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Comparison of SoC in Ni-MH and Lithium-Ion Battery for E-Vehicle

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ABSTRACT- The current energy side of the battery is indicating in a percentage level is called state of charge (SOC). Nickel-metal hydride and lithium-ion batteries are a type of rechargeable battery. The chemical response at the positive electrode in nickel-metal hydride (NiMH) batteries is like that in nickel-cadmium (NiCd) batteries, as both use nickel oxide hydroxide NiO(OH). However, while NiCd cells use cadmium, NiMH batteries feature a hydrogen-absorbing alloy in their negative electrodes. NiMH batteries provide two to three times the capacity and a significantly higher energy density compared to NiCd batteries of the same size. The research was mainly focused on the aspect of SoC of Ni-MH and Lion batteries with operation of an electric vehicle with total weights of 600 kg was investigated using mat lab Simulink.

Keywords: SoC, Nickel–metal hydride battery, Lion battery, Electric vehicle, MATAB/Simulink.

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1. INTRODUCTION

Electric vehicles are ahead popularity as a preferred mode of transportation. Experts anticipate that by 2030, electric vehicles may make up approximately 25% of all vehicles globally [1]. In E vehicles, the engine operates using fuel, while the motor is energized by a battery [2]. Repeated overcharging of a NiMH battery can cause the development of small crystals on the electrodes, which diminishes their ability to fully charge and leads to lower voltage. Conversely, undercharging can degrade the battery's performance, while overcharging can shorten its lifespan. To mitigate these problems, our cost-effective Battery Management System (BMS) prevents overcharging and protects against potential damage. Lithium-ion batteries, frequently used in electric bikes, provide consistent performance and high output. They are lighter, more compact, and more costly compared to traditional lead-acid batteries. Lithium-ion batteries is their capability for rapid charging and slow discharging, which enables quick vehicle recharges and extended usage. They also function well at elevated temperatures. With their lightweight construction and superior power-to-weight ratio, lithium-ion batteries typically deliver better performance compared to lead-acid batteries and some other options.

The primary objective of the research work was to assess the energy consumption of a vehicle fitted with a battery pack and to explore how the vehicle's overall weight influences its energy usage. An E_{drv+} is denoted as energy drawn from the battery when vehicle in operating is given by the *equation (1):*

$$E_{drv+} = \int_{t0}^{t1} V.I\, dt, \tag{1}$$

When the current *I* greater than 0

The E_{drv-} is denoted as the energy delivered to the battery when regenerative braking was occurred in the vehicle resolute by the *equation (2):*

$$E_{drv-} = \int_{t0}^{t1} V.I\, dt, \tag{2}$$

When the current *I* lesser than 0

The total energy is calculated by using *equation (3):*

$$E_{drv} = E_{drv+} + E_{drv-} \tag{3}$$

Despite technological progress, many countries still lack effective recycling systems for BEVs. Moreover, the widespread use of BEVs and other electrical devices results in considerable energy consumption, potentially increasing CO2 emissions, particularly in areas without access to renewable energy sources [4]. Integrating regenerative braking technology into electric vehicle designs can notably improve their energy efficiency [5,6]. However, their widespread use is limited by issues such as high costs, potential overheating risks, and a finite lifespan. Nickel-metal-hydride batteries, when employed in hybrid propulsion systems and maintained within a state of charge (SOC) range of about 30-70%, demonstrate exceptional durability, often lasting more than 10 years [9]. The electrolyte concentration profiles in NiMH batteries display a steady increase throughout the discharge cycle, without significant fluctuations. This consistent behavior is attributed to reduced concentration polarization caused by electrolyte transport limitations. It has been observed that the losses in NiMH batteries are larger and remain constant during operation. In contrast, Li-ion batteries exhibit less variation in losses. The concentration of the electrolyte has a direct impact on the overpotential losses that occur during both the charging and discharging phases [10]. This study aims to present an overview of recent developments in lithium-ion (Li-ion), lead-acid, and nickel metal hydride (NiMH) batteries used in electric vehicles (EVs). The research focuses on enhancing battery performance in terms of energy and power density, safety, and cost. Different approaches from the literature have been analyzed and compared to highlight advancements in these areas [11].

