Technium Electro
Technium Electro Vol. 3, pp.12-21 (2025)
ISSN:3008-6795
www.techniumscience.com

State of the Art in Battery Technologies and Future Perspectives for Autonomous Naval Platforms

Pascu Adrian-Nicolae [1], **Cristea Ovidiu** [1], **Popa Adrian** [1], **Manea Mihaela-Greti** [1]

[1] Romanian Naval Academy" Mircea cel Batran", Fulgerului Street, no.1, Constanta

Corresponding author: Pascu Adrian-Nicolae- adrian.pascu@anmb.ro

Abstract. This paper investigates the integration of advanced battery technologies within naval energy systems, with a particular emphasis on their application in autonomous surface vehicles (ASVs). The study examines key electrochemical storage solutions, such as Li-ion, lithium-titanate (LTO), and solid-state batteries, highlighting their operational advantages, technological limitations, and suitability for deployment in marine environments. As part of the experimental component, a robotic arm prototype designed for an ASV was developed using specialized engineering software. The power supply architecture was implemented through three series-connected Li-ion cells, and subsequently validated through circuit modeling in Fritzing. The experimental results demonstrate the reliability and efficiency of Li-ion accumulators as a viable energy source for naval applications, thus supporting the transition towards sustainable and hybrid electro-energy systems in maritime operations.

Keywords. Li-ion batteries, ASV, naval energy systems, robotics

1. Introduction

The need for energy has increased drastically due to population growth, and improving energy efficiency is necessary for progress in the economy and technology. Conventional energy sources, or non-renewable energy sources, are finite resources that become depleted over time. Non-renewable energy is defined as energy that does not regenerate at a sufficient rate to allow long-term economic extraction on a human scale. Coal, crude oil, natural gas, and uranium are examples of non-renewable energy sources.[1][2][3]

Energy from fossil fuels, such as coal, oil, natural gas, nuclear material, the sun, and wind, are the primary sources of electricity. Wind, sunlight, and flowing water are used to generate energy, while coal, oil, and natural gas are used directly in vehicles and equipment.

Economic growth in recent decades has been driven by increased production activity, which in turn has been accompanied by significant energy consumption. Technological innovations, financial development, economic growth, and the consumption of renewable energy have a direct impact on the ecological footprint.[4][5]

2. Energy sources in the naval domain

A. Conventional Energy Sources

At present, naval propulsion systems rely predominantly on liquid fuels and, to a growing extent, on liquefied natural gas (LNG).[6] Among the most widely employed are marine gas oil (MGO) and marine diesel oil (MDO), whose extensive global availability ensures their widespread use across the maritime sector. However, the combustion of these fuels results in significant emissions of CO_2, sulfur oxides (SO_x), and nitrogen oxides (NO_x), which has led to increasingly stringent restrictions under international regulations such as MARPOL and IMO directives.[7][8]

LNG is generally perceived as a transitional alternative, given its capacity to substantially reduce SO_x, NO_x, and CO_2 emissions. For large-scale vessels (e.g., frigates, naval ships), gas turbines are frequently employed to achieve superior power density and rapid response capabilities.[9] While these propulsion systems provide a highly favorable power-to-weight ratio, they are also characterized by elevated fuel consumption.

B. Alternative Energy Sources

Driven by regulatory pressures and the International Maritime Organization’s (IMO) decarbonization targets, the development and deployment of alternative energy solutions have gained momentum:

- Fuel cells: Operating with hydrogen or methanol, these devices generate electricity through electrochemical reactions without combustion, offering high efficiency and, in the case of pure hydrogen, zero-emission operation.
- Renewable energy: Refers to power derived from natural processes and fluxes, including wind, solar, hydro, wave, geothermal, and bioenergy sources, which can be harnessed to complement or partially substitute conventional propulsion.[10][11], [12]
- Hybrid systems and batteries: Hybrid propulsion architectures—combining conventional engines with high-capacity batteries—are increasingly adopted in the maritime domain. Such systems enable vessels to operate in “zero-emission” mode within ports or environmentally sensitive areas. Additionally, hybridization enhances overall efficiency by allowing conventional engines to operate at steady-state loads, while batteries supply peak demand, thereby reducing fuel consumption and mechanical wear.[1][4]

C. The Role of Batteries in Enhancing Energy Efficiency

Battery storage systems have become pivotal in advancing maritime decarbonization strategies, serving as an effective bridge between conventional and renewable energy sources. Their integration provides multiple operational and environmental benefits, including:[13]

- Mitigation of greenhouse gas emissions;
- Reduction of overall fuel consumption;
- Enhancement of global energy efficiency across vessel operations;
- Storage of renewable energy for optimized, demand-driven utilization.

