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Design of Battery Performance Enhancements Using PSO, Fuzzy and ANFIS Controller

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Abstract: In this paper we explore the application of Particle Swarm Optimization (PSO), Fuzzy Logic, and Adaptive Neuro-Fuzzy Inference System (ANFIS) controllers to optimize battery performance. These innovative control methods exhibit promise in improving battery efficiency and extending its lifespan. The study addresses critical battery management issues such as capacity deterioration, voltage swings, and inefficient charge and discharge processes. PSO facilitates real-time optimization of the battery's operational parameters, leading to enhanced energy usage and prolonged battery life. Fuzzy Logic contributes to the adaptability of batteries by offering a robust decision-making framework that adjusts to unpredictable and changing environmental conditions, complementing the PSO algorithm. Furthermore, the ANFIS controller dynamically models the battery's behavior, enabling precise performance prediction.

Keywords: EV, Battery, Co2, PSO, Fuzzy.

1. Introduction:

Countries are presently grappling with challenges in establishing new energy systems, spurred by the growing recognition of climate change and the depletion of fossil resources. While expectations point to increases in populations, welfare, and energy consumption, the adverse environmental impacts of human activity need to be curtailed. In 2017, approximately 40 percent and 25 percent of global CO2 emissions originated from the energy and transportation sectors, respectively. The Paris Agreement, involving nearly 190 nations, serves as a global framework to mitigate climate change and restrict global warming to below 2°C. This concerted effort has directed significant attention and research funding towards technologies like renewable energy and electric vehicles (EVs).

An electric car is defined as a vehicle powered entirely or partially by electricity from an on-board battery. There are various types of EVs, some exclusively powered by electricity, while others also utilize liquid fuels. EVs boast significantly higher efficiency compared to traditional internal combustion engine vehicles. Most EV models require grid power for charging, and there are diverse billing methods available, ranging from basic to sophisticated, with varying timing incentives. Vehicles capable of returning stored power to the grid are termed vehicle-to-grid (V2G) EVs.

For EVs to genuinely reduce emissions, it is imperative that the power for charging comes from renewable sources. Renewable energy technologies encompass biomass, geothermal, hydropower, wind, and solar energy, deployable as dispersed energy producers or centralized power facilities. While solar photovoltaic (PV) technology holds promise in reducing emissions, its integration poses challenges to grid stability due to the erratic nature of these sources. Addressing this requires investments in energy storage and adjustments in energy usage to align with variable generation.

Planning the charging strategy for EVs, balancing energy supply and scheduling, is seen as a hurdle. Charging should aim to minimize costs while ensuring a secure and reliable energy supply, offering benefits such as lower running costs, reduced CO2 emissions, and improved grid power quality. The synergy of EVs and renewable electricity holds potential for emission reductions in power generation and transportation sectors, with current focus primarily on road transportation.

2 Proposed System

The system design incorporates a load, a bi-directional converter, a PV module, and a battery. The input to the module is solar radiation, which, upon reaching the module, generates solar output current. The variability in the nature of sun irradiation is a key consideration in the system.

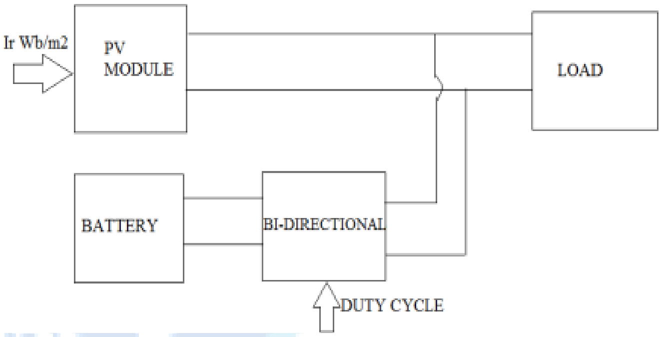


Fig. 1. Block Diagram of Approach

Hence, we establish a parallel connection between the module and a battery to maintain a constant voltage at the load end. A bi-directional converter, integrated into the system and connected to the batteries, ensures the voltage remains constant at the load side, even amid changes in radiation levels. The system components utilized in the proposed design are illustrated in Figure 1.