The Comparison of NiMH and Lion batteries are shown in *table 1*.

Table 1. Parameters of Ni-MH and Lion battery [12]

Parameters	**Ni-MH battery**	**Lion battery**
Cost	Moderate	High
complex battery management system	Not Required	Required
Safety	Fuse protection is enough	Required Protection Circuits
Recycling of waste batteries	Easy	Not easy
Discharge	Lower SoC	Higher SoC

2. DESIGN SPECIFICATION OF E VEHICLE USING MAT LAB SIMULINK

As known, it is evident that knowing the electric loading of the stator is necessary for the magnetic field analysis to simplify the mathematical analysis, the height of the stator coils is assumed to be negligibly small and the distributed stator winding is replaced by a current sheet carrying the stator electric loading. Usually, the excitation system which produces the rotating magnetic field is consisting of poly-phase windings. Each phase windings for disc motor are embedded in radial direction in slots of a laminated iron core of one stator side. Thus, both stator electric loadings and the corresponding flux density waves are the specification of electric vehicles which is used in the Simulink as mentioned in the *figure 1*. The longitudinal driver controls acceleration based on the braking command, using both reference and feedback velocity. The control type of longitudinal driver is PI and the reference and feedback unit is mentioning Km/Hr. The limitation of the simulation model is 1000 sec, the signal will linearly increase, remain constant for next 200 sec and decrease linearly for rest of the time.

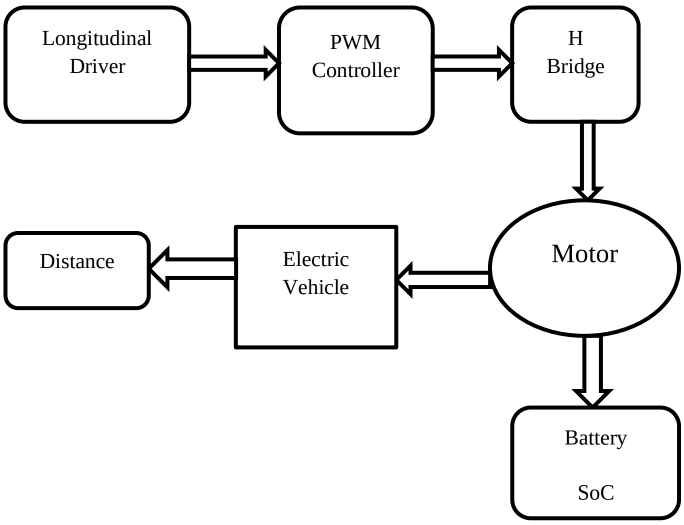

Figure 1. Block Diagram of Electric Vehicle based on MATLAB/ Simulink

The parameter setting in the PWM frequency is 50 Hz and the Simulation mode is averaged. The input voltage for duty cycle 0% and 100% is maintained 0 and 1 V respectively and the output voltage amplitude is 1V as shown in *table 2*. This block creates a Pulse-Width Modulated (PWM) voltage across the PWM and REF ports. The output voltage is zero when the pulse is low, and is equal to the Output voltage amplitude parameter when high.

Table 2. Parameter settings for controlled Pulse-Width Modulated (PWM) in MAT LAB Simulink

PWM	PWM Frequency	50 Hz
	Simulation Mode	Averaged
Input	Input voltage for duty cycle 0%	0
	Input voltage for duty cycle 100%	1 V
Output	Output voltage amplitude:	1 V

In H-bridge, the simulation mode power supply should be maintained as internal and regenerative braking depends on REV flag and current sign. The Enable threshold voltage, Reverse threshold voltage, Braking threshold voltage should be fixed as 0.0001 V as indicated in *table 3*. In output voltage amplitude is 50 V,0.1 and 0.05 ohms is maintained for bridge resistance and freewheeling diode resistance respectively. The freewheeling diode off state conductance value is 1 e^{-6} S.