3. Battery development status

The fundamental operating principle of batteries is governed by the redox reactions occurring during the processes of energy storage and release. These reactions involve the transfer of electrons at the electrodes, which defines the electrochemical behavior of each system. Depending on their chemical composition and cell architecture, batteries are classified into several categories:[6], [10][14]

- Carbon-Zinc batteries
- Alkaline batteries
- Nickel-Cadmium (Ni-Cd) batteries
- Lithium-Ion (Li-Ion) batteries
- Lead-Acid batteries

Carbon-Zinc batteries typically deliver a nominal voltage of 1.5 V; however, their output decreases progressively as the battery discharges. Furthermore, their efficiency deteriorates significantly under low-temperature conditions.[15]

Alkaline batteries emerged as an improved alternative to carbon-zinc cells. They offer several advantages, including up to five times higher energy output, superior energy density, enhanced performance, and extended service life. Their main drawback lies in their inability to be recharged, which limits their long-term applicability.[9]

Nickel-Cadmium batteries generate voltages in the range of 1.2–1.5 V and can undergo up to 1,000 charge–discharge cycles. They exhibit strong resilience under adverse weather conditions, particularly low temperatures. Compared to Li-Ion batteries, Ni-Cd systems generally have a longer lifespan and lower maintenance requirements. However, their commercial cost is higher, their energy density is lower, and cadmium's toxicity necessitates specialized handling and disposal protocols.[16]

Lithium-Ion batteries represent one of the most widely adopted technologies, particularly in aerospace and defense applications, due to their rechargeability, high energy density, lightweight construction, and compact form factor. Typically delivering around 3.7 V per cell, they provide excellent performance, although their cycle life is reduced after two to three years of operation.[17][9][18] Key disadvantages include their relatively high cost, the reactivity of lithium as a chemical element, and associated environmental concerns. To mitigate safety risks such as short-circuiting and potential ignition, separators are employed between electrodes to reduce the likelihood of thermal runaway.

Lead-Acid batteries were the first rechargeable technology to be commercialized. They are inexpensive, capable of delivering high current outputs, and remain widely used. Each cell generates approximately 2 V, with six cells connected in series producing 12 V. They recharge rapidly and maintain reliable performance under low-temperature conditions.[19]

The incorporation of batteries into naval energy architectures is a crucial step toward modernization and the reduction of carbon emissions in maritime transport. At present, batteries are primarily employed as complementary power sources, operating alongside conventional fossil-fuel engines rather than serving as stand-alone systems.[17]

In practice, batteries are integrated through energy management systems that coordinate power flows between generators, consumers, and storage units. Their applications currently include:[9]

- Peak-shaving, by covering demand surges and maintaining engines at optimal load conditions
- Power supply during port entry and departure, reducing both emissions and acoustic pollution
- Storage of surplus energy from renewable sources for later use

A critical aspect of battery deployment is operational safety, which is ensured through advanced monitoring systems that track parameters such as temperature, voltage, and current to prevent thermal runaway. Moreover, optimizing charge–discharge cycles plays a pivotal role in extending service life and reducing operational costs.[9]

Through these functionalities, batteries are no longer limited to auxiliary or backup roles but are emerging as fundamental components of modern naval energy architectures. Their integration not only reduces emissions in line with international decarbonization strategies but also supports the transition from conventional to hybrid and fully electric maritime systems.[1]

4. Innovations in battery technology and their applications in autonomous naval energy systems

The advancement of stored energy technologies, particularly rechargeable batteries, represents a decisive factor in the transition towards sustainable and high-efficiency naval energy systems. Within the context of unmanned surface vehicles (USVs), the integration of advanced energy storage solutions has become indispensable to ensuring extended autonomy and operational reliability.[20]

Technological progress has enabled the adaptation of a broad spectrum of battery chemistries to maritime applications, including:[4]

