Lithium Battery Monitoring and Mathematically Modelling its Equation

Vurity Anudeep, Harshith Ch., Ram Kumar Paidi, Ch. Radha Charan

Abstract**: *Ever since people have managed to start shifting to electric vehicles, the lack of a cost-efficient battery monitoring system has been a real lack of concern for this mode of transportation. Not everyone wants to start a car after 6 months only to realize later that the battery is dead. Hence knowing the status of the battery on the back of our hand is crucial. This system will provide a steady supply of data about the status of vulnerable lithium-ion car battery which may include parameters such as the state of discharge (SOD) and state of temperature (SOT) to smartphones thereby eliminating this nuisance and also have inbuilt protection to help extend the battery life and avoid unwanted repairs which increases the maintenance costs. Using machine learning concepts like linear regressions and plotting's. A mathematical equation was developed for the lithium battery and this equation will provide an easy calculation for above discussed parameters and reduce the circuit complexity.***

Keywords—Crucial, data, Curve fitting, Linear Regression, Lithium-ion, maintenance, SOD, SOT.

I. INTRODUCTION

In pursuit of using only renewable energy sources, scientist have pushed the technology to include HEV's or "*Hybrid Electric Vehicles*" and eventually replace the more traditional vehicles running only using internal combustion engines. However, one of the problems with these HEV's is the lack of an *economical* battery monitoring system that communicates to us about the status of the battery during all times. The other problems involved are mostly concerned with the protection of the batteries. In this paper, a cost effective solution was proposed to these issues by adding a wireless feature to this system that runs on a set of algorithms designed specifically for it. The modeling of the battery theoretically using machine learning on MATLAB platform has been done. This will reduce the circuit complexity as BMS circuits need not have current calculation circuit. A safety circuit was also built to protect the battery from over discharging and enable thermal throttling of the battery pack with special algorithms. Further, on testing these circuits on a prototype, the results projected were the effective status of the battery in the prototype wirelessly on a smartphone. [1]

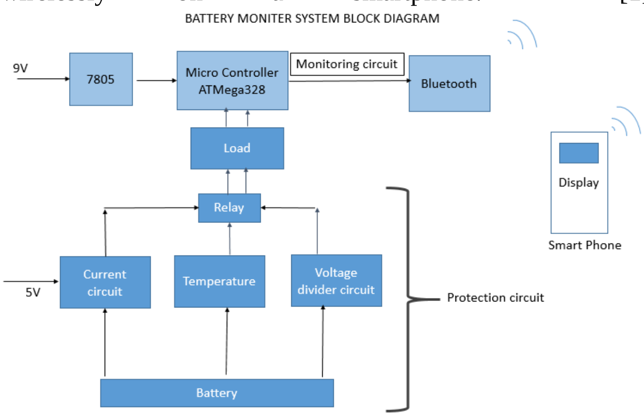

Fig. 1. Block Diagram of the Proposed Battery Monitoring System

II. HARDWARE PARAMETERS & COMPONENTS

A. *Battery Statistics*

SoC (State of Charge) can be utilized to estimate the charge remaining in a battery pack. It is the equivalent of a fuel gauge for the battery pack in an EV, describing its remaining capacity (0% = empty; 100% = full). SoC is a very important parameter reflecting the battery performance, so its accurate estimation can not only protect battery, prevent over discharge, and improve the battery life but also allow the application to make rational control strategies to save energy. Stete of Discharge SoD indicates the percentage of the battery that has been discharged relative to the overall capacity of the battery. For example, if the manufacture of a 13.5 kilo-watt hours (kWh) battery and discharges 13 kWh, the SOD is approximately 96%. State of temperature indicates the temperature levels of the battery. If the rise of the temperature of the battery increases then the battery will automatically shut down. But if this happens in a battery pack, then the batteries will distribute the load among themselves such that the overheated ones will work with lesser and lesser load, thereby cooling down via thermal throttling. [1]

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B. *Components used in the hardware:*

