International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

Design of Battery Health Monitoring System Using Arduino Uno

Shivanand Basgonda Patil[1], Akshay Sanjay Kamme[2], Aniket Sunil Patil[3], Vaibhav Ravso Patil[4], Apurva A Londhe [5]

Final Year UG Student, Dept. of Electrical Engineering, Sharad Institute of Technology College of Engineering, Yadrav, Maharashtra, India [1,2,3,4]

Assistant Professor, Dept. of Electrical Engineering, Sharad Institute of Technology College of Engineering, Yadrav, Maharashtra, India[5]

ABSTRACT: One important feature of a battery management system is to provide the user with the overall health of the battery pack. The Orion BMS monitors the internal resistance of each cell and tracks the capacity of the weakest cell. It uses this information to calculate a cell health percentage value from 0 to 100%. The BMS then compares the calculated cell health information against pre programmed thresholds and if any cells (or the entire pack) fall short of the threshold, a trouble code is set and freeze frame data is stored for later analysis. The Orion Battery Monitoring System implements an extensive list of features designed to protect the battery pack. For the automotive engineer the Battery Management System is a component of a much more complex fast acting Energy Management System and must interface with other on board systems such as engine management, climate controls, communication and safety systems. Such systems encompass not only the monitoring and protection of the battery but also methods for keeping it ready to deliver full power when called upon and methods for prolonging its life.

I.INTRODUCTION

The search for alternative ways to replace the generation of electric energy that comes from the use of non-renewable sources is very important for the current situation of the electric sector. Seeking to generate energy through renewable sources, various devices capable of converting other types of energy into electric energy have been developed. For example, solar panels that transform solar energy into electric energy or wind turbines to transform kinetic energy from wind into electric energy. These devices need to store the generated energy because wind and sunshine are not always available. Additionally, these sources of energy vary in different timescales, from some seconds to hours and days. In this way, storing energy becomes indispensable to overcome the intermittency behaviour of non-renewable sources.

A way to store electrical energy is through the use of batteries. A battery is a set of cells connected in series. These cells can be manufactured in various combinations of materials. Some examples of materials used for the construction of these cells are nickel-cadmium (NiCd), Lithium-ion (Li-ion), Lithium polymer (Li-ion polymer),lead-acid (Pb) and Sodium-Sulphur (NaS) .The choice of what battery technology best fits an application is based on several criteria like robustness, cost, life-cycle, power density, temperature, depth of discharge and so on .Lithium-ion batteries are the primary choice for portable electronics applications and they are very attractive for electric vehicles due to as efficiency around 95%, long lifecycle (3000 cycles) and high energy and power densities. However, their relative high cost and the need for careful circuitry for safety and protection are their main hurdles .Nickel-cadmium batteries are attractive for Uninterrupted Power Supply (UPS) and generator-starting applications. However, the sales of these batteries declined for the period of 1995 to 2003, motivated mainly by the increasing environmental controls for toxic cadmium.

Sodium-Sulphur batteries are the most promising technology for variable renewable energy sources, such as wind and solar power. In the past decades, installations based on sodium-Sulphur grew exponentially from 10 MW in 1998 to 305 MW at the end of 2008. Sodium-Sulphur batteries can be cycled 2500 times, have high power density, have general capacity around 1MW and have efficiency around 75 – 90%. Additionally, they are environmentally benign and 99% of the overall weight of the battery material can be recycled. The drawbacks of sodium-Sulphur batteries are the high capital cost and the necessity to keep the internal temperature around 350 °C.

Lead-acid batteries have been used for more than 130 years. Lead acid batteries have high reliability, low cost, strong surge capability, efficiency around 65 to 80 %. Even though lead-acid batteries are being replaced in a variety of scenario for lithium-ion batteries, they still have preferable in some niche of applications. Lead-acid batteries are attractive for UPS systems, power quality devices and for spinning reverse applications.