- Lithium-Ion (Li-Ion) batteries, which remain the most prevalent due to their high energy density, reliability, and relatively short recharge times.
- Lithium-Titanate (LTO) batteries, preferred in applications requiring extended lifecycle performance and enhanced safety margins.
- Solid-State batteries, currently in the development stage, offering superior energy density alongside a significantly reduced risk of thermal runaway and fire hazards.
- Conventional lead-acid batteries, historically the most widely used in naval systems, are progressively being phased out due to their lower energy efficiency and considerable weight limitations.
- In autonomous naval platforms, battery integration has become increasingly frequent and takes several forms:
- Supplying on-board electronics and sensor arrays;
- Powering small-scale electric propulsion systems to minimize noise, vibration, and emissions;
- Supporting hybrid architectures in combination with auxiliary generators to extend operational endurance.

A relevant example is the implementation of rechargeable batteries in small-scale USVs, where they provide several hours of autonomy. This functionality is supported by Battery Management Systems

(BMS), which optimize charge–discharge cycles while ensuring real-time monitoring of safety parameters.[9][16][21]

Despite their growing adoption in maritime applications, batteries continue to face several challenges that restrict large-scale deployment in the naval sector, including:

- Limited endurance compared with conventional fossil fuels;
- Risks of overheating and the associated need for advanced thermal management solutions;
- Progressive performance degradation over time, accompanied by recycling requirements;
- High acquisition and integration costs within naval environments.

These factors illustrate both the transformative potential and the current limitations of battery technologies in naval applications, underscoring the need for continued research and innovation to enable their widespread adoption in line with global decarbonization strategies.[17]

5. Mathematical modelling of the robotic system

The development of a robotic system intended for integration within Unmanned Surface Vehicles (USVs) requires not only a practical approach to design and assembly but also a rigorous mathematical foundation. Mathematical modeling plays a central role in both the design and optimization processes, as it enables accurate dimensioning of components, determination of functional parameters, and structural validation of the overall assembly.[22]

In the case of the current prototype, a series of strength and resistance calculations were performed, ranging from basic estimations to more comprehensive computational analyses. Consequently, this chapter outlines the mathematical methodology employed in the design of the robotic system, providing a robust basis for future developments aimed at achieving reliable and efficient autonomous solutions.

The robotic system, equipped with seven stepper motors (as illustrated in Figure 1), facilitates both rotational and translational movements of individual components. Its mathematical formulation is based on the following relation:[23]

Θi=generalized coordinates, i=1, 2, …, 7
li=length of element i

This mathematical framework establishes the foundation for the kinematic and dynamic modeling of the robotic architecture, ensuring accurate prediction of system behavior under operational conditions.

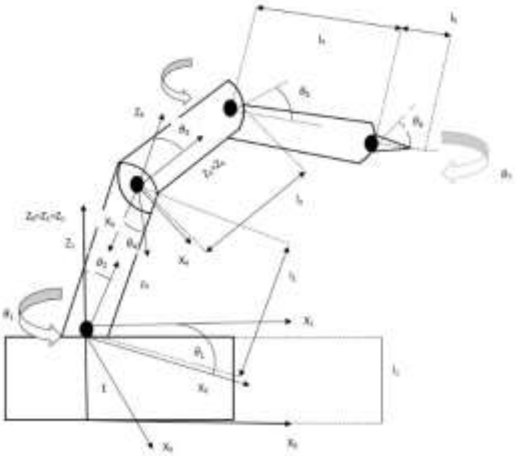

Fig. 1. Robotic system with 7 degrees of freedom

The control objective consisted in determining the joint parameters required to achieve a desired position of the end-effector. This target position was defined by the reference values of the Cartesian coordinates (x, y, z) together with the angular variables θ_6 and θ_7, which govern the rotational configurations of the final joint. The position of the end-effector was determined according to the following equation:[23], [24]

$$EE = T_z(l_1)R_z(\theta_1)R_y(\theta_2)T_z(l_2)R_y(\theta_3)T_z(l_3)R_z(\theta_4)R_y(\theta_5)T_z(l_4)R_y(\theta_6)R_x(\theta_7)[0 \quad 0 \quad l_5 \quad l]^T \tag{1}$$

$$T_z(l_1) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & l_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

