Available online at www.scientiaresearchlibrary.com

Scientia Research Library **ISSN 2348-0424**
USA CODEN: JETRB4

Journal of Engineering And Technology Research, 2021, 9 (1):1-10

(*http://www.scientiaresearchlibrary.com/arhcive.php*)

Modelling and Characteristics Evaluation for Ni-MH Battery of Electric Vehicle

Nasr Ismael Alhusein

Department of Electrical and Electronic Engineering, Bani Waleed University, Bani Walid, Libya

---

ABSTRACT

The broad adoption of electric vehicles can have a substantial effect on urban air quality, national energy independence, and international trade balance. The main technological component for the creation of viable electric vehicles is an efficient battery. This paper presents an improved and easy-to-use battery dynamic model where the type of battery used in this work is the first Ni-MH battery popular in electric vehicles. The battery model that was presented in this paper is a model that is already available in the Matlab library, but it has been explained during charge and discharge process and its outputs are obtained in an easier way for the readers, as the battery was a simple Ni-MH battery ,whose four main outputs were Battery voltage, state of charge SOC, motor speed and motor armature current signal.

Keywords: Electric vehicle, Ni-MH battery, State of charge (SOC), Simulation, Matlab/Simulink.

INTRODUCTION

Electric vehicles are becoming increasingly popular as a mode of road transportation. Some experts predict that by 2030, electric vehicles will account for an average of 25 percent of all vehicles on the world's roads [1]. According to the same forecast, a large majority of the remaining vehicles will feature hybrid propulsion systems, which typically include an electric motor in addition to an internal combustion engine. Internal combustion engines are still being developed; nonetheless, it is evident that the electric drive will replace the internal combustion engine in automotive applications [2] over the course of decades. The primary benefit of replacing combustion engine propulsion in the automotive industry with electric drive is the elimination of harmful gas emissions at the point of usage. In a broader perspective, it is important to consider not only the ways of producing electricity for vehicle use [3] and energy and emissivity-related aspects of production processes [4], but also the recycling of waste electric vehicle components [3]. Particular consideration should be given to energy storage systems that primarily utilize electrochemical batteries.

In the first electric automobiles, lead-acid batteries were utilized [5]. In the years that followed, nickel-cadmium batteries were also utilized; however, their usage of hazardous cadmium has led to their elimination from automotive uses. Similar to Ni-Cd batteries, nickel-metal-hydride batteries have begun to be employed in automobile applications [6]. These were used, among other places, in the renowned second-generation GM EV1 electric vehicle. They have not yet been widely used in vehicles with solely electric drive mechanisms for numerous reasons. Some authors believe that a fuel lobby is obstructing the development of NiMH batteries with large capacity [7]. However, it should be noted that the energy density of nickel-metal-hydride batteries is lower than that of Li-ion batteries, which are undergoing rapid development, and thus one kWh of stored energy is significantly more expensive. Information from the research and development sector regarding the development of NiMH batteries with exceptionally high performance predicts an expansion of this technology's application in electric vehicles. [8]. However, NiMH batteries have found widespread application in hybrid automobiles as a mature, problem-free technology. Energy storage systems in modern automobiles with pure electric drives are often comprised of a variety of lithium-ion batteries. Engineers want to develop batteries with a high specific energy and specific power, an increased number of work cycles, and a decrease in production costs.

Technical description of the Ni-MH Battery

A Nickel-Metal Hydride (NiMH) battery system is an energy storage system based on electrochemical charge/discharge reactions between a positive electrode (cathode) containing nickel oxide-hydroxide as the active material and a negative electrode (anode) consisting of a hydrogen-absorbing alloy.

The electrodes are separated by a permeable membrane that permits electron and ionic movement between them and are immersed in an electrolyte consisting of aqueous potassium hydroxide that does not experience major changes during operation. Figure 1 illustrates the charging principle for NiMH batteries.