When batteries are used in projects, it is usually essential to know how much energy is stored and available to be used. This information can be obtained through the SoC estimation. Valuable information about batteries is the SoH. With this information, it is possible to have a greater control over the energy that is stored and therefore facilitating the energy management of the entire system. Estimators for SoC and SoH of lead-acid battery have been constantly presented in the literature. In the authors proposed a SoC estimator based on Kalman filtering method. The estimators were verified with simulation and experimentally. A fuzzy SoC estimator was proposed for lead-acid batteries used in electric vehicles. Focusing on presenting a simple but efficient way to measure the SoC and SoH of lead-acid batteries, this article aims to demonstrate how to design and implement an estimator for lead-acid batteries using methods of Coulomb Counting to estimate the SoC and evaluating the internal resistance with the help of Ohm's law to estimate the SoH.

II. OBJECTIVES

1) Cell Protection: Cell protection can be external to the battery and this is one of the of the prime functions of the Battery Management System.
2) Charge Control: This is an essential feature of BMS. More batteries are damaged by inappropriate charging than by any other cause.
3) Demand Management: While not directly related to the operation of the battery itself, demand management refers to the application in which the battery is used.
4) SoC Determination: This may simply be for providing the user with an indication of the capacity left in the battery, or it could be needed in a control circuit to ensure optimum control of the charging process.
5) SoH Determination: This is vital for assessing the readiness of emergency power equipment and is an indicator of whether maintenance actions are needed.
6) Cell Balancing: Cell balancing is a way of compensating for weaker cells by equalising the charge on all the cells in the chain and thus extending battery life.

III. LITERATURE REVIEW

- Who was the pioneer in the field? Give the chronological development with another and their published work with proper comment. Describe few latest research papers on which this work depends. Give all these references chronologically.
- Presently, fossil fuels supply 80% and renewable resources supply only 13 % of the total global energy demand. There are several concerns with the ongoing trend, mainly the limited sources of fossil fuels. Several studies suggest that the reserves of oil, coal and natural gas could be exhausted within the next 200 years. Another issue worth addressing is the impact of emissions from burning fossil fuels on the environment.
- The presence of excess carbon dioxide in the atmosphere has been attributed to a rise in global temperatures, rise in sea levels, negative impacts on natural ecosystems and a rise in catastrophic weather events. The world's predicted carbon dioxide emission by year and Master's Thesis – A.Delbari; McMaster University, Mechanical Engineering 6 region, given no change to the current trend, is demonstrated in Figure 2.1. It is apparent that a change from the current trend of energy use is necessary in order to sustain the needs of the future generations and avoid global climate change.
- Alessandro Volta inspired by earlier experiments of Luigi Galvani first invented the primary cell and battery in the early 1800's. Galvani conducted an experiment in which he witnessed the twitching of a frog's leg as a result of application of electric current. Later in 1821, Michael Farraday showcased the basic principles of electricity. Farraday continued on his research and in 1831 demonstrated the principles of electromagnetic induction which are essential in electric vehicles. The year of 1859 saw the development of the first Lead acid battery by Belgian Gaston Plante. The Lead-acid battery is still used today as a starter battery in most internal combustion vehicles. Gustave Trouve of France, revealed the first electric vehicle in 1881. Trouve utilized the previously developed lead-acid battery to power a tricycle. The end of 1800's saw the development of nickel-iron battery by Thomas Edison. Although quite high in production cost, the nickel-iron battery was able to store 40% more energy per unit weight than the lead-acid battery. The same period saw the development of nickel-zinc and zinc-air batteries .
- Known as the golden age of electrical vehicles (1880-1920), this period witnessed the advancement of electric vehicle technology. The technologies developed during this time allowed electric vehicles to compete with their gasoline and steam powered counter parts.

- However in the 1970's several factors encouraged more efforts to be placed on developing electric vehicles. These factors included more emphasis being placed on limitations and environmental impacts of fossil fuels, the oil embargo effectuated by major oil producers and the nuclear power debate. Furthermore local, federal and global regulations such as California's zero emission regulation and the Kyoto Protocol additionally advanced the global effort for advancements in electric vehicle technology. The US government started electrification initiatives at this time such as the introduction of the "Partnership for a New Generation of Vehicles", which resulted in three more electric vehicle prototypes at a price tag of one billion dollars with none of the vehicles ever going to production. Japanese manufacturers became hybrid front runners with Toyota releasing the Prius in 1997 and Honda releasing Insight in 2003. In 2004 the Ford Escape became the first American hybrid vehicle.