$$T_z(l_2) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & l_2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

$$R_z(\theta_1) = \begin{bmatrix} \cos(\theta_1) & -sin(\theta_1) & 0 & 0 \\ sin(\theta_1) & cos(\theta_1) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4}$$

$$R_z(\theta_4) = \begin{bmatrix} \cos(\theta_4) & -sin(\theta_4) & 0 & 0 \\ sin(\theta_4) & cos(\theta_4) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{5}$$

$$R_y(\theta_2) = \begin{bmatrix} \cos(\theta_2) & 0 & sin(\theta_2) & 0 \\ 0 & 1 & 0 & 0 \\ -sin(\theta_2) & 0 & cos(\theta_2) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{6}$$

$$R_y(\theta_3) = \begin{bmatrix} \cos(\theta_3) & 0 & sin(\theta_3) & 0 \\ 0 & 1 & 0 & 0 \\ -sin(\theta_3) & 0 & cos(\theta_3) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{7}$$

$$R_y(\theta_5) = \begin{bmatrix} \cos(\theta_5) & 0 & sin(\theta_5) & 0 \\ 0 & 1 & 0 & 0 \\ -sin(\theta_5) & 0 & cos(\theta_5) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{8}$$

$$R_y(\theta_6) = \begin{bmatrix} \cos(\theta_6) & 0 & sin(\theta_6) & 0 \\ 0 & 1 & 0 & 0 \\ -sin(\theta_6) & 0 & cos(\theta_6) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{9}$$

$$R_x(\theta_7) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos(\theta_7) & -sin(\theta_7) \\ 0 & sin(\theta_7) & cos(\theta_7) \end{bmatrix} \tag{10}$$

Since the rotation of the final joint of the robotic arm is determined by the reference trajectory, it remains in a fixed position until the reference values of angles θ_6 and θ_7 are modified. The resulting Jacobian matrix has a dimension of 3×5.[17]

- DOF – Degrees of Freedom;
- EE – End-Effector;
- k – Instantaneous time;
- R – Rotation matrix;
- T – Translation matrix;
- θ – Homogeneous Transformation Matrix;
- q – Rotation angle between the link and the reference frame;
- l – Link of the robotic arm.

Nevertheless, determining the mechanical strength of the system’s components is essential to ensure the stability, safety, and durability of the robotic structure. Mechanical strength analysis evaluates the capability of materials to withstand operational stresses, thereby preventing potential deformations or structural failures during operation.

Accordingly, the calculation of forces acting on the robotic system depends on multiple factors, including the arm’s weight, the payload mass, the length of each link, the motion range, and the type of actuators employed for arm displacement, as illustrated in Figure 2.[17]

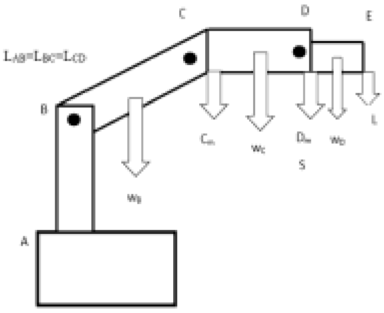

Fig.2. Force diagram of the robotic arm

With the necessary data available, the force required to operate a robotic system can be determined using the following mathematical relationships:

$$F = \frac{m * g * d}{L * sin\theta + (\frac{m}{M} * cos\theta)} \tag{11}$$

- F – required force
- m – payload mass
- g – gravitational acceleration (9.8 m/s²)
- d – distance from the payload’s center of gravity to the considered joint
- L – length of the robotic arm
- θ – angle between the arm and the horizontal plane
- M – total mass of the robotic arm

This equation accounts for the influence of the payload, the arm’s mass, and its angular orientation relative to the horizontal. It can also be applied to determine the force requirements at various points along the arm by adjusting the parameters d and θ.[20]

Based on the performed calculations, the essential parameters for accurate dimensioning of the entire robotic system were established. The results confirm both the stability of the design and the optimal correlation between the theoretical model and its practical implementation.[22]

6. Integration of a battery powered robotic prototype autonomous naval platforms

In this study, a robotic system intended for naval applications was designed and manufactured using 3D printing technology.

