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PERFORMANCE EVALUATION OF NICKEL METAL HYDRIDE (NiMH) RECHARGEABLE BATTERY USING MATLAB/SIMULINK

Jambaima Umar[1] and Babagana D. Maikale[2]
[1]Department of Electrical and Electronics Engineering, School of Engineering, Federal Polytechnic Monguno, Borno State
[2]Department of Electrical and Electronics Engineering, School of Engineering, Ramat Polytechnic Maiduguri, Borno Sate
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Abstract: *Nickel Metal hydride (Ni-MH) batteries, are used as hydrogen storage material with high hydrogen volumetric capacity and reversible hydrogen absorption/desorption reactions. The study helps contribute to the lingering research gap regarding the NiMH battery. Recent research works conducted on NiMH battery cover areas such as the battery capacity and its memory effect. This research work addresses the charge/discharge characteristics and the battery voltage. The methodology employs the use of a generic battery model which is modelled using the Simulink library materials. Simulation using nickel hydrogen battery model thus makes it possible to analyse the characteristics of chargeability and dischargeability. The result showed that the battery has a nominal voltage of 200 volt. The machine runs at 120 rad/s and the charge and discharge characteristics showed that the battery is least affected my memoryt.*

Keywords: *State of Charge (SOC), Memory Effect, Simulink, Rechargeable Battery*

Introduction

Nickel Metal hydride batteries (Ni-MH) are used as hydrogen storage material, with high hydrogen volumetric capacity and reversible hydrogen absorption/desorption reactions. NiMH battery continued to be an important energy storage source in 2017. Ni-MH batteries have high robustness at high temperature, fast charge (3-4 minutes) and a wide temperature range (between – 55 and 70^{0} C). Nickel Metal Hydride batteries are used widely in hybrid electric vehicles. The basics of the nickel hydrogen battery (Ni-MH cell) are based on its ability to absorb, release and transfer hydrogen between the electrodes. The success of NiMH technology comes from their rare earth metal alloys used in the negative electrode, which contributes to larger volume available for the positive electrode. This is the primary reason for higher capacity and longer service life over competing technologies. Ni-MH battery is an alkaline battery and it has an aqueous electrolyte (potassium hydroxide, KOH). Rechargeable alkaline batteries are dominant in the market for several technical reasons, such as high electrolyte conductivity (good for high power applications), operation over a wide range of temperature and higher energy density, which results in lower cost per watt-hour.

The electrolyte has a very high conductivity, due to its aqueous solution, and it doesn't take part in the process to any significant extent. The concentration of the electrolyte remains rather constant over the charge and discharge process. Due to this the resistance of the cell also remains almost constant over the SOC range. This leads to a battery with high power performance and long cycle life. The NiMH cells active materials are made of metal alloys or metallic oxides that are good conductors in a charged state. The nickel oxide hydroxide electrode exchanges a proton only in the charge-discharge process and the electron transfer is very quick. This corresponds to a high-power capacity. The small change in size of the electrode during charge and discharge also results in greater mechanical stability and therefore longer cycle life.

The rapid growth of communications, computers, consumer electronics, and electric and hybrid vehicles have created an urgent need for high energy density storage batteries. Although conventional Nickel cadmium (Ni-Cd) and lead-acid batteries have been improved in recent years, they still need a better performance and higher power density. The innate toxicity of cadmium and lead also has become a severe problem.

Applications of rechargeable Nickel metal hydride (Ni-MH) battery began with hydrogen storage alloy as negative electrode in 1990 (M. Okada et al, 2002). Ni-MH batteries have received much attention because of their higher energy density, superior charge-discharge characteristics, comparatively less memory effect and reduced polluting nature. Ni-MH batteries have higher gravimetric and volumetric energy densities as compared to Nickel Cadmium (Ni-Cd) batteries of the same size by approximately 30–40% (N. Cui et al, 2000). On the other hand, rechargeable Lithium ion (Li-ion) batteries present as strong competitors to the Ni-MH batteries, with their high specific power density and light weight. For safety reasons, however, they cannot be operated without an electronic control. Li-ion batteries are quite expensive as compared to other rechargeable batteries.