IV. SYSTEM DEVELOPMENT

3.1 Design Methodology:-

As previously stated, currently there are many types of batteries in the market, each one with its advantages and disadvantages. One of the longest in the market is the lead- acid battery. These have as advantages the large temperature range in which they can be operated. One disadvantage of lead-acid batteries is the low number of cycles, staying between 400 and 2000 cycles.Despite the new batteries that are emerging, such as lithium batteries and lithium polymer batteries, there is still plenty of room in the market for lead acid batteries, especially in systems where its temperature is not controlled and robustness is required. With this in mind, the choice to work with lead-acid batteries to construct the estimator of the SoC and SoH is justified.

State of Charge (SoC):-

The SoC of a battery is a percentage value that represents the amount of energy that is stored at the time it is being observed. One of the most commonly used methods to estimate the SoC value is called the Coulomb Counting. This method basically controls the amount of charge that is stored inside the battery. where Ca is the discharge capacity of the battery, that is, the amount of energy the battery can store in a way that does not compromise its state of health. The energy that is withdrawn from the battery is measured by the integral of the current at time t.

$$SoC = \frac{C_{a-\int idt}}{C_a} \times 100\%$$

Equation gives us the percentage of energy that is stored in a battery.

State of Health (SoH):-

To estimate the SoH of a lead-acid battery,

$$SoH = \frac{R_{Eol-R_i}}{R_{Eol-R_n}} \times 100\%$$

This equation is used. Where REoL is the internal resistance of the battery when it is in a state considered as the end of life, that is, the capacity to store charge is considerably below when a battery is new. This value in general is informed by battery manufacturer. The Rn is the internal resistance of the battery when it is new. This value is also informed by the battery manufacturer. And Ri is the actual internal resistance of the battery. To find this value, one can use methods such as evaluating internal resistance through the use of Ohm's law. In order to use Ohm's law it is necessary to apply a pulse to the battery. After the pulse is applied, it will return information about the voltage and current, thus, using Ohm's law, it is possible to measure the actual internal resistance of the same .here VB being the voltage, and IB being the battery current in response to the pulse and VBO and IBO are the actual voltage and current of the battery, respectively.

3.2 Selection

General devices

To implement the prototype, it is necessary to use some general devices, as follows:

1) Microcontroller:-

With the data generated by the sensors, after being conditioned, it is necessary to process this data to provide information about SoC and SoH. To process this information the aurdino uno processor used.

2) Solid-state Relay:-

The solid-state relay Ssr-25dd is used as a switch to apply a pulse to the battery. To switch on the relay, the microcontroller sends a pulse, which in turn, passes through a buffer circuit.

3) Signal Conditioning:-

Having the data generated by the sensors, it is possible to process them using the processor, thus obtaining the estimates on SoC and SoH. However, to use the information of the current sensors and the voltage sensor, it is necessary to perform the conditioning of these signals in order to reduce their amplitude, but keeping the information intact, thus allowing the processor to process the signals from the sensors correctly. For the signal conditioning, the circuit of Figure 1 was used. This circuit, through the use of operational amplifiers and potentiometers, is able to apply a gain to the input signal, thus changing the amplitude of the signal but maintaining the signal information. For the prototype, three signal conditioning circuits were used, one for each sensor, each circuit was adjusted to apply a gain of 1/10 in each signal.