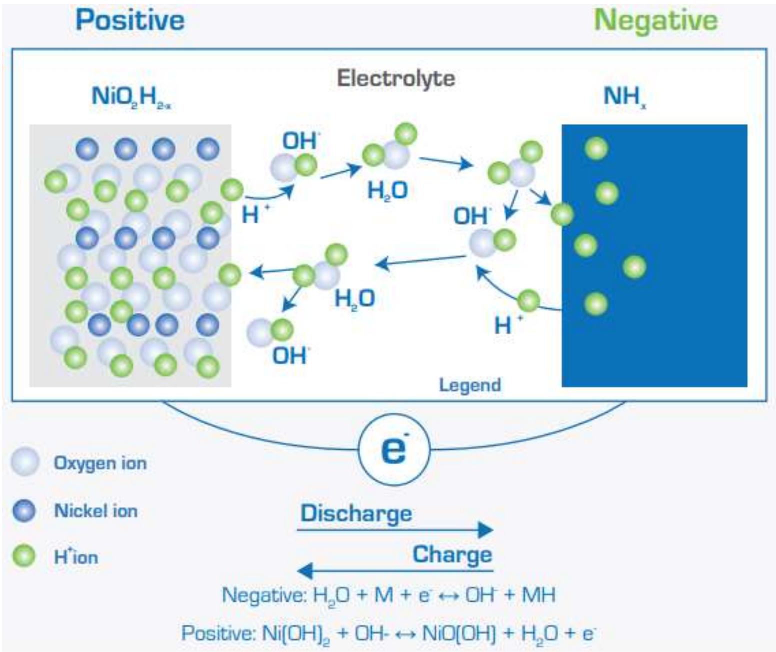

Figure 1 Illustration of charging principal of NiMH.

The primary components of a Ni-MH battery are the elementary cell, which consists of an assembly of electrodes, electrolyte, and separators, and the positive and negative plates. Battery systems consisting of a huge assembly of cells or modules with a control system, and Power Conversion

System (PCS).

The following Ni-MH battery design types are available:

A distinctive intermetallic compound for the negative electrode, Variable electrode thickness based on the power/energy ratio various cell sizes ranging from 1 Ah to 200 Ah. Cylindrical (small cells) or prismatic (big cells) cell morphologies, and According to size and function, various battery systems exist: fixed or moving. Figure 2 shows one of famous design of Ni-MH batteries.

Figure 2 One of the designs available for Ni-MH battery.

State of the art and Future developments

In the realm of compact rechargeable batteries, the NiMH technology formerly supplanted the Ni-Cd technology, but is now being supplanted by the Li-Ion technology. The Ni-MH technology is the current standard for hybrid vehicles, however Li-Ion technology is projected to replace it in the near future. NiMH technology complements Ni-Cd technology on the industrial battery market when improved performance and no maintenance are required.

Several large Ni-MH systems for grid purposes have been developed: Recycling technology and collecting circuits are operational and developed.

Other technologies, such as Li-ion, compete with the NiMH technology. There are no anticipated future breakthroughs for this technology.

NiMH Batteries description and simulation

This section of paper shows a 200 Volt, 6.5 Ampere Ni-MH battery model during charge and discharge process.

Discharging or charging is always occurring inside a battery at any given time. The electrolyte solution contains charged ions, made up of sulphate and hydrogen. The sulphate ions are negatively charged, while the hydrogen ions have a positive charge.

In addition to the electron flow within the battery as it discharges, the ratio of sulphuric acid to water in the electrolyte solution is also changing to more water and less acid. A chemical by-product of this process is lead sulphate that coats the battery plates within each cell reducing its surface area.

Charging a battery reverses the chemical process that occurred during discharge. The sulphate and hydrogen ions switch places. The electrical energy used to charge a battery is converted back to chemical energy and stored inside the battery. Battery chargers, including alternators and generators, produce a higher voltage than the battery's open circuit voltage.

There are two important variables to know when talking about battery manufacturing and modeling SOC (state of charge) and SOH (state of health). Understanding and monitoring cells' states, at a particular point in time, is often needed in battery development in order to optimize their use.

We may want to better understand the State-of-Charge (SOC) and State-of-Health (SOH) of the battery. These parameters are important because they are directly related to battery performance.

State-of-health (SOH) and State-of-Charge (SOC) are key quality indicators as they provide very useful data needed for the optimization of the Battery Management System (BMS).

The state of charge of a battery describes the difference between a fully charged battery and the same battery in use. It is associated with the remaining quantity of electricity available in the cell.