Duty cycles of the bi-directional converter switches are regulated by a PI controller, individually fine-tuned by PSO and WOA. Additionally, a fuzzy controller is employed for their regulation. The PI controller utilizes the voltage error signal, representing the difference between input and output voltage. This error signal is directed to the PI controller, and its output is transmitted to the DC-DC PWM block, which, in turn, adjusts the duty cycle for switches based on the PI's output signal.

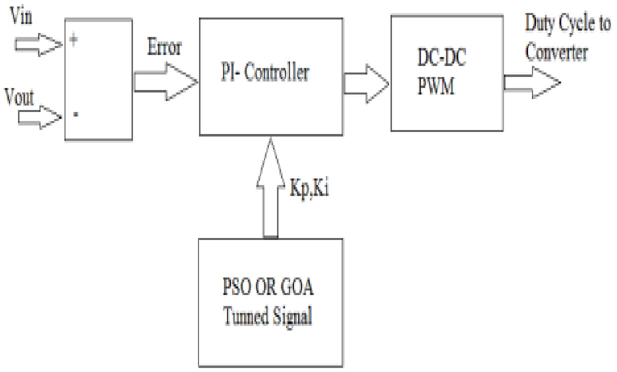


Fig. 2. Block Diagram of Bi-directional Converter Switch duty cycle Generation

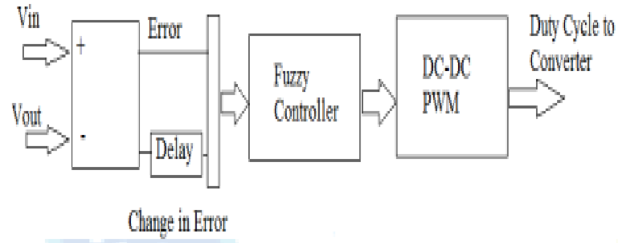


Fig. 3. Block Diagram of Fuzzy logic Controller Duty cycle Generation

The block diagram presented in Figure 3 illustrates the model based on a fuzzy controller.

The primary objective of the proposed system is as follows:

1. The objective is to simulate a PV-based electric vehicle charging station with enhanced battery performance.
2. Furthermore, to minimize voltage drop within a specified timeframe through the application of diverse optimization algorithms.

3. With PSO

To achieve optimal tuning for a PI controller, the PSO method is employed. Figure 4.3 illustrates the Simulink model of the PSO-based approach. The PV module input is depicted in the diagram as temperature and radiation.