Results and Discussion

The simulation was prepared using MATLAB/Simulation package available in MATLAB 2016. The battery model was simulated during charge and discharge process. The simulation results capture the battery voltage, State of Charge (SOC) of the battery, motor speed and motor armature current signals are available at the output of the block as shown in figure 4.1, 4.2, 4.3 and 4.4 respectively. The simulation of 200 volt, 6.5 Ah NiMH battery connected to a constant load of 50A in parallel with a DC machine was performed and the result presented.

Battery Voltage Magnitude

At time t = 0 sec, the DC machine started with the battery power at a 200V as shown in fig 4.1. The battery was also discharged by the constant DC load of 50 amp connected in parallel with the DC machine as depicted in Simulink model of fig 3.3.

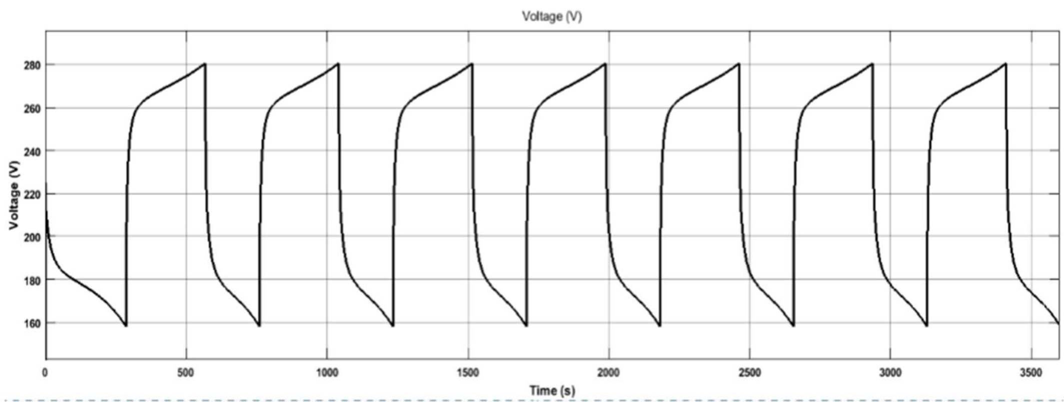

Figure 1: Battery Voltage Magnitude Measurement in volt

Battery State of Charge (SOC)

From figure 4.2 at t = 0 sec, the battery state of charge was 100%. As the time reaches t = 280 second, the state of charge (SOC) of the battery drop to 40%, a mechanical toque (negative load torque) of 200NM was applied to the machine so it acts as a generator to recharge the battery and provide a current of 100amps.

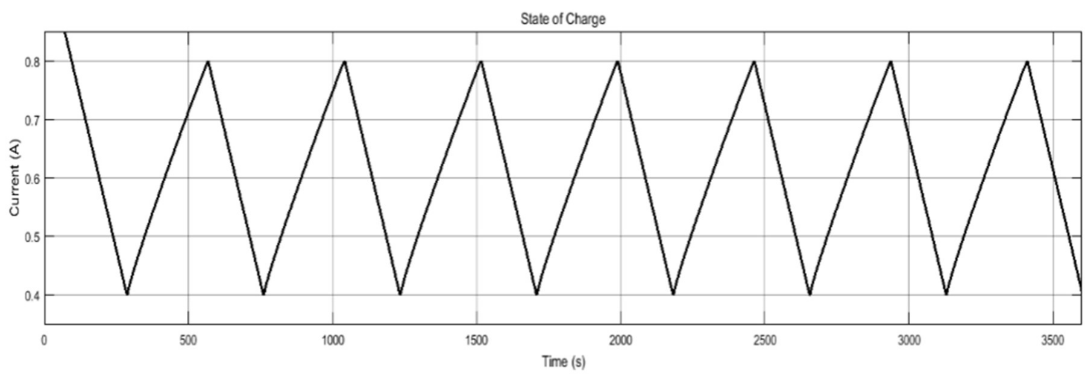

Figure 2: Behavior of the battery State of Charge (SOC) in Per Unit (p.u)

Hence, 50 amps goes to load and 50 amps goes to recharge the battery as shown in figure 4.3.

Motor Current and Speed Characteristics

It can be observed from fig 2, At t = 500 sec, the state of charge of the battery goes over 80% and the mechanical torque is removed. So (now) only the battery supplies the 50-amp load. Finally, result of fig 4.4 reveals the machine's response by raising the voltage of fig 4.1 and SOC of fig 4.2 to nearly 250V and 80% charge respectively. The initial speed was at to 120 rad/sec. Observed from fig 4.1, At t=280 sec when only the battery supplies 50amp load, there's a sharp drop in source voltage. Likewise, figure 4.2 reveals the effects on the SOC, which equally falls to 40%. Therefore, at the same time (negative load torque) of 200NM was applied to the machine so it acts as a generator to recharge the battery and provide a current of 100 amps as displayed in fig 4.3.