It is defined as the ratio of the remaining charge in the battery, divided by the maximum charge that can be delivered by the battery. It is expressed as a percentage as below.

$$SOC/\% = 100(Q_0 + Q)/Q_{max}$$

$$= SOC_0/\% + 100(Q/Q_{max})$$

Where:

Q_0/mAh= Initial charge of the battery.

Q/mAh= the quantity of electricity delivered by or supplied to, the battery. It follows the convention of the current: it is negative during the discharge and positive during the charge.

Qmax/mAh= the maximum charge that can be stored in the battery.

SOC_0/%= the initial state-of-charge (SOC/%) of the battery.

- If the battery is new: $Qmax=C_r$ and $Q_0= 0.5Q_{max}$ generally. C^r is the rated capacity of the battery as given by the manufacturer.
- If the battery is fully charged: $Q_0= Q_{max}$ and SOC_0=100%.

The state-of-health (SOH) of a battery describes the difference between a battery being studied and a fresh battery and considers cell aging.

It is defined as the ratio of the maximum battery charge to its rated capacity. It is expressed as a percentage as seen below.

$$SOH/\% = 100(Q_{max}/Cr)$$

Where:

Qmax/mAh= the maximum charge available of the battery.

Cr= the rated capacity.

To clarify the difference between the state-of-health SOH and the State-of-Charge (SOC), see the following figure 3. The evolution of the discharge capacity and the State of Health (SOH) during long-term cycling of the cell are illustrated.

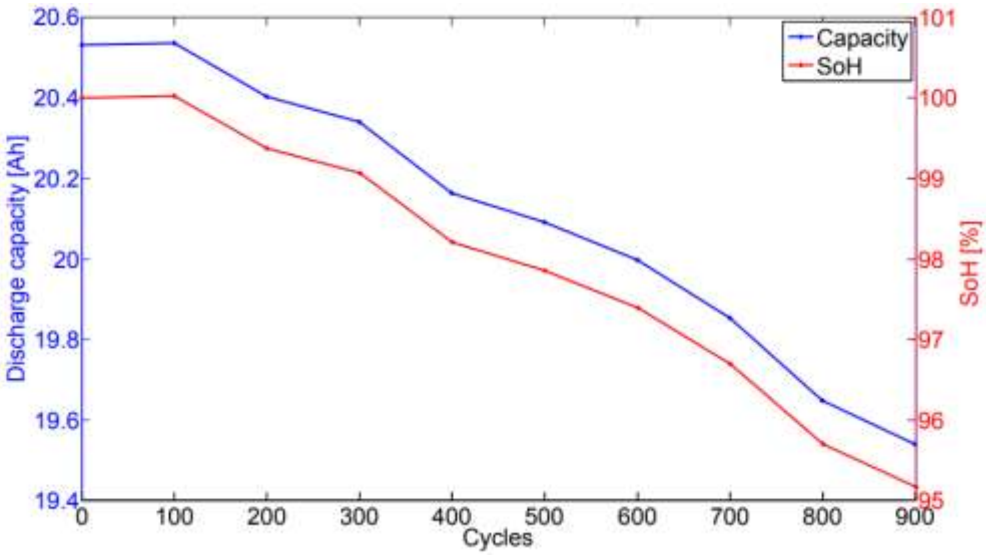

Figure 3 Aged battery cell discharge capacity with SOH and SOC evolutions with the number of cycles.

In this work, The Ni-MH Battery is connected to a constant load of 50 Amps as shown in the Simulink model which illustrated in figure 4. The DC machine is connected in parallel with the load and operates at no load torque. When the State-Of-Charge (SOC) of the battery goes under forty percent a negative load torque of 200 N.m is applied to the machine so it acts as a generator to recharge the battery. When the SOC goes over eighty percent, the load torque is removed so only the battery supplies the 50 amps load.