- Micro Controller (ATMEGA328P)**:** It controls both the protection circuit and monitoring circuit
- DHT11**:** It is a temperature and humidity sensor but are using this for temperature measuring purpose.
- 18650 battery**:** It is a 2000 mAh Li-Ion battery**.**
- HC 05 Bluetooth Module**:** A Bluetooth module is used for wireless measurement
- Solid state relay**:** It has a maximum capacity of 30Amps load. This relay is used as a circuit breaker to safe the battery.
- 7805IC**:** It is a voltage Regulator with 5V output
- 9V battery**:** It is the supply source for micro controller.
- ACS712 (Current sensor)**:** To measure the current via Hall Effect.
- Voltage divider circuit**: T**his is to map the voltage according to prototype capacity
- 16 MHz quartz crystal oscillator: This helps to increase the data transfer speed of microcontroller to the smartphone via the Bluetooth module.[2]

III. BATTERY MONITORING SYSTEM ALGORITHM AND WORKING

A. *Algorithm*

The circuit was built based on the fig.3.1 block diagram. A 9V voltage is given to microcontroller but as it can handle the voltage up to 5V. It provides a voltage regulator which would send a constant 5V supply to the controller. A microcontroller is used to control the protective circuit as well as Bluetooth module. It also provides the 5V input supply to the current and voltage divider circuit. The working of the algorithm inside the microcontroller is shown in the figure 3.1 [3]

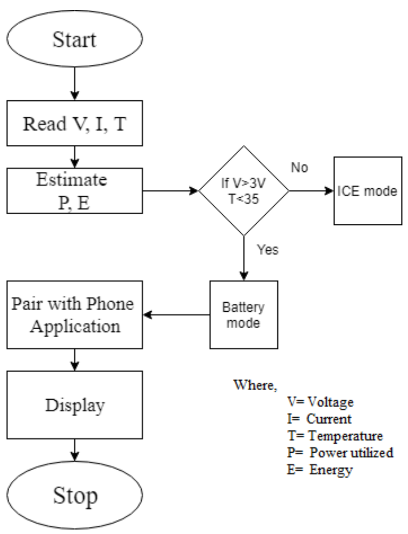

Fig. 3.1. Flowchart of Battery Monitoring System

B. *Bluetooth component circuit:*

Microcontroller gives the required battery data and this data is sent to mobile screens via a Bluetooth component circuit. A mobile app is made for this purpose and this would enable us to monitor the circuit (fig. 3.2.).[3]

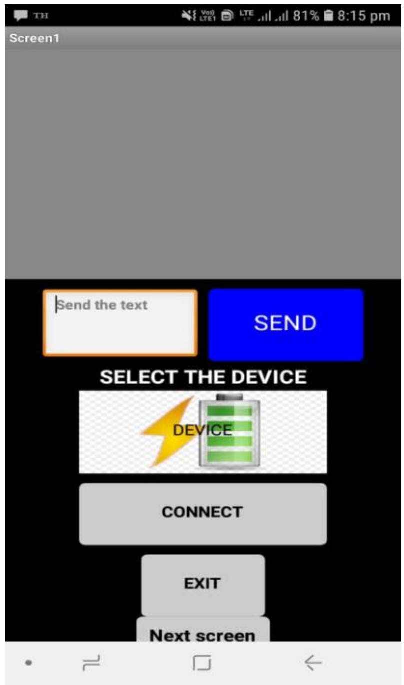

Fig. 3.2. Battery Status Being Displayed on a Smartphone

IV. PROTECTION CIRCUIT

Whenever the battery discharges less than 2.5V the battery wouldn't work. To prevent this problem a Protection circuit is required to establish a safety parameter to system. Three kinds of protective measures are used in the circuit. When any of the system requirements don't match to the safety requirements, the relay would get triggered which has a maximum capacity of 30A .This triggering would break the circuit and the system would shut down and send a warning message to our respective mobile phones. If the safety parameters meet the circuit then the relay will automatically close the circuit. [4]

A. *Current Circuit*

The current circuit will measure the discharge current using a hall-effect sensor and will trigger the relay during excessive discharge current (fig. 4.1) which would seriously damage the battery and may even cause it to explode. [5]

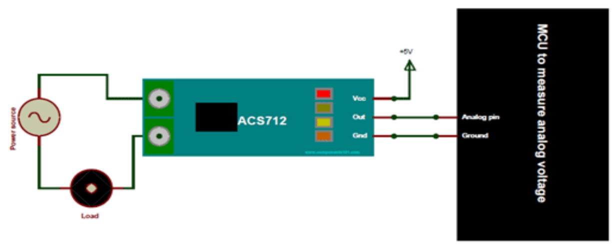

Fig 4.1. Current Protection Circuit

B. *Voltage Divider Circuit*

The Voltage Divider circuit (fig 4.2.) will be used to limit the discharge voltage of one battery incase the other one stops working for unknown reasons and also trigger the relay if the discharge voltage is higher than the rated discharge voltage which would have caused reduction in battery life expectancy.[5]

