Rechargeable Battery Management for Mobile Robot

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***Abstract* - This paper elaborates on a comparative analysis of the issues in the usage of batteries for mobile robots. The design issues and the variations suggested in design based on analysis of a spark robot are discussed in detail and indicate how the battery pack changes influence the performance in terms of a governing equation developed based on the depth of discharge.**

***Index Terms* - Battery, spark robot, energy efficiency**

I.INTRODUCTION

With the advent of electrical vehicle technology and also hybrid vehicles, the studies on battery technology have become predominantly important from the perspective of design, maintenance and also from the seller and buyer trader perspective. The ever-increasing demand and the need for the batteries define the need for comparison, analysis and studies.

There have been numerous studies on state of charge of batteries based on the application starting from a simple battery used for a remote in a toy controller to sophisticated weapons and vehicles. The size, space and design of batteries become predominant based on the fact that standard cell measurements lie the guiding motto for the design of circuits and for calculation of parameters with accuracy and precision.

Wu et al [1] discusses about the state of charge(SOC) of a battery taking the equivalent model of a battery based on an algorithm. Though the method used is based on electromotive force, dynamic loading effects of loading and the design of the battery to accommodate dynamic loading would vary the analysis.

Chengke et al [2] discusses a different aspect of batteries in the context of power systems on two different aspects of cost and also on the frontier of charging and discharging with the usage.

However, in both the cases, and in many papers referred in various discussions on the ongoing work, we do see the comparative analysis specific to a particular operation. This paper discusses the battery management modules of mobile robots taking the case of a spark robot which is a low-cost educational robot.

II.MATHEMATICAL MODELING

Governing Equations

Existing literature has projected the varying governing equations for battery design. Authors [3] have developed governing equations for Nickel-Cadmium and Lead Acid batteries using SCILAB based on existing literature. In this model, a governing equation for the NiMH battery governing equation is compared to the existing method and analyzed.

The equation governing NiMH proposed for mobile robot is given as follows

$$y(t) = 9 - (9 - DOD) * N_c \qquad (1)$$

The equation takes into consideration the standard operating voltage of a rechargeable NiMH battery installed on the casing of the spark robot. The Depth of discharge(DOD) is the depth of discharge which is proportional to the full capacity rating of the battery and N_c is the standard rating of the number of cells that are present in the battery.

In the case of normal comparison between Lead-Acid batteries and Nickel Cadmium batteries, a relative analysis of cell voltage to the depth of discharge would indicate the performance of the battery in terms of usage.

Maintaining the Integrity of the Specifications

The methodology here involves comparing the standard cell that is configured with the robot with the performance of a standard Nickel Cadmium battery. The nonlinearities involved with the discharge are approximated based on algorithms by different authors in different methods.

III.RESULTS

A normal study by many researchers as quoted in [3] would indicate that the performance is highly nonlinear in nature for a nickel cadmium battery as shown in figure 1.

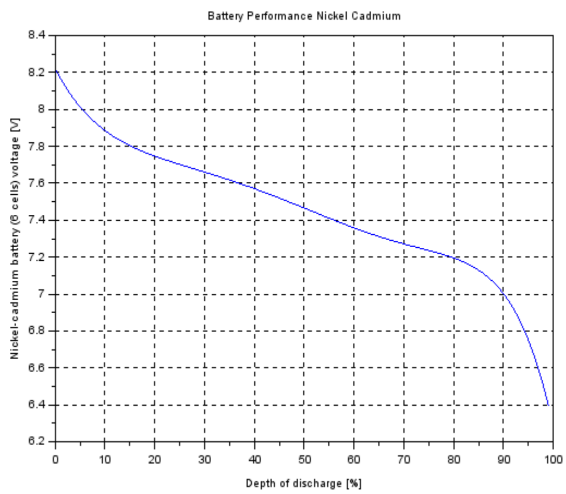

Figure 1: Nonlinearity of depth of discharge

The nonlinearity shown in figure 1 is logarithmic in nature and is drooping indicating a normal discharge which when analyzed on a time scale might indicate that the performance is usual. However, it is to be remembered that the nonlinearity when scaled down and divided into portions of linearity shows strict linear variations of the performance. This performance is normally based on the fact that the operating voltages at the load end would be more or less confined to a fixed value resulting in a typically constant voltage profile regulating the end user voltage which makes the operation of the vehicle or the dynamic system that is using the Nickel Cadmium battery to be more or less stable in all terms.