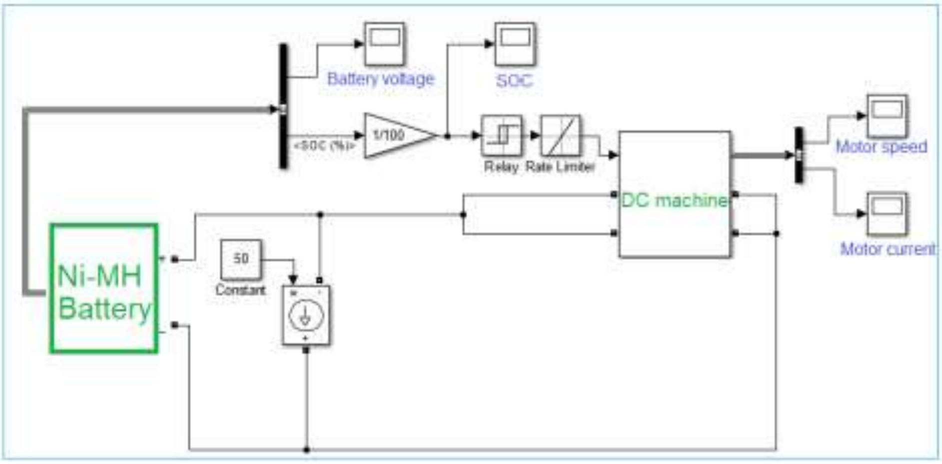

Figure 4 Model description of Ni-MH Battery.

The DC machine is started using battery power at t = zero s. The velocity accelerates to 120 rad/s. The battery is also depleted by the 50 amps of steady DC demand. At t = 280 seconds, the SOC falls below 40 percent. A mechanical torque of -200 Nm is applied to the machine, causing it to function as a generator and generate 100 amps of current. Therefore, 50 amps are allocated to the load and 50 amps are allocated to battery recharging. At time t = 500 s, the SOC exceeds 80 percent. The mechanical torque has been released, and the machine is now free to run. In addition, the cycle begins again.

Battery voltage, SOC, Motor speed and Motor current signals are available at the output of the block as shown in the following four figures.

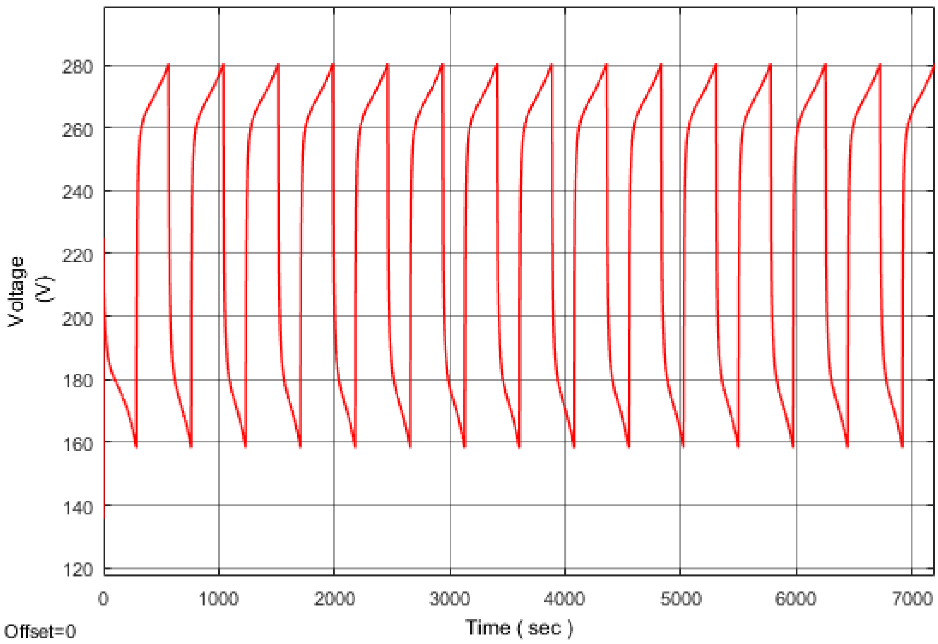

Figure 5 the Battery voltage.