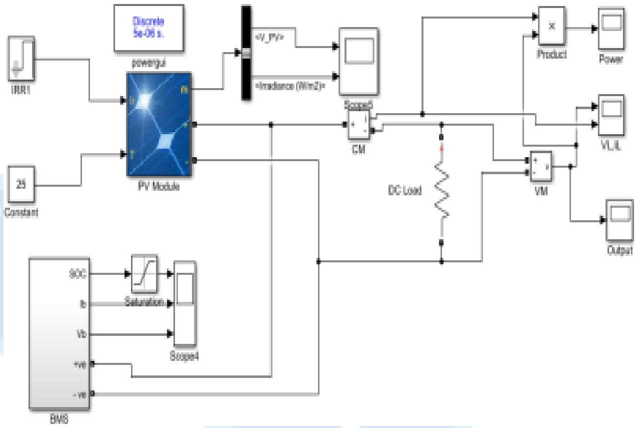


Fig. 4. Simulink Model using PSO

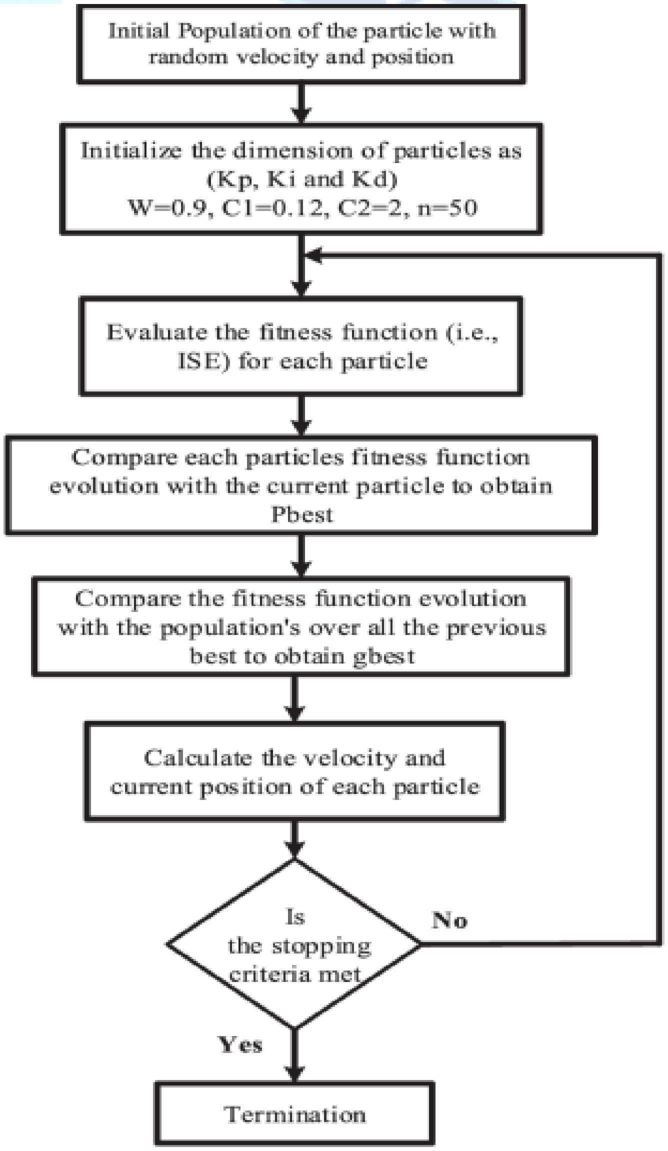


Fig. 5. Algorithm of PSO

The BMS and load are connected to the module in parallel. The SOC is linked to a saturation block, limiting its value between 25 and 100. Figure 4.5 displays components such as the battery, PI controller, bidirectional switches, inductor, and diodes that constitute the battery management system. The device controls the connection of the battery with the load and supply. The bi-directional converter functions to regulate the flow of current from the PV module to the battery and from the battery to the load.

4. Result and Discussion:

The final approach involves the application of the whale optimization algorithm to enhance the battery performance in the proposed system. The implementation of this approach utilizes a Matlab script file, iteratively executed to achieve the optimal cost function value. The ideal values of Kp and Ki are determined based on the objective cost function value.

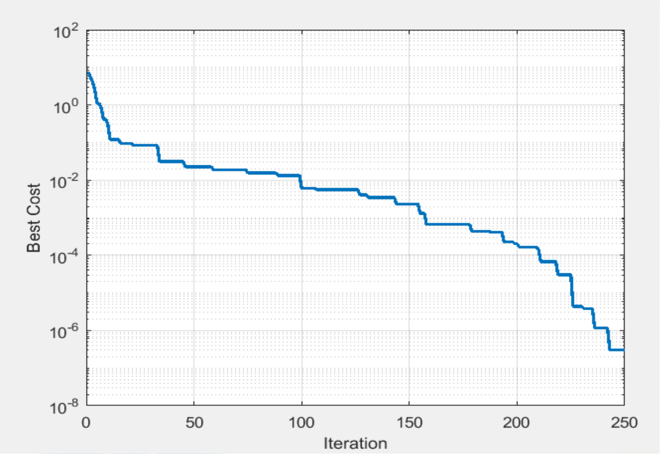


Fig. 6: WOA Optimization Curve

WOA is shown to be performed for 250 iterations in Figure 6. In the y-axis of the preceding graphic, the cost function's value is displayed for each iteration.