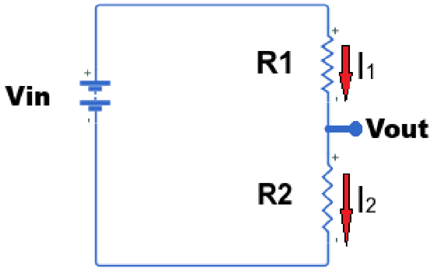

Fig. 4.2. Voltage Divider circuit

C. *Temperature Circuit*

The temperature circuit simply uses the temperature sensor to detect the state of temperature of the battery and will trigger the safety relay in case the battery gets over heated. The working of this is given below: [5]

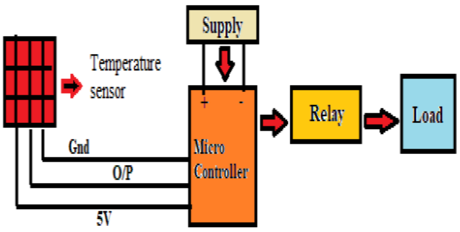

Fig. 4.3. Block Diagram of Temperature Circuit

V. MATHEMATICALMODELLING AND PRACTICAL EXPERIMENT RESULTS

A prototype was built that could measure the battery parameters as stated above and then send the data to smartphone to show us the status of the battery at all times. (fig. 5.1) It is run using a microcontroller "ATMEGA328P" and is supplied by a 9 Volt high watt battery which also has the voltage divider circuit to regulate the current.

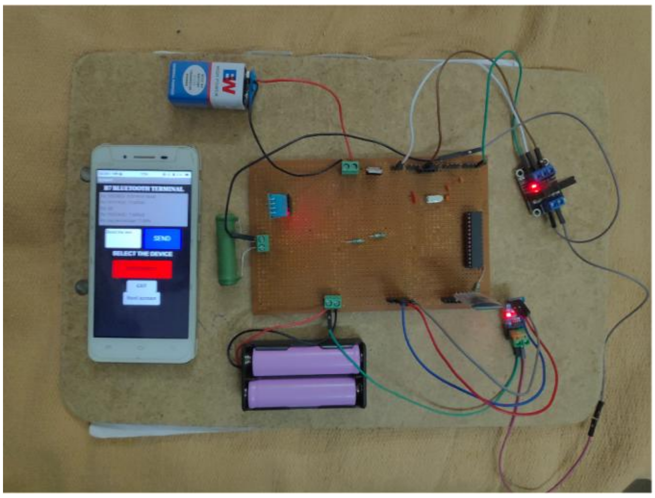

Fig. 5.1 BMS Prototype Model

The software used to run this device is "Arduino Integrated Development Environment" and the software used for running the android app in the smartphone to show the status of the battery is made from "MIT App Inventor". Through prototype, the output power was measured via the battery under various discharge voltages (fig. 5.2,) and then compared it to results of the theoretical model (fig. 5.3.).[6]

Sno	Voltage(v)	Power(W)	Energy(Wh)
1	4.3	4.38	1.97
2	4.4	4.53	2.01
3	4.5	4.75	2.01
4	4.6	4.98	2.06
5	4.7	5.21	2.12
6	4.8	5.48	2.18
7	4.9	5.67	2.22
8	5	5.86	2.26
9	5.1	6.13	2.32
10	5.2	6.34	2.4

Table. 1. Practical Results of Variation of Discharge Voltage with Power Output and Energy Output