Table 3. Parameter settings for H Bridge in MATLAB/ Simulink

Simulation Mode & Load Assumption	Power supply	Int
	Simulation Mode	Avg
	Regenerative braking:	Depends on Current sign and REV flag.
	Load current characteristics:	Smooth
Input Threshold	Enable threshold voltage:	0.0001 V
	Reverse threshold voltage:	
	Braking threshold voltage:	
	PWM signal amplitude:	1

The Vehicle Body weight is 600 Kgs and the number of wheels in axle is, the Horizontal distance from CG to front axle and rear axle is fixed as 1.4 and 1.6 m respectively. The density of air and drag coefficient is 1.18 Kg/m^3 and 0.25, the frontal area of the vehicle is 2 m^2 as shown in the *table 4*.

Table 4. Parameter settings for Vehicle body in MAT LAB/Simulink

Main	Mass:	600 Kgs
	No of wheels in axle:	2
	Horizontal distance from CG to front axle and rear axle:	1.4 and 1.6 m
	CG height from ground level	0.5 m
	Gravity	9.81 m/s^2
Drag	Front area:	2 m^2
	Coefficient of Drag	0.25
	Density of Air	1.18 Kg/m^3

The Tire rolling radius is 0.3 m, Static and Kinetic friction coefficient is 0.90 and 0.70 respectively. The traction velocity and engagement force are 0.1 m/s and 10 N, the tire is slipping at initial condition as specified in *table 5*. Represents a model of a tire parameterized with static and kinetic friction coefficients. When the static friction limit is exceeded, the tire loses traction and begins to slip. The kinetic friction coefficient determines the ability of the tire to transmit torque when slipping. The kinetic friction coefficient is fixed or a function of the current slip. The tire regains traction when the magnitude of the relative velocity between the tire and ground is less than the traction velocity tolerance parameter.

Table 5. Parameter settings for Vehicle tire in MATLAB/ Simulink

Main	Rolling radius:	0.3 m
	Static and Kinetic friction coefficient:	0.90 and 0.70
Advanced	Traction velocity and Engagement force:	0.1 m/s and 10 N
	Initial traction state:	Tire is initially slipping

This model provides a generic framework for various common battery types. It allows for the specification of temperature and aging effects (due to cycling) for Lithium-Ion and Nickel-Metal-Hydride batteries, as detailed in *table 6*. Nominal voltage (V) and Rated capacity (Ah) is 50 V ,50Ah respectively. The Response time of Battery is 30 s and Initial SoC is 100% as detailed in *table 7*.

Table 6. Parameter settings for Vehicle Battery in MAT LAB Simulink

Nominal voltage (V) and Rated capacity (Ah)	**50V and 50Ah**
Initial SoC	100 %
Response time of Battery	30 s

This DC motor model captures both electrical and torque characteristics, assuming no loss of electromagnetic energy. Consequently, the back-emf and torque constants are numerically identical in international standard units. The field type of the motor is permanent magnet and model of the motor is rated load and speed, the armature inductance is 12µH.The No-load speed and Rated speed (at rated load) are 14000 RPM and 12000 RPM respectively. The supply voltage and capacity of the motor is 50V and 50KW as detailed in *table 7*.

Table 7. Parameter settings for DC Motor in MATLAB/ Simulink

Electrical Torque	Type of Field	PM
	Model	By rated Load as well as Speed
	inductance (Armature):	12 *10^{-6} H
	No-load speed and Rated speed (at rated load)	14000 RPM and 12000 RPM
	Power	50 KW
	DC supply voltage:	50 V

3. RESULTS AND DISCUSSION

State of Charge (SoC) reflects the amount of energy that can be extracted from a battery. It plays a crucial role in avoiding both over-discharge and over-charge situations, thereby helping to maintain the battery's health and reduce aging effects [15]. Classifying these methods is challenging because many approaches integrate two or more techniques and incorporate various heuristic or deterministic mathematical tools [16]. In this research the SoC analysis of nickel–metal hydride battery and Lithium Ion Battery in Electric Vehicle. First make a signal builder in a Mat Lab Simulink signal which will linearly increase between 0 to 400 seconds and next 200 seconds speed would be 100 Km/Hr. The remaining seconds speed would be decreases from 50 Km/Hr to zero and the signal builder is connected to longitudinal driver velocity reference as an input, the signal wave form is shown in *figure 2*.