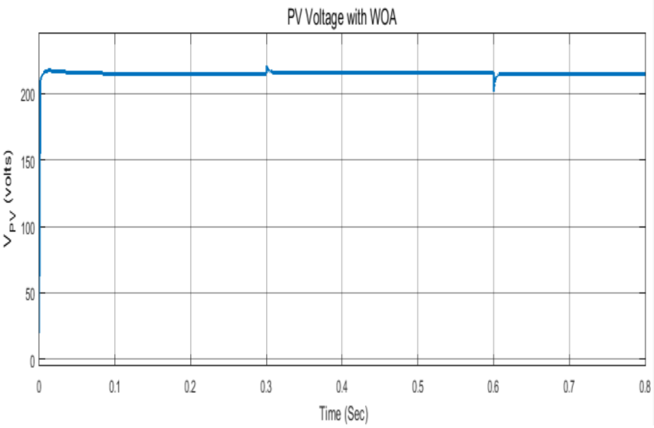


Fig. 7: PV voltage with WOA

Figure 7 makes it evident that there is less variance in PV voltage when compared to the prior approach.

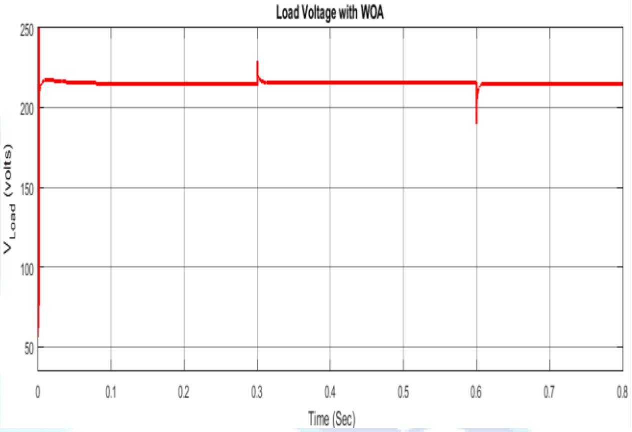
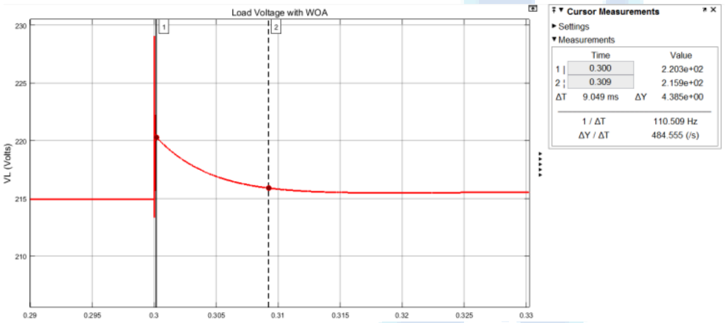


Fig. 8. Load voltage with WOA

Within this method, the load voltage remains nearly constant at 220 volts, as depicted in Figure 8. Minimal changes in load voltage are observed, occurring only when there are variations in irradiation values. It is evident that this method yields superior outcomes compared to the two previous approaches, PSO and Fuzzy.



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        Time            Value
1 |     0.300           2.203e+02
2 ¦     0.309           2.159e+02
ΔT      9.049 ms   ΔY   4.385e+00

