ability to learn by actually observing data sets.

This research presents the use of ANN for LIB SOC estimation. A MATLAB Neural Net Fitting tool (nftool) with a graphical user interface manages this simulation.

The battery manufacturer's data allows for this sensible assessment. This technical data shows a non-linear relationship between Open Circuit Voltage (OCV) and SOC at six different temperatures, ranging from -30°C to 55°C. Accurate 5 order polynomial equations of the curves are extracted using the curve fitting technique, as shown below in eq. 3 [10], and associated coefficients are displayed in table 1.

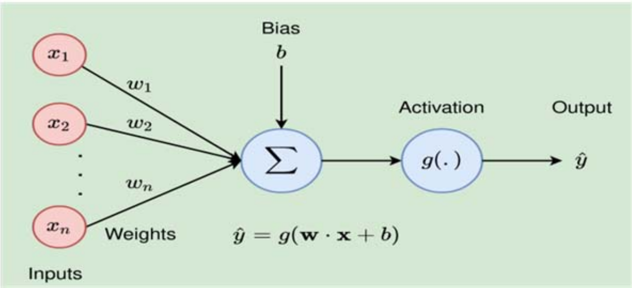

Fig 2. Basic Principles of simple neuron design.

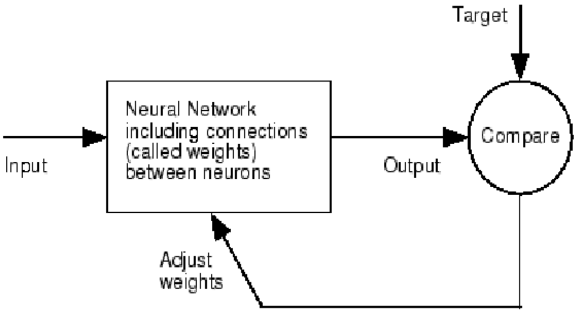

Fig 3. Fundamentals of ANN Design

Table 1. *Coefficients of Approximating Polynomial*

Temperature [°C]	a0	a1	a2	a3	a4	a5
55	3.4710	0.6186	0.5083	-4.6414	8.3420	-4.1599
40	3.4770	0.8145	-1.1715	-0.0489	3.2388	-2.1649
25	3.4613	0.8955	-1.2740	-0.5109	4.2599	-2.6941
0	3.3935	1.0298	-1.6024	1.1475	0.5460	-0.2981
-20	3.4431	0.3995	-0.5327	0.8659	0.6231	-0.5971
-30	2.0284	14.117	-52.030	92.857	-78.174	25.5020

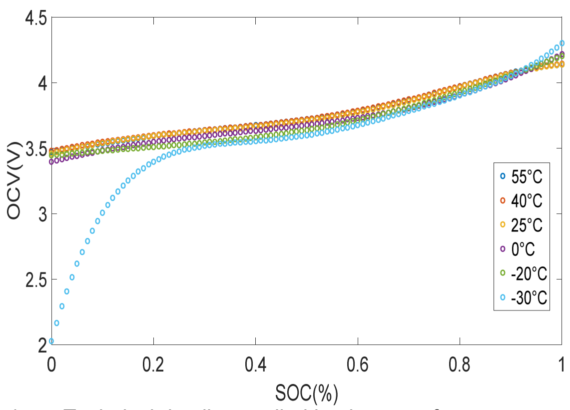

Fig 4 Technical details supplied by the manufacturer at varying temperatures, including SOC and OCV.(Reference Table 1).

The following picture displays the manufacturer's data as they are listed in Table 1.

IV. ANN-based simulation of lithium-ion battery SOC estimation

This kind of artificial neural network (ANN) uses a two-layer "feed-forward backprop" with ten neurons. The training function is denoted by "TRAINLM," while the adaptation learning function is designated by "LEARNFGM."

The performance of the ANN with Matlab is displayed in figures 5-8.