However, if figure 2 is observed, the performance based on the governing law defined in equation 1 is linear. Now, the converse is possible because of errors in approximation and dynamic nature of loads and sensor and motor loading.

Figure 2 below indicates that the battery is performing well, however, it is to be observed and it is to be noted that as the terrains of the dynamic mobile robot changes, the loading on the motors would varying effecting the battery loading and also the performance and functionality of the robot that is moving.

Figure 2 and figure 1 would represent two different batteries operating under two different conditions. Figure 1 indicates a nonlinear characteristic and figure 2 a linear characteristic. However, figure 2 if broken down to smaller scale on differentiation would depict the nonlinearity with varied degrees of variation in voltage when compared to one.

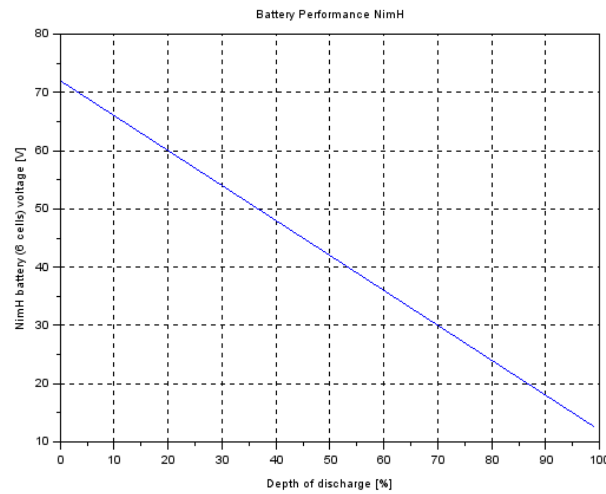

Figure 2: Battery performance of NiMH

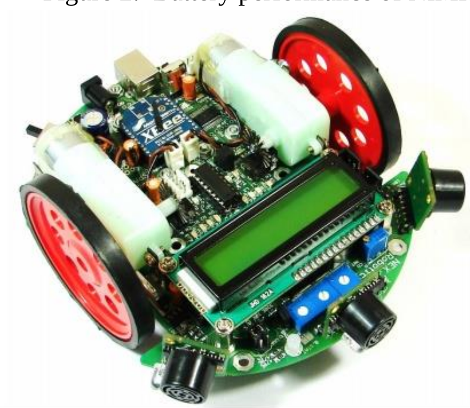

Figure 3: Spark Robot(Inhouse)

This becomes important because if it is tried to make an analogy with fuel cell design for a rover which is energized and charged based on solar radiations, the extrapolation of the Nickel cadmium battery and NiMH battery would be an initial saddle point to start with where the point of concentration would again be very much be defined based on the terrain.

As shown in figure 3, the spark robot is a lightweight robot running on NiMH battery pack of 6 cells. However, the interesting observation that was drawn from the work and studies in the laboratory is that the robot suffers when the terrains are non-uniform making it difficult. Though the robot by itself is an educational robot, it does throw some interesting aspect of the design of the robot battery system. Though the architecture has indications for low battery, it would be efficient if the design of robot considers the weight to cost to terrain performance of the robot which very much becomes sporadically varying.

A typical method followed for the discharge of the battery is to run a program and observe the discharge time. However, this becomes really insignificant when the microcontroller is fully operated with all it's 3 proximity sensors, 3 white line sensors, 3 ultrasonic sensors and 60 RPM DC geared motors with provision for voltage sensing.

Thus based on the observation on the standard comparison with a lead-acid battery, Nickel-Cadmium battery, the Ni-MH batter used in this robot was studied and it was determined that the terrain of usage would define the battery performance rather than the battery by itself.

IV.CONCLUSIONS

It could be concluded from the observations done on the mobile robot that if the system terrain is not considered for a vehicle design as a loading condition for a dynamic mobile robot, the depth of discharge curves calculated with approximations and formulae would be erroneous. However, this error can be reduced if aspects like granular computing based fuzzy calculation of the governing equations are done which would make a precise approximation of the usage of the battery which reduces the load on the battery and also on the various interconnected devices which are energized by the battery.

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