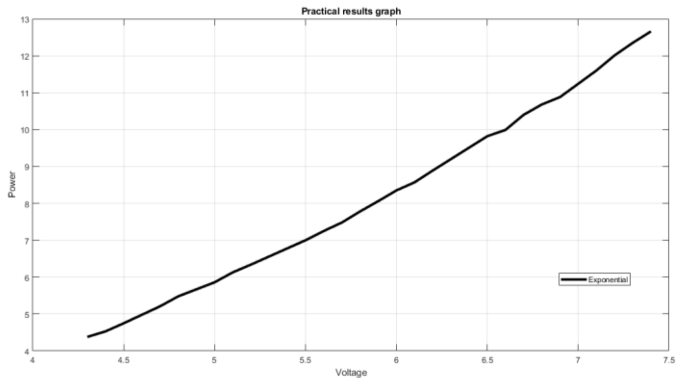

Fig. 5.2. Practical Variation of Voltage with the Power Output

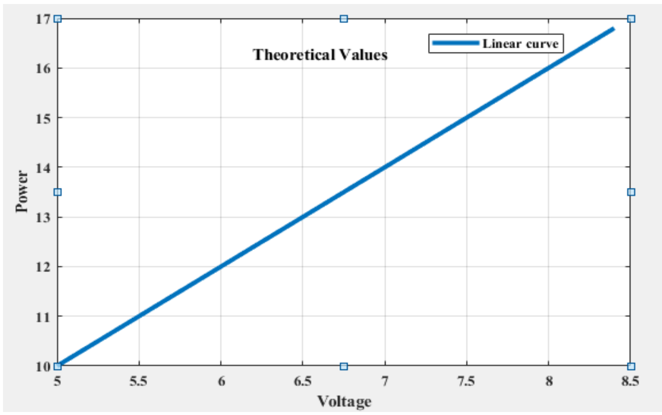

Fig. 5.3. Theoretical Variation of voltage with the power output

Then the plots are fit in both of the results to derive an equation to show the variation of power with discharge voltage as shown in the figure 5.4.

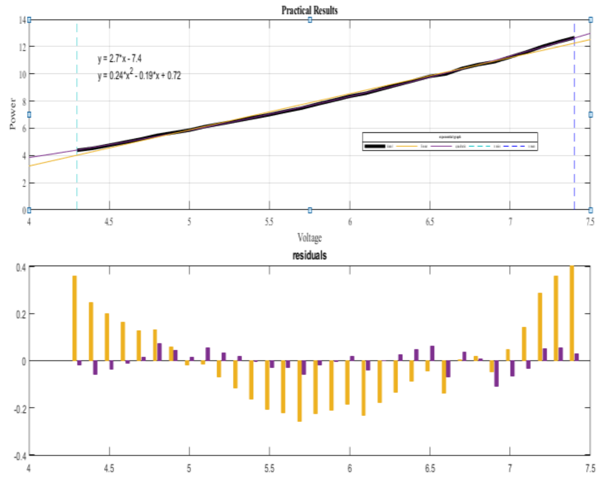

Fig. 5.4. Curve Fitting Of Theoretical and Practical Values

By machine learning technique like linear regression where the data of different voltage vs power values are plotted and curve fitting techniques are used to generate our required equation. [6] [7] the below equation (eq. 5.1) helps in finding the variation of power with the discharge voltage of a standard test lithium ion battery without any current measuring circuit.

$$P=0.24*V^2-0.19*V+0.72$$

Eq 5.1 Equation relating to the output power to the discharge voltage obtained from curve fitting

Then a successful test was conducted on our protective circuit against excessive internal temperatures caused by overloading which helps us extend the battery life and reduce further maintenance costs. The above Final equation will help in deriving the Power vs Voltage without calculating the current. This equation varies with model of the battery but this procedure can be more specific within the model of the battery. Using this procedure cost efficient monitoring is possible with more ease.

VI. CONCLUSION

In this paper, a mathematical model was developed on a lithium ion test battery pack by using concepts of machine learning to determine the variation of output power for the rated discharge range of a battery by comparing the theoretical and practical values obtained. This equation is used to minimize the cost of battery monitoring system by elimination the current measurement circuit. A successful protection circuit was also built for protecting our battery pack with low budgets. An app was also developed which takes the readings of the batteries status and would keep us up to date with the battery conditions.

VII. FUTURE SCOPE

In the future, a battery pack could be modelled where the load could be distributed to other parts of the battery pack during extreme temperatures for effective cooling and also upgrade to graphene batteries for higher resistance to discharge currents followed by an effective machine learning algorithm to predict the average battery life expectancy with a prolonged usage and show state of health as per the prediction.

REFERENCES

1. G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. *(references)*
2. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
3. I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
4. K. Elissa, "Title of paper if known," unpublished.
5. R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
6. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
7. M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

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