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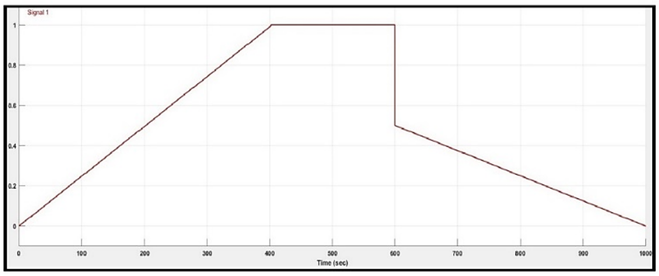

Figure 2. Input signal of velocity reference in longitudinal driver block

The actual and reference speed calculate the following things, first one is the actual speed is based on signal builder and trying to follow the reference speed and the reference speed is that approximately 50 Km/hr in actual speed from graph as shown in *figure 3*.

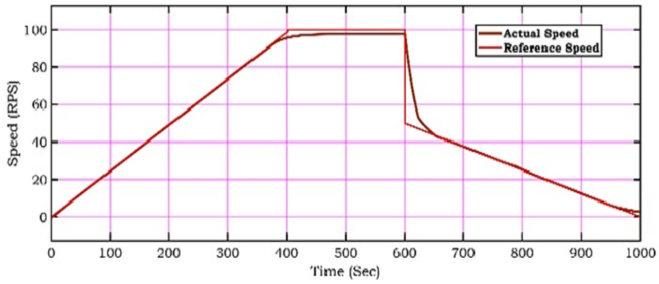

Figure 3. Actual and reference speed of the Vehicle

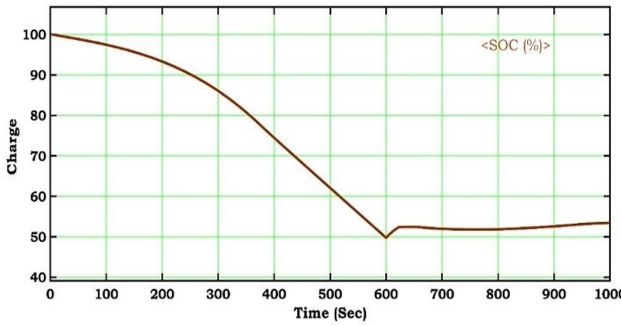

Figure 4. SoC of Lithium Ion Battery

The *figure 4* shows the State of Charge for the Lithium-Ion battery, up to 400 seconds the battery is discharged non linearly and 400-600 seconds the battery is discharged linearly, after 600 seconds the battery is having 50 percentage of charge then slowly increase the charge and discharge based on the feedback system of the vehicle.

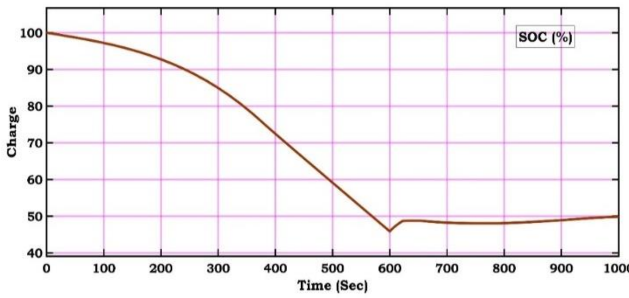

Figure 5. SoC of Nickel–Metal Hydride battery

The *figure 5* shows the SoC for the NiMH battery, up to 400 seconds the battery is discharged non linearly and 400-600 seconds the battery is discharged linearly as same like Lithium-Ion battery, after 600 seconds the battery is discharged 45 percentage of charge at 600 seconds. In Lithium-Ion battery drained 50 percentage at 600 seconds whereas nickel–metal hydride battery drained 45 percentage only at same interval and charge store in the battery is 55 percentage.