Figure 3 illustrates the robotic system, whose design optimization was achieved through the use of multiple software tools, including SnapMaker Luban, 3D Builder, and, in particular, FUSION 360 for critical details. This integrated approach enabled the development of a functional and adaptable robotic system suitable for naval research and intervention missions.[25]

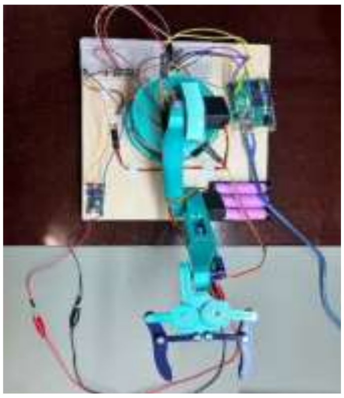

Fig. 3. Complete assembly of the robotic system

A critical component in the operation of this prototype is the Li-Ion battery-based power supply system, supported by a voltage converter. The converter, illustrated in Figure 4, is employed to step down the total voltage of 11.1 V—obtained by connecting three ICR18650-26JM cells in series—to the 5 V required for the operation of the servomotors. The converter regulates the magnetic energy flow during the active phase and releases it during the blocking phase. Meanwhile, the diodes and capacitors maintain output voltage stability, preventing fluctuations that could adversely affect servomotor performance.

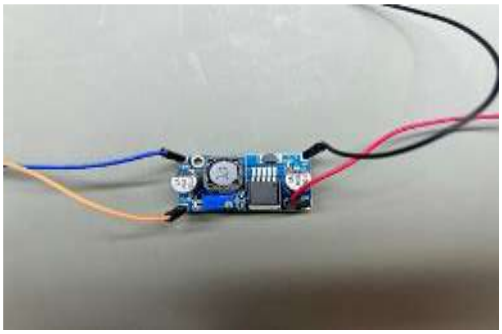

Fig. 4. Converter for enabling optimal servomotor operation

For the actuation of the robotic system, SG90 micro-servomotors, shown in Figure 5, were employed. These devices are well-regarded for their reliability, owing to their compact size, low weight, and cost-effectiveness. The SG90 servomotors provide a maximum torque of 1.8 kg/cm at a voltage of 6 V, although their optimal performance is achieved at 5 V, according to the manufacturer's specifications.

Fig. 5. SG90 micro-servomotors

In terms of battery integration in series, an ABS plastic enclosure, illustrated in Figure 6, was employed to provide electrical insulation and enhanced mechanical protection. This enclosure facilitates the connection of three Li-ion cells, yielding a total nominal voltage of 11.1 V, which is subsequently regulated via a DC-DC converter to supply the system with the optimal operating voltage. The selection of Li-ion technology is motivated by its favorable trade-off between high energy density, long cycle life, compact form factor, and suitability for mobile robotic applications. Additionally, the design ensures safe handling and thermal stability, which are critical for reliable performance in compact autonomous systems.

Fig. 6. Enclosure for connecting batteries in series to power the servomotors

For the design, implementation, and visualization of the electrical connections, the Fritzing software was employed. This open-source application facilitates the design of electrical circuits and enabled the creation of a block diagram, shown in Figure 7, illustrating the connections between the batteries, the voltage converter, and the servomotor. Its use allowed for the theoretical validation of the design, minimizing potential assembly errors and ensuring accurate circuit implementation.

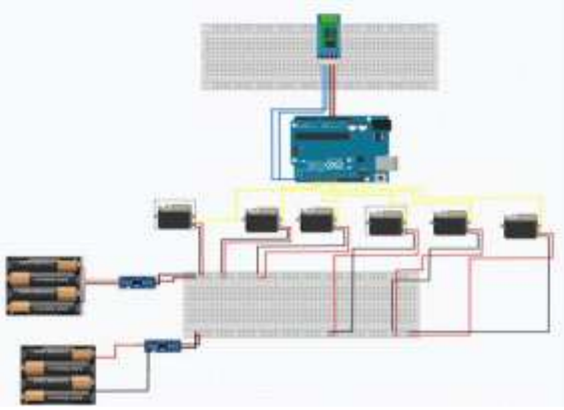

Fig.7. Block diagram of the components used in the prototype development.