        1 / ΔT          110.509 Hz
        ΔY / ΔT         484.555 (/s)
```

Fig. 9. Zoom View Load voltage with WOA

Consideration of time is essential to ascertain the precise magnitude of voltage variation. Figure 9 provides a zoomed-in section of the load voltage, revealing the specific duration required for the voltage to return to its 220 volts value. Remarkably, it takes only 9 milliseconds, an extremely brief period, to reach this 220 volts value. In comparison to previous methods, this approach exhibits a significantly quicker attainment of the 220-volt value.

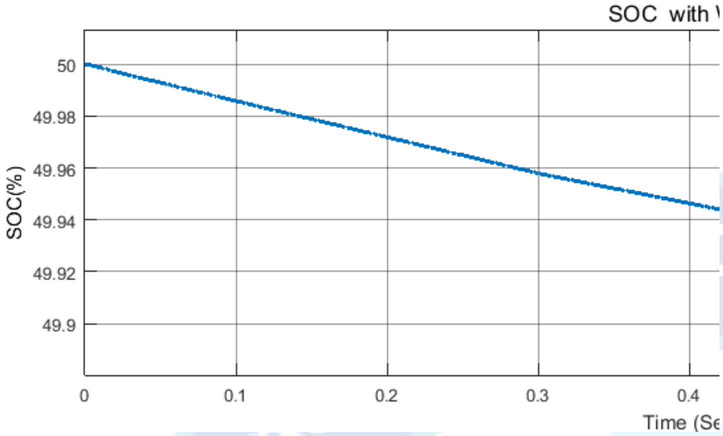

Fig. 10 Battery SOC with WOA

SOC of battery is showing in figure 10 which is very similar to previous techniques.

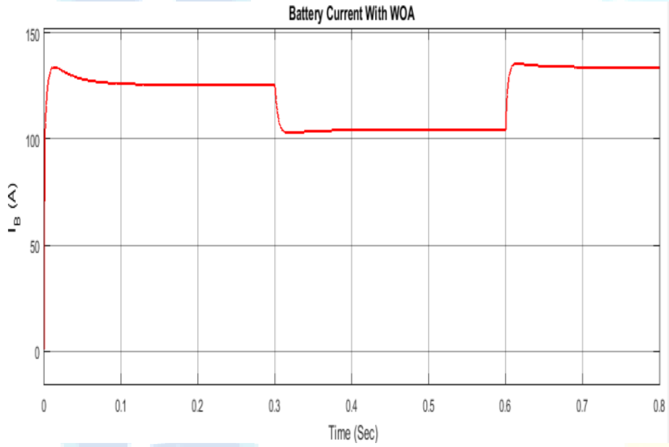

Fig. 11. Battery Current with WOA

The change in battery current is seen in figure 11 above. Only when the sun irradiation is changing can variation appear.

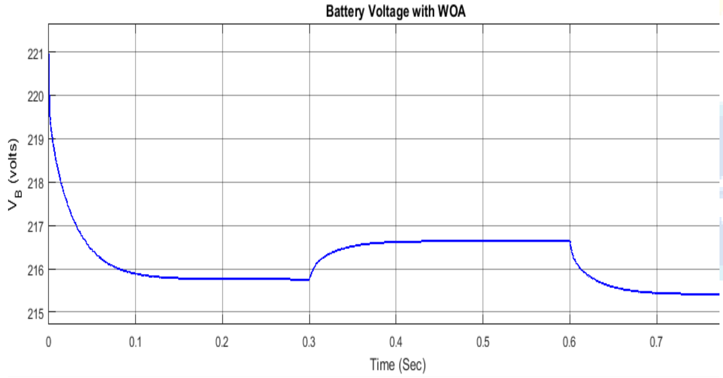

Fig 12. Battery Voltage with WOA

Figure 12 illustrates the fluctuation in battery voltage, commencing at 0.3 seconds and extending for 0.6 seconds. The voltage increases at 0.3 seconds due to a rise in irradiation, and at 0.6 seconds, it decreases owing to a reduction in irradiation. Overall, this approach outperforms the other strategies previously examined. It effectively minimizes the duration of voltage transients and swiftly stabilizes them, as evidenced by the aforementioned data. Once a consistent irradiation value is reached, the battery initiates the charging process. Based on the gathered data, we conclude that the WOA yields more precise and superior outcomes compared to the earlier methods.

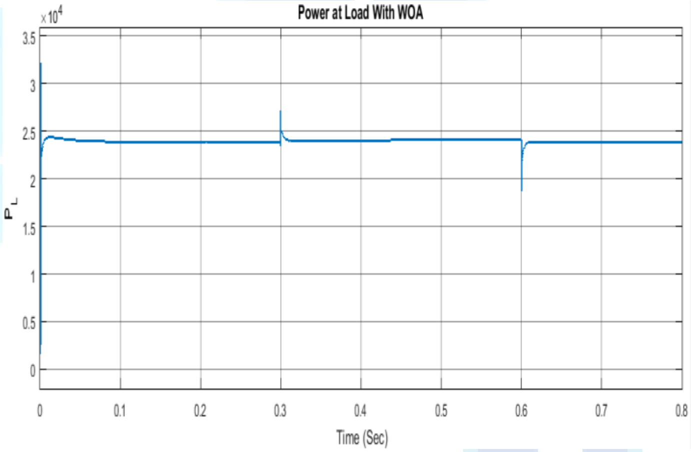

Fig 13. Battery Voltage with WOA

Fig 13 above illustrates power provided to load. It is a PSO-like approach.

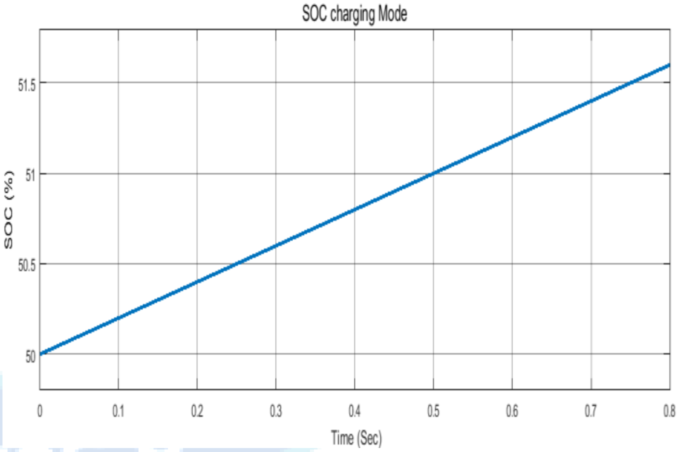

Fig 14. Battery Charging SOC