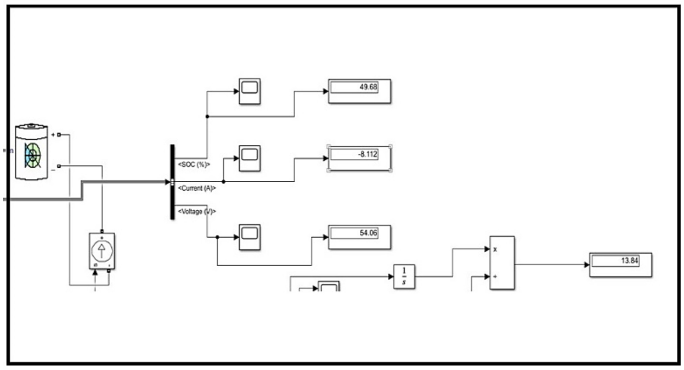

Figure 6. Simulink Model of Lithium Battery SoC and Distance Travel by the Vehicle

The Simulink model has run for 1000 seconds in Mat Lab software, the SoC percentage is 49.68 %, approximately 50 % discharged and the distance travelled by the vehicle is 13.84 Kilo meter per 1000 seconds as shown *figure 6*. Here, the same current which will flow from battery to motor during acceleration and during breaking action current will flow from motor to battery.

In MATLAB, when studying battery performance, the scope typically displays data related to the battery's charge status.

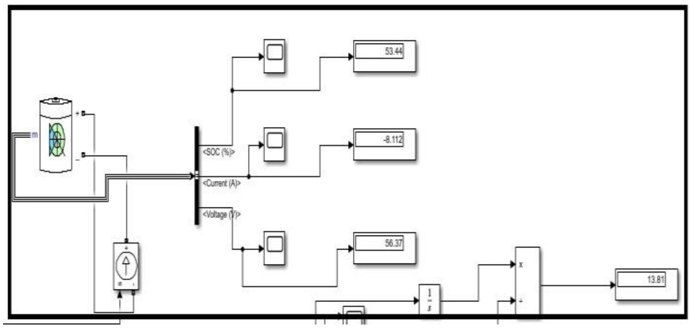

Figure 7. Simulink Model of Nickel–Metal Hydride Battery SoC and Distance Travel by the Vehicle

The Simulink model of Nickel–Metal Hydride Battery has run same as lithium-Ion model, in NMH battery still having a charge of 53.44 percentage (approximately 54%) and only 46 percentage discharged during the period of 1000 Seconds as shown in *figure 7*. The acceleration and breaking are same as Lithium-Ion Battery model. The distance travelled by the vehicle is 13.81 Kilometer per 1000 seconds while using the Nickel–Metal Hydride Battery and almost travel a distance equal to the Lithium-Ion Battery. In the *figure 8*, the distance travelled by the electric vehicle is almost equal and the discharge of lithium-ion battery is less than Nickel–Metal Hydride battery.