The successful integration of a Li-ion battery-based power system within the robotic prototype unequivocally validates the capability of autonomous subsystems to operate efficiently on electrical energy. This implementation exemplifies the convergence of advanced energy storage technologies, precision 3D-printed structures, and intelligent power management strategies, establishing a blueprint for highly modular and scalable robotic architectures. By enabling rapid prototyping, robust system reliability, and optimized energy utilization, this approach lays the foundation for the next generation of autonomous maritime platforms and other complex robotic environments. The results of this study underscore the transformative potential of combining innovative energy solutions with adaptive, compact robotic design, setting a new benchmark for sustainable, high-performance autonomous systems in both research and real-world operational scenarios.

References

[1] C. Lin, Y. Cao, P. Xie, Y. Tian, and Z. Tao, "Thermal Regulation Fast Charging for Lithium-Ion Batteries," CPSS ISESC 2024 - 2024 CPSS IEEE Int. Symp. Energy Storage Convers., pp. 16–21, 2024, doi: 10.1109/ISESC63657.2024.10785498.

[2] J. Si, Q. Feng, C. Zhang, A. Yu, Q. Wang, and G. Buja, "State of Health and Remaining Useful Life Prediction of Li-ion Batteries Based on Improved Support Vector Regression," Proc. 2024 IEEE 7th Int. Electr. Energy Conf. CIEEC 2024, pp. 1770–1775, 2024, doi: 10.1109/CIEEC60922.2024.10583055.

[3] N. S. Popa, "Review of electric propulsion for small boats/drones," Sci. Bull. Nav. Acad., vol. 24, no. 1, pp. 122–129, 2021, doi: 10.21279/1454-864X-21-I1-015.

[4] D. Choi et al., "Reliability Testing of Commercial Li-Ion Battery Cells for Electrochemical Energy Storages (EES)," 2025 IEEE Electr. Energy Storage Appl. Technol. Conf. EESAT 2025, pp. 1–5, 2025, doi: 10.1109/EESAT62935.2025.10891238.

[5] R. Szabo and R. S. Ricman, "Robotic Arm Position Computing Method in the 2D and 3D Spaces," Actuators, vol. 12, no. 3, Mar. 2023, doi: 10.3390/act12030112.

[6] K. R. Ahmad, P. J. Grbovic, G. De Falco, and R. Petrella, "Li-Ion Battery Fast Charging Methods: Review and Comparison," 2024 IEEE 10th Int. Power Electron. Motion Control Conf. IPEMC 2024 ECCE Asia, no. Cccv, pp. 5131–5137, 2024, doi: 10.1109/IPEMC-ECCEAsia60879.2024.10567271.

[7] J. Singh and M. Jamil, "A Review on State of Charge (SoC) Estimation Methods of Li-Ion Batteries Used in Electrified Transportation," 2025 Int. Conf. Cogn. Comput. Eng. Commun. Sci. Biomed. Heal. Informatics, IC3ECSBHI 2025, pp. 845–849, 2025, doi: 10.1109/IC3ECSBHI63591.2025.10990787.

[8] S. Ghosh, K. V. Chowdary, and S. Behera, "Modelling and Simulation of Lithium-Ion Battery with Thermal Dependence," 3rd IEEE Int. Conf. Ind. Electron. Dev. Appl. ICIDeA 2025, pp. 18–21, 2025, doi: 10.1109/ICIDeA64800.2025.10962970.

[9] IEEE Region 10, Institute of Electrical and Electronics Engineers. Xi'an Sub-Section, and Institute of Electrical and Electronics Engineers, 2013 IEEE International Conference of IEEE Region 10 (TENCON 2013) : Shaanxi Guesthouse, Xi'an, Shaanxi, China : October 22-25, 2013.

[10] M. Sesharanjith, M. Vishaal Dharsan, G. Sundaresh, K. Darshan, and S. Arunkumar, "Li- Ion Battery Life Cycle Estimation by KNN Algorithm," 8th Int. Conf. Electron. Commun. Aerosp. Technol. ICECA 2024 - Proc., no. Iceca, pp. 683–686, 2024, doi: 10.1109/ICECA63461.2024.10800892.

[11] C. Popa, N.-S. Popa, E.-A. Andrei, A.-D. Deliu, B. Căşeriu, and M.-O. Popescu, "A NOVEL OFFSHORE WIND-POWERED SYSTEM FOR SUPPLYING ELECTRICITY TO SHIPS," U.P.B. Sci. Bull., Ser. C, vol. 87, no. 2, p. 2025.