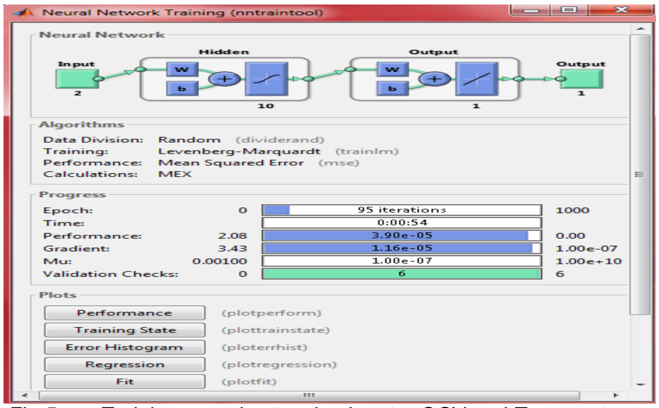

Fig 5. Training neural networks: Input = OCV and Temperature; Output = SOC

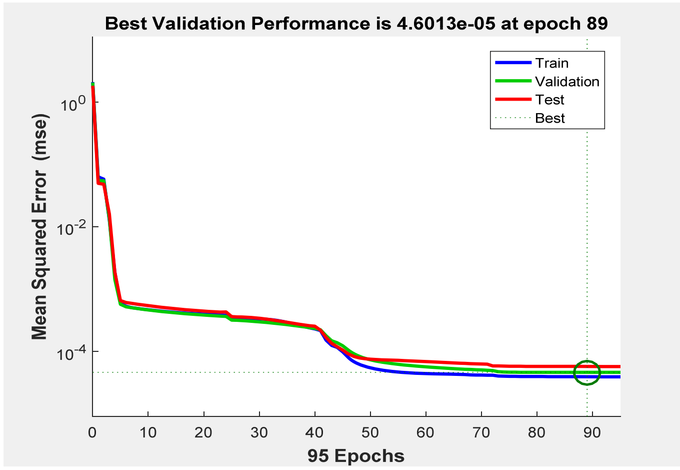

Fig 6. Training neural networks: optimal validation results for SOC estimation

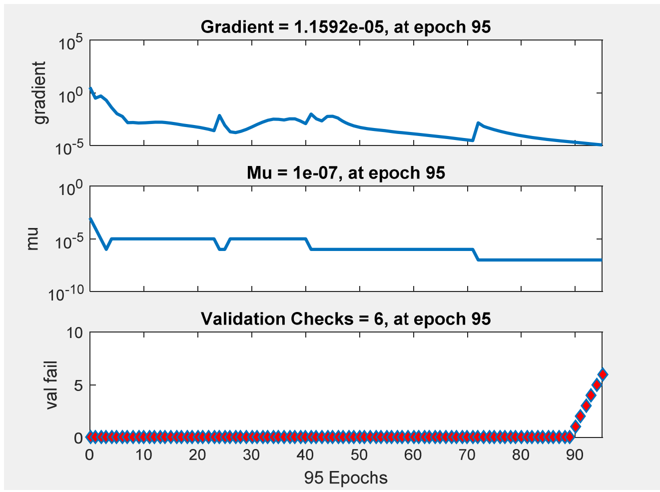

Fig 7. Training state of neural networks for SOC estimation.

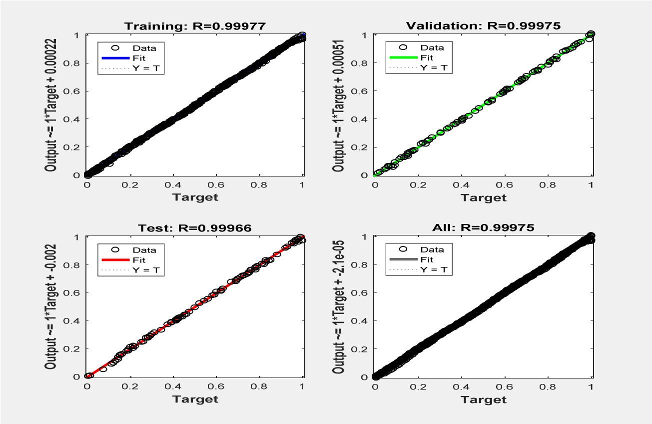

Fig 8. Regression and validation performance of SOC estimation in neural network training.