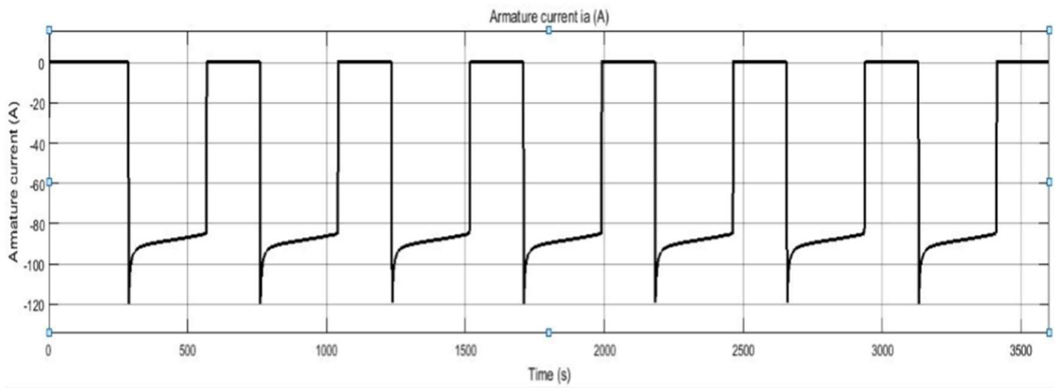

Figure 3: Motor current signal in (A)

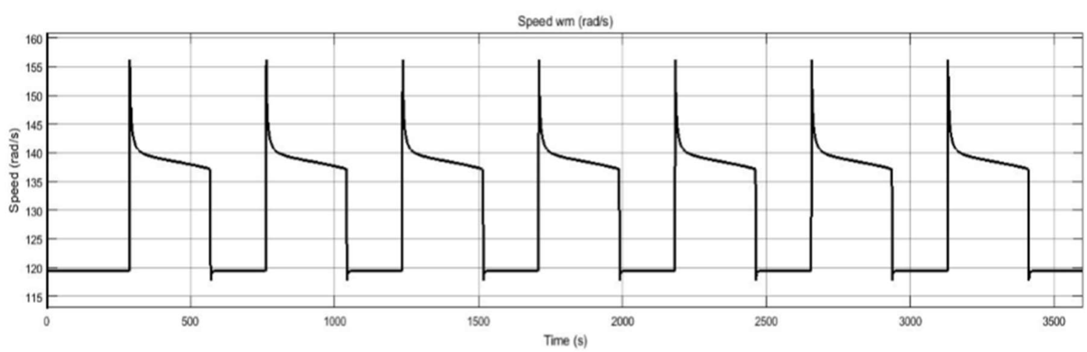

Figure 4: Motor speed characteristics.

When the SOC goes over 80%, the load torque was removed so only the battery supplies the 50 amps load. Therefore, the machine operates free and the cycle restarts.

The simulation result showed that the SOC of the battery kept increasing from 40% to 80% while charging and vice-versa while discharging. The battery voltage is 200V. It took the battery 280 seconds to discharge from 100% SOC to 40% to a load of 50 Ah, whereas upon application of negative load torque of - 200Nm, the motor acted as a generator producing 100 Ah of which 50% supplies a load and 50% goes to recharge the battery. It took 220 seconds for the battery to recharge to 80%. The negative load torque is removed at this point. The circle is repeated continuously to examine whether the battery is affected by memory effect. It was found that the state of charge and the charge/discharge time remained the same for all repeated circles. This means that the battery, NiMH is not affected by memory effect.

Conclusion

The model is able to estimate state of charge as well as battery voltage. The major portions of this project are the introduction to batteries presented in chapter one, review of battery types and past research works carried out on rechargeable batteries, which are presented in chapter two. The methodology, which was presented in chapter three explained the detailed procedure used in modelling the battery. The model based on the charge/discharge characteristics also presented. Based on the simulation results obtained in chapter four, it can be concluded therefore, that nickel metal hydride battery not only has high battery capacity but also study its charge discharge characteristics.

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