In the depicted figure 14, the State of Charge (SOC) is ascending, signifying that the battery is in a charging state. The charging mode occurs in each proposed system model when irradiation remains constant throughout the simulation duration of 0.8 seconds. During the charging process, the current value is negative. However, the battery voltage remains constant during the charging phase. Rapid variations in solar irradiation lead to fluctuations in both battery voltage and current during the charging mode.

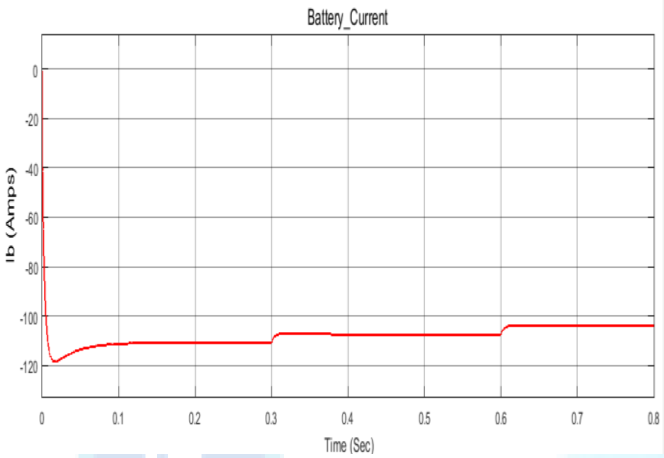

Fig 15. Battery Current in Charging Model

The battery current value is displayed in figure 15 above. It shows the battery's current type while in charging mode.

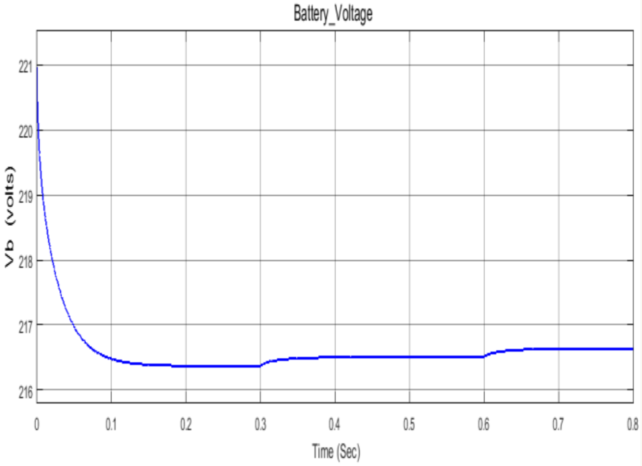

Fig. 16. Battery Voltage in Charging Model

When the battery is charging, the voltage is depicted in Figure 16.

5. Conclusion:

The proposed system underwent a comparative analysis, with a focus on measuring peak voltage. The outcomes of different optimization techniques are detailed. The table provides information on the peak voltage achieved by the fuzzy technique, recording a maximum peak voltage of 222 volts. Notably, the settling time for fuzzy optimization was relatively extensive at 10 milliseconds. Despite settling time differences, all employed techniques—PSO, WHALE optimization, and fuzzy optimization—exhibited the same occurrence time, which is 0.3 seconds. Remarkably, the settling time was optimal in the case of whale optimization, achieving 9.82 milliseconds, surpassing others. Future work will delve into comprehensive studies and analyses of diverse optimization techniques within this framework.

References:

[1] Höök, M. &Xu, T., 2013. Depletion of fossil fuels and anthropogenic climate change a review. Energy Policy, Volume 52, pp. 797- 809.

[2] IEA, 2017. Data and statistics: CO2 emissions by sector, World 1990-2017. [3] European Commission, 2019. Climate action: Paris Agreement.

[4] Kukoda, S., 2019. Climate Week NYC: Renewable energy holds the key to making electric vehicles truly zero-emission.

[5] Richardson, D. B., 2013. Electric vehicles and the electric grid: A review of modeling approaches, Impacts, and renewable energy integration. Renewable and Sustainable Energy Reviews, Volume 19, pp. 247-254.