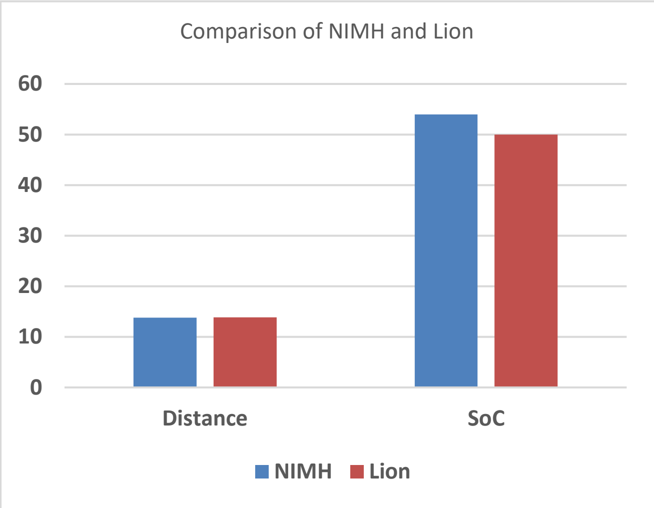

Figure 8. Comparison Chart of Nickel–Metal Hydride and Lithium-Ion Battery's SoC and Distance Travel by the Vehicle

4. CONCLUSION

In this study, Ni–MH batteries are manufactured in large quantities, with global annual production exceeding 1 billion cells for portable power uses. Simulation estimates indicate that in Lithium-Ion Battery travelled 13.84 KM for 1000 seconds, calculating per hour is 49.8 KM/Hour and discharge the battery is 50 percentage. In Ni–MH battery travelled 13.81 Km per 1000 seconds that is 49.72 KM/Hour almost equal distance covered by using Lithium-Ion Battery at same time the discharge level is 46 percentage only. Lithium batteries are expensive, need complex protection circuits, are challenging to recycle, and have higher state of charge (SoC) levels. In contrast, Ni–MH batteries are more affordable, require only a simple fuse for protection, are easier to recycle, and operate at lower SoC levels. The study concludes that Ni-MH batteries are better suited for high current rate discharges compared to Li-ion batteries. The effects of SOC and current rates on energy efficiency under pulse current rates were analyzed. For both battery types, energy efficiency shows slight variations with SOC but declines significantly as current rates increase.

REFERENCES

[1] Brooke L, not dead yet: The resilient ICE looks to 2050, Automotive Engineering, vol.5(4), 2018, 22–23.

[2] M. B Smith and J. Castellano, Costs associated with non-residential electric vehicle supply equipment, U.S. Department of Energy, Atlanta, Bost, 2015.

[3] Delucchi M,Yang C,Burke A,Ogden J,Kurani K,Kessler J, An assessment of electric vehicles: technology, infrastructure requirements ,greenhouse-gas emissions, petroleum use, material use, life time cost, consumer acceptance and policy initiatives.Philos TransR Soc A 2014;372:203–25.

[4] Mariasiu F. Energy Sources Management and Future Automotive Technologies: Environmental Impact. IntJ Energy Econ Policy 2012; 2:342–7.

[5] Varga BO.Energy management of electric and hybrid vehicles dependent on power train configuration. Cent Eur JEng 2012; 2:253–63.

[6] Damiani L,Repetto M,Prato AP. Improvement of power train efficiency through energy breakdown analysis. ApplEnergy2014;121:252–63.

[7] Sutikno T,Idris NRN,Jidin A.A review of direct torque control of induction motors for sustainable reliability and energy efficient drives. Renew Sustain Energy Rev 2014; 32:548–58.

[8] Sergio Manzetti, Florin Mariasiu,"Electric vehicle battery technologies: From present state to future systems"Renewable and Sustainable Energy Reviews,51, (2015),1004–1012.

[9] Marcin Noga,Zdzislaw Juda,"The application of NIMH batteries in a light-duty electric vehicle",TECHNICAL TRANSACTIONS 1/2019,MECHANICS,197-221,DOI: 10.4467/2353737XCT.19.014.10054.

[10] Umapathi Krishnamoorthy, Parimala Gandhi Ayyavu, Hitesh Panchal, Dayana Shanmugam,Sukanya Balasubramani, Ali Jawad Al-rubaie, Ameer Al-khaykan, Ankit D. Oza, Sagram Hembrom,Tvarit Patel, Petrica Vizureanuand Diana-Petronela Burduhos-Nergis,"Efficient Battery Models for Performance Studies-Lithium Ion and Nickel Metal Hydride Battery",Batteries , Vol.9 ,pp.1-14,2023,https://doi.org/10.3390/batteries9010052.