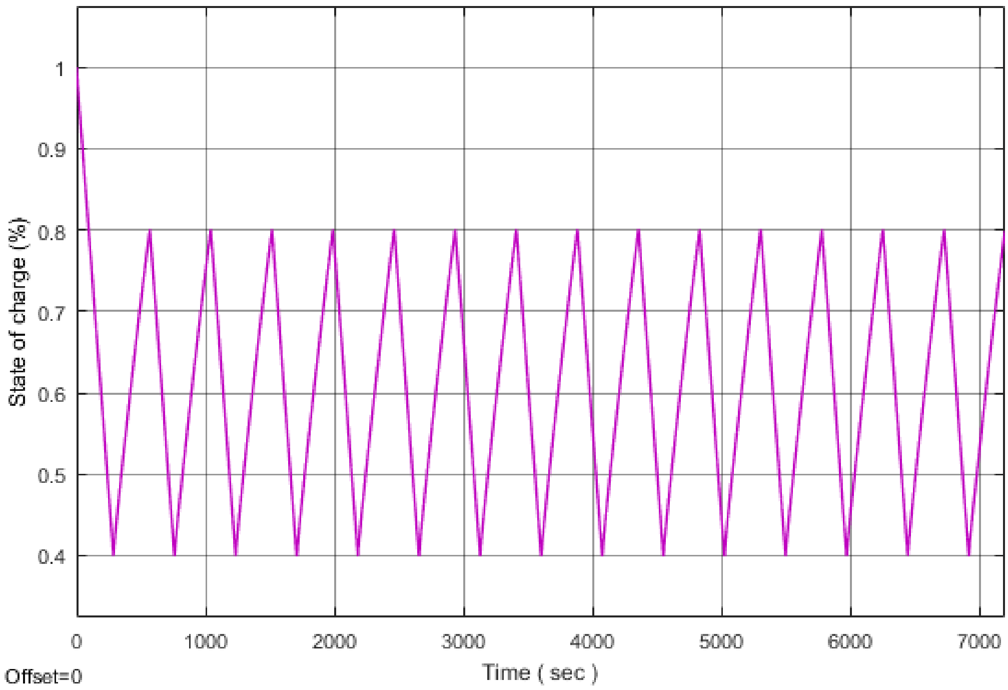

Figure 6 State of charge (SOC) behaviour of the battery.

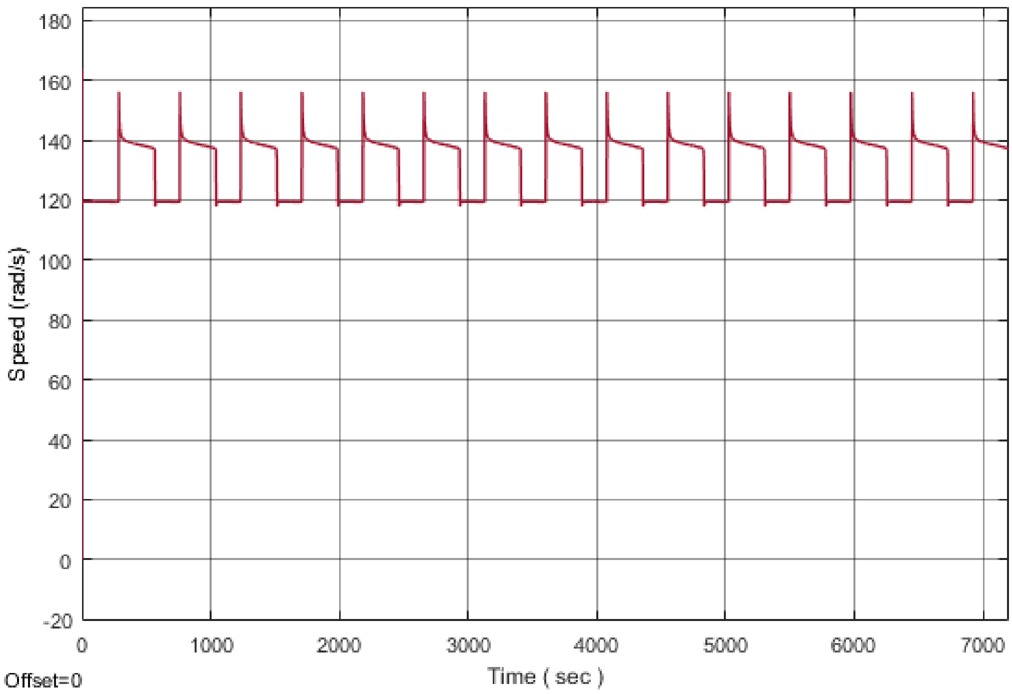

Figure 7 Motor current signal.