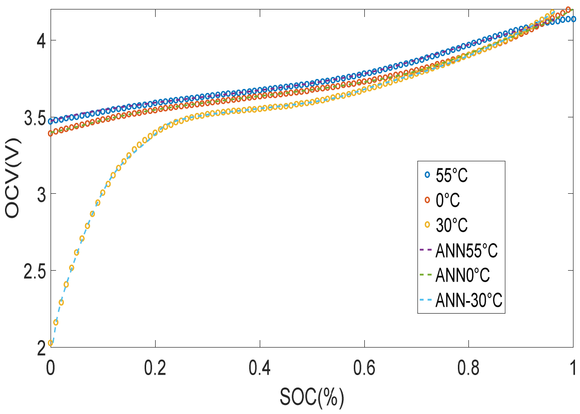

Fig 9. A comparison between the ANN model and the manufacturer.

Figure 9 compares the manufacturer model with the ANN model's prediction. It is evident that the ANN's prediction at -30 °C is accurate..

V. ConclusionN

Temperature has a big impact on how LIB behaves, thus it needs to be predicted. To utilize Lithium-Ion battery packs in energy storage, it is necessary to support the battery management system in maintaining a secure and effective storage system to prevent depreciation and prolong battery life, precision of SOC calculation is essential. The ANN model closely resembles the manufacturer's data, and the results achieved are satisfactory.

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REFERENCES

[1] Wenping Cao, Abid Ali, Shah Bukhari, and Lassi Aarniovuori, "Review of Electrical Motor Drives for Electric Vehicle Applications," Mehran University Research, Journal of Engineering & Technology, Vol. 38, No. 3, pp. 525-540, July 2019
[2] Hartmut Hinz, "Comparison of Lithium-Ion Battery Models for Simulating Storage Systems in Distributed Power Generation," inventions, 4, 41, pp. 1-22, 2019.
[3] Hussein, A.A.H.; Batarseh, I., "An Overview of Generic Battery Models," In Proceedings of the IEEE Power and Energy Society General Meeting, San Diego, CA, USA, pp. 24-29, July 2011.
[4] Sun, K.; Shu, Q., "Overview of the Types of Battery Models," In Proceedings of the 30th Chinese Control Conference, Yantai, China, pp. 22-24 July 2011
[5] Mousavi, G.; Nikdel, N., "Various battery models for various simulation studies and applications," Renew.Sustain. Energy Rev, 32, pp. 477-485, 2014.
[6] Fotouhi, A.; Auger, D.J.; Propp, K.; Longo, S.; Wild, W., "A Review on Electric Vehicle Battery Modelling: From Lithium-ion toward Lithium-Sulfur," Renew. Sustain. Energy Rev., 56, pp. 1008-1021, 2016.
[7] Nejad, S.; Gladwin, D.T.; Stone, D.A., "A systematic review of lumped-parameter equivalent circuit models for real-time estimation of lithium-ion battery states," J. Power Sources, 316, pp. 183-196, 2016.
[8] Meng, J.; Luo, G.; Ricco, M.; Swierczynski, M.; Stroe, D.-I.; Teodorescu, R., "Overview of Lithium-Ion Battery Modeling Methods for State-of-Charge Estimation in Electrical Vehicles," Appl. Sci., 8, 659, pp.1-17,2018.
[9] Matlab/2016
[10] Mohamed A. Awadallah, Bala Venkatesh, "Accuracy improvement of SOC estimation in lithium-ion batteries," Centre for Urban Energy, Ryerson University, Toronto, Canada, Journal of Energy Storage,2016,Vol 6,pp 95-104