[11] Ourici A (2023) Battery Technologies Comparison for Electric Vehicles. Indian Journal of Science and Technology 16(20):1461-1468. https://doi.org/10.17485/IJST/v16i20.2221.

[12] BU-107: Comparison Table of Secondary Batteries, https://batteryuniversity.com/learn/article/secondary_batteries (access: 15.05.2018).

[13] Vignesh, R.; Ashok, B. Intelligent energy management through neuro-fuzzy based adaptive ECMS approach for an optimal battery utilization in plugin parallel hybrid electric vehicle. Energy Convers. Manag. 2023, 280, 116792.

[14] Ibrahim, M.A.; Alsammak, A.N. Dynamic Modelling and Current Control for Switched Reluctance Motor Drives in Electric Vehicles. IOP Conf. Ser. Mater. Sci. Eng. 2023, 1295, 012006.

[15] Tang, X.; Liu, B.; Gao, F. State of charge estimation of lifepo4 battery based on a gain-classifier observer. Energy Procedia 2017, 105, 2071–2076, https://doi.org/10.1016/j.egypro.2017.03.585.

[16] Fleischer, C.; Waag, W.; Bai, Z.; Sauer, D.U. Adaptive on-line state of available power prediction of lithium-ion batteries. J. Power Electron. 2013, 13, 516–527.https://doi.org/10.6113/JPE.2013.13.4.516.

[17] Wu B, Chen C, Danilov DL, Eichel RA, Notten PHL. All-Solid-State Thin Film Li-Ion Batteries. New Challenges, New Materials, and New Designs Batteries.2023;9(186). https://doi.org/10.3390/batteries9030186.

[18] Schmidt-Rohr K. How Batteries Store and Release Energy: Explaining Basic Electrochemistry. Journal of Chemical Education. 2018;95(10):1801–810. https://doi.org/10.1021/acs.jchemed.8b00479.

[19] Kim J, Oh J, Lee H. Review on battery thermal management system for electric vehicles. Applied Thermal Engineering. 2019; 149:192–212. https://doi.org/10.1016/j.applthermaleng.2018.12.020.

[20] Luo W., Zhu S., Gong J., Zhou Z., Research and Development of Fire Extinguishing Technology for Power Lithium Batteries, Procedia Engineering, vol. 211, 2018, 531–537, 10.1016/j.proeng.2017.12.045.

[21] Markel T., Brooker A., Hendricks T., Johnson V., Kelly K., Kramer B., O'Keefe M., Sprik S., Wipke K., ADVISOR: A systems analysis tool for advanced vehicle modeling,J of Power Sources, vol. 110(2), 2002, 255-266, 10.1016/s0378-7753(02)00189-1.

[22] Shin J.W., Kim J.O., Choi J.Y., Oh S.H., Design of 2-speed transmission for electric commercial vehicle, International Journal of Automotive Technology, vol. 15(1), 2014, 145–150,10.1007/s12239-014-0016-8.

[23] Slaski G., Ohde B., A statistical analysis of energy and power demand for the tractive purposes of an electric vehicle in urban traffic – an analysis of a

Review Article | Volume 12, Issue 4| Pages 1258-1263 | e-ISSN: 2347-470X

short and long observation period, IOP Conf. Ser.: Mater. Sci. Eng., vol. 148, 2016, 012027, 10.1088/1757-899X/148/1/012027.

[24] Young K.H., Ng K.Y.S., Bendersky L.A., A Technical Report of the Robust Affordable Next Generation Energy Storage System-BASF Program, Batteries, vol. 2(1), 2016, 2, 10.3390/batteries2010002.

[25] Zhu J.H., Liu C.T., Pike L.M., Liaw P.K., A thermodynamic interpretation of the size-ratio limits for laves phase formation, Metallurgical and Materials Transactions A, vol. 30(5), 1999, 1449–1452, 10.1007/s11661-999-0292-5.