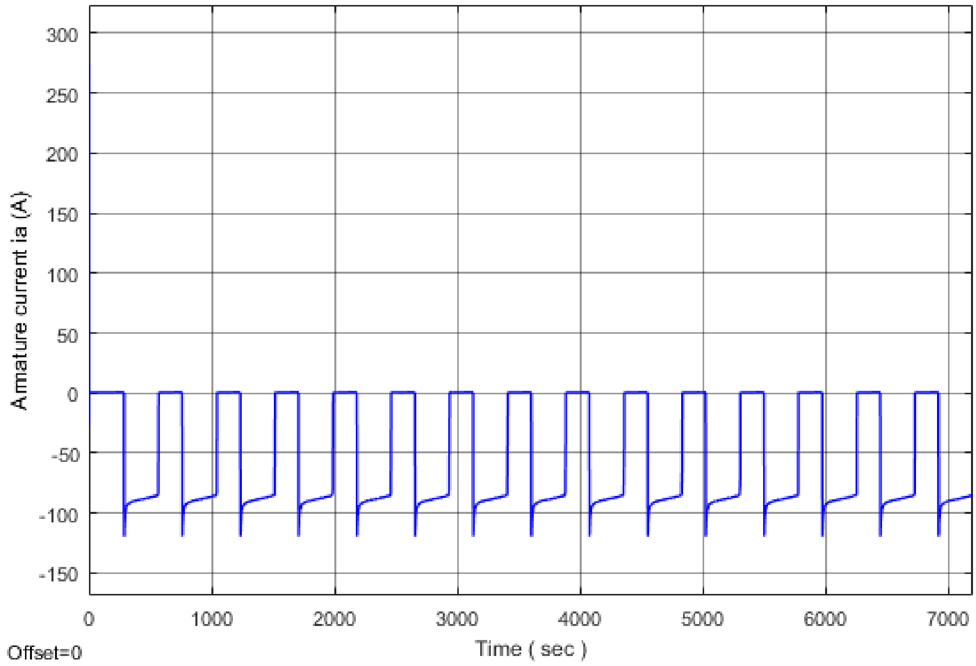

Figure 8 Motor current signal.

CONCLUSION

In the light-duty electric car, the newly designed, lightweight energy storage technology based on NiMH batteries has accomplished its purpose. The vehicle's drivetrain functions adequately. The evaluation of Ni-MH batteries for electric vehicles, the presumptive objective of the work, has been attained. Some important details related to the battery such as the working principle and a general description of the battery have been clarified, in addition to explaining two important parameters, the first is the state of charge (SOC) and the second is the state of health (SOH). At the end of the work, curves representing the outputs of the system studied for the batteries were presented. These outputs are battery voltage, SOC, motor speed and motor current signals.

REFERENCE

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

[2] Noga M., Various aspects of research of the SI engine with an additional expansion process, MATEC Web of Conferences, vol. 118, **2017**, 00017, 10.1051/ matecconf/201711800017.

[3] Noga M., Juda Z., Energy Efficiency of a Light-Duty Electric Vehicle, Proceedings of 21st International Scientific Conference Transport Means 2017, Juodkrantė, Lithuania, 20-22 September **2017**, 78–85.

[4] Hao H., Mu Z., Jiang S., Liu Z., Zhao F., GHG Emissions from the Production of Lithium-Ion Batteries for Electric Vehicles in China, Sustainability, vol. 9(4), **2017**, 504, 10.3390/ su9040504.

[5] Karden E., Development trends for future automobiles and their demand on the battery, [in:] Garche J., Karden E., Moseley P. T., Rand D.A.J., (Eds.): Lead-Acid Batteries for Future Automobiles, Elsevier , Amsterdam, **2017**, 3–25, 978-0-44463-700-0.

[6] 20 Truths about the GM EV1 Electric Car,

http://web.archive.org/web/20090123001021/http://www.greencar.com:80/features/gm-ev1/ (access: 30.06.2018).

[7] Patent encumbrance of large automotive NiMH batteries,

https://en.wikipedia.org/wiki/Patent_encumbrance_of_large_automotive_NiMH_batteries (access 30.06.2018).

[8] Johnson N.M., Battery technology for CO2 reduction, [in:] Folkson, R., (Ed.): Alternative Fuels and Advanced Vehicle Technologies for Improved Environmental Performance, Woodhead Publishing, Sawston, **2014**, 582–631, 978-0-85709-522-0.