[6] Bagalini, V., Zhao, B. Y., Wang, R. Z. &Desideri, U., 2019. Solar PV-Battery-Electric Grid Based Energy System for Residential Applications: System Configuration and Viability.Research, Volume 2019, pp.1-17.

[7] Ministry of transport, 2015. Plan Maestro Fluvial de Colombia 2015, Bogotá: ARCADIS NEDERLAND.

[8] Mejía-Gutierrez, R. et al., 2019. Informe IFI 1.2.1: Investigation of the conditions and needs for the implementation of the electric mobility river system in Magangué, Medellín: Energética 2030.

[9] Rodríguez-Urrego, D. & Rodríguez-Urrego, L., 2018. Photovoltaic energy in Colombia: Current status, inventory, policies and future prospects. Renewable and Sustainable Energy Reviews, Volume 92, pp. 160-170.

[10] Andwari, A. M. et al., 2017. A review of Battery Electric Vehicle technology and readinesslevels. Renewable and Sustainable Energy Reviews, Volume 78, pp. 414-430.

[11] US Department of Energy, 2011. Fuel economy: All-Electric Vehicles. [13] Bhatt, P. N., Mehar, H. &Sahajwani, M., 2019. Electrical Motors for Electric Vehicle – A Comparative Study. Indore: International Conference on Recent Advances in Interdisciplinary Trends in Engineering & Applications.

[12] Kurniawan, A., 2016. A Review of Solar-Powered Boat Development. IPTEK TheJournal for Technology and Science, 27(1).

[13] Liu, K., Li, K., Peng, Q. & Zhang, C., 2018. A brief review on key technologies in the battery management system of electric vehicles. Frontiers of Mechanical Engineering,14(1), p. 47–64.

[14] Hanifah, R. A., Toha, S. F. & Ahmad, S., 2015. Electric Vehicle Battery Modelling and
Performance Comparison in Relation to Range Anxiety. Procedia Computer Science, Volume 76, pp. 250 - 256.

[15] Wang, L. et al., 2017. Characteristic Analysis of

Lithium Titanate Battery, Beijing: The 8th International Conference on Applied Energy – ICAE2016.
[16] Ogura, K. &Kolhe, M. L., 2017. 4 - Battery technologies for electric vehicles. In: T. Muneer, M. L. Kolhe& A. Doyle, eds. Electric Vehicles: Prospects and Challenges. Amsterdam: [19] Goldie-Scot, L., 2019. A Behind the Scenes Take on Lithium-ion Battery Prices, San Francisco: Bloomberg NEF.