[12] N.-S. Popa, M.-G. Manea, C. Popa, V. Mocanu, H. Isac, and M.-O. Popescu, "SOLAR ENERGY UTILIZATION FOR POWERING SURFACE DRONES: STUDY ON MATHEMATICAL MODELS FOR ELECTRICITY PRODUCTION PREDICTION," U.P.B. Sci. Bull., Ser. C, vol. 86, p. 2024.

[13] P. Pillai, J. Nguyen, and B. Balasingam, "Performance Comparison of Open-Circuit Voltage Modelling of Li-ion Batteries at Different C-Rates," 2023 IEEE Transp. Electrif. Conf. Expo, ITEC 2023, pp. 1–6, 2023, doi: 10.1109/ITEC55900.2023.10187059.

[14] N.-S. Popa and C. Popa, "Li-Ion battery discharge study," Sci. Bull. Nav. Acad., vol. 2021, pp. 159–166, 2021, doi: 10.21279/1454-864X-21-I2-016.

[15] K. Liu, X. Hu, H. Zhou, L. Tong, W. D. Widanage, and J. Marco, "Feature Analyses and Modeling of Lithium-Ion Battery Manufacturing Based on Random Forest Classification," IEEE/ASME Trans. Mechatronics, vol. 26, no. 6, pp. 2944–2955, 2021, doi: 10.1109/TMECH.2020.3049046.

[16] R. Tabasha, A. Ismail, H. M. Khalid, and J. Mounsefa, "Comparative Analysis of Artificial

Intelligence and Statistical Models for Li-Ion Battery Cells State Estimation in Electric Vehicles," 2024 6th Int. Conf. Smart Power Internet Energy Syst. SPIES 2024, pp. 463–470, 2024, doi: 10.1109/SPIES63782.2024.10983364.

[17] IEEE Electrical Insulation Society Staff, 2012 12th International Conference on Control Automation Robotics and Vision.

[18] N.-S. POPA, C. POPA, V. MOCANU, and L.-M. POPA, "STATE OF THE ART IN BATTERY TECHNOLOGY: INNOVATIONS AND ADVANCEMENTS," J. Mar. Technol. Environ., vol. 2, no. 2, p. 80, Jul. 2023, doi: 10.53464/JMTE.02.2023.13.

[19] V. Kandasamy and M. Venkatesan, "Adaptive Electric Vehicle Charging Method to Improve the Battery Life," 2nd Int. Conf. Adv. Electr. Electron. Commun. Comput. Autom. ICAECA 2023, pp. 1–4, 2023, doi: 10.1109/ICAECA56562.2023.10200210.

[20] X. Chen, Association of Global Intelligent Science and Technology, and M. IEEE Systems, Proceedings of the International Conference on Cyber-Physical Social Intelligence (ICCSI 2022) Nanjing, China, November 18-21, 2022.

[21] C. Popa, N. S. Popa, M. Bălăceanu, A. Pohontu, A. D. Deliu, and M. C. Cuciureanu, "Maximizing wind energy: The Crucial Role of Altitude and Coastal Proximity," in 2024 IEEE Conference on Advanced Topics on Measurement and Simulation, ATOMS 2024, Institute of Electrical and Electronics Engineers Inc., 2024, pp. 375–378. doi: 10.1109/ATOMS60779.2024.10921626.

[22] Q. Cai and Y. Han, "A Navigation Control Evaluation Method of USV Based on Fuzzy Rough Set," in CTISC 2022 - 2022 4th International Conference on Advances in Computer Technology, Information Science and Communications, Institute of Electrical and Electronics Engineers Inc., 2022. doi: 10.1109/CTISC54888.2022.9849738.

[23] R. Krasňanský, P. Valach, D. Soós, and J. Zarbakhsh, "Reference trajectory tracking for a multi-DOF robot arm," Arch. Control Sci., vol. 25, no. 4, pp. 513–527, Jan. 2015, doi: 10.1515/acsc-2015-0033.

[24] A. M. Shuman, "Modeling and Control of 6-axis Robot Arm," 2020.

[25] "Corel PDF Fusion Reviewer's Guide."