[9] A. Alsharif, C. W. Tan, R. Ayop, A. A. Ahmed, A.Alanssari, and M. M. Khaleel, "Energy Management Strategy for Vehicle-to-Grid Technology Integration with Energy Sources: Mini review," *African Journal of Advanced Pure and Applied Sciences* (AJAPAS), vol. 1, Issue 1,pp. 22-26,**2021**.

[10] A. Alsharif, C. W. Tan, R. Ayop, A. A. Ahmed, and M. M. Khaleel, "Electric Vehicle Integration with Energy Sources: Problem and Solution Review," African Journal of Advanced Pure and Applied Sciences (AJAPAS), vol. 1, Issue 1,pp. 27-20,**2021**.

[11] A. Alsharif, C. W. Tan, R. Ayop, A. A. Ahmed, and M. M. Khaleel, "Electric Vehicle Integration with Energy Sources: Problem and Solution Review," *African Journal of Advanced Pure and Applied Sciences* (AJAPAS), vol. 1, Issue 1,pp. 27-20,**2021**.

[12] A. Ali Ahmed and M. Emheisen, "Analysis of Vehicle Handling Using a Simple Track Model of Automobile," 2019 19th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), **2019**, pp. 130-133, doi: 10.1109/STA.2019.8717244.

[13] A. A. Ahmed, J. Santhosh and F. W. Aldbea, "Vehicle Dynamics Modeling and Simulation with Control Using Single Track Model," 2020 IEEE International Women in Engineering (WIE) Conference on Electrical and Computer Engineering (WIECON-ECE), **2020**, pp. 1-4, doi: 10.1109/WIECON-ECE52138.2020.9397983.

[14] A. A. Ahmed and A. F. Saleh Alshandoli, "Using Of Neural Network Controller And Fuzzy PID Control To Improve Electric Vehicle Stability Based On A14-DOF Model," 2020 International Conference on Electrical Engineering (ICEE), **2020**, pp. 1-6, doi: 10.1109/ICEE49691.2020.9249784.

[16] A. A. Ahmed and O. S. M. Jomah, "Vehicle Yaw Rate Control For Lane Change Maneuver Using Fuzzy PID Controller And Neural Network Controller," 2020 IEEE 2nd International Conference on Electronics, Control, Optimization and Computer Science (ICECOCS), **2020**, pp. 1-6, doi: 10.1109/ICECOCS50124.2020.9314541.

[17] Mustafa Emheisen, Abdussalam Ali Ahmed, Abubaker Emheisen, Osama M. Abuzaid, Evaluation Of Vehicle Stability Using Simple Single Track Model And Different Control Methods, Liceet2018 Libyan international conference on electrical engineering and technologies,04-06/03/**2018**, Tripoli, Libya.

[18] Abdussalam Ali Ahmed | Mohamed Belrzaeg "General Overview and Forecasting of Factors Affecting the Use of Electric Vehicles" Published in International Journal of Trend in Scientific

Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-2, February **2022**, URL: https://www.ijtsrd.com/papers/ijtsrd49405.pdf

[19] K. Kartika Riyanti, I. Kakaravada, and A. A. Ahmed, "An Automatic Load Detector Design to Determine the Strength of Pedestrian Bridges Using Load Cell Sensor Based on Arduino", *Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics,* vol. 4, no. 1, pp. 15-22, Feb. **2022**.

[20] Mohamed Belrzaeg, Abdussalam Ali Ahmed, Amhimmid Q Almabrouk, Mohamed Mohamed Khaleel, Alforjani Ali Ahmed and Meshaal Almukhtar, "Vehicle dynamics and tire models: An overview," *World Journal of Advanced Research and Reviews*, **2021**, 12(01), 331–348

[21] Abdussalam Ali Ahmed, Faraj Ahmed Elzarook Barood and Munir S. Khalifa, Vehicle yaw rate simulation and control based on single-track model, *World Journal of Advanced Research and Reviews*, **2021**, 10(01), 019–029, Article DOI:10.30574/wjarr.2021.10.1.0127

[22] Abdussalam Ali Ahmed, Omar Ahmed Mohamed Edbeib, Aisha Douma, and Ibrahim Imbayah Khalefah Imbayah, Electric vehicles revolution: The future, challenges, and prospects in the Arab countries, *Global Journal of Engineering and Technology Advances*, **2021**,06(03),081-087,DOI:10.30574/gjeta.2021.6.3.0040.