4) State of Health (SoH):-

In order to measure the health status of the battery, it is necessary some battery information, i.e. the internal resistance of the battery when the battery is new and the internal resistance of the battery at the end of life. These information can be obtained from the manufacturer. The actual internal resistance is obtained using the strategy of applying a pulse to the battery and using the pulse response information that the battery emits. To generate the pulse, an external, adjustable source connected to the battery was used, according to Figure 2. A solid-state relay is used as switch S1. The voltage and current sensors are being measured and the response of the battery to the pulse is observed. The theoretical battery response curves are shown in Figure 3(a) and Figure 3(b), where the curves in Figure 3(a) is the actual current curve (dashed line), ideal current curve (continuous line), and the curve in Figure 3(b) is be the curve of voltage. To estimate the actual internal resistance of the battery, the Ohm law, is used (3), with values referring to the difference ΔU (VB – VB0) for the voltage and ΔI (IB – IB0) for the current, as shown in Figure 3(a) and Figure 3(b). Thus, with all values obtained (REoL, RN e Ri), it is enough to apply (2) to obtain the state of health of the battery in percentage. The SoH is better expressed in percentage. Thus, its value indicates the current state of health of the battery. Table I presents the SoH classification according to the percentage of SoH.

5) Obtaining the discharge capacity (Ca):-

The discharge capacity is a parameter usually supplied by the battery manufacturer. However, the Ca value changes from battery to battery, mainly due to their internal physical differences. Therefore, it is necessary to obtain the discharge capacity of the battery being used.

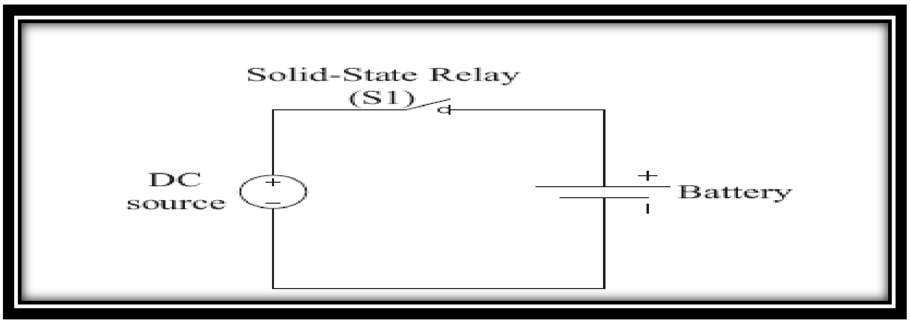


Fig. 2. Simplified diagram for connecting an adjustable source to the battery.

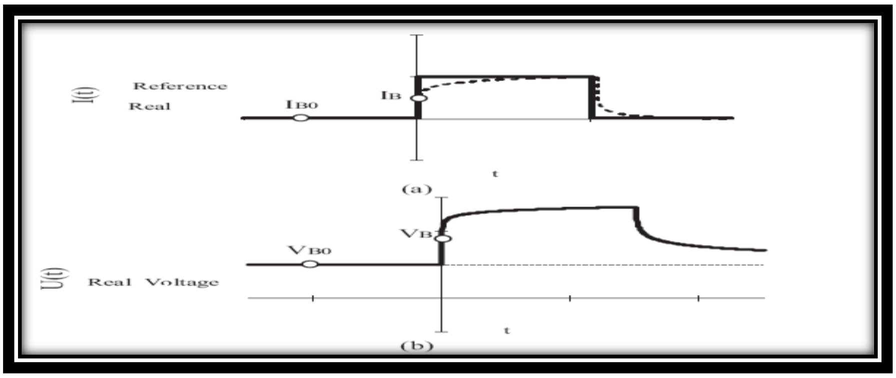


Fig.3. (a) Theoretical battery current response to pulse and (b) Theoretical battery voltage response to pulse.

TABLE I
SoH Classification

Sr.no.	Classification	Percentage Range of Values
1	Excellent	95%<SoH≤100%
2	Good	90%<SoH≤95%
3	Regular	85%<SoH≤90%
4	Bad	80%<SoH≤85%
5	Very Bad	SoH≤80%

To obtain the value of Ca a method is used by evaluating the amount of charge the battery uses when it is discharged from the fully charged point to the point where it is considered totally discharged. The fully charged point of the battery can be considered when the voltage at the battery terminals is 1.5V above the rated voltage of the battery. The point where the battery is considered fully discharged is obtained while the battery is being discharged. The observed curve in the discharge of a battery has an almost constant behaviour of supplying power from the beginning of the discharge to a point where there is an abrupt drop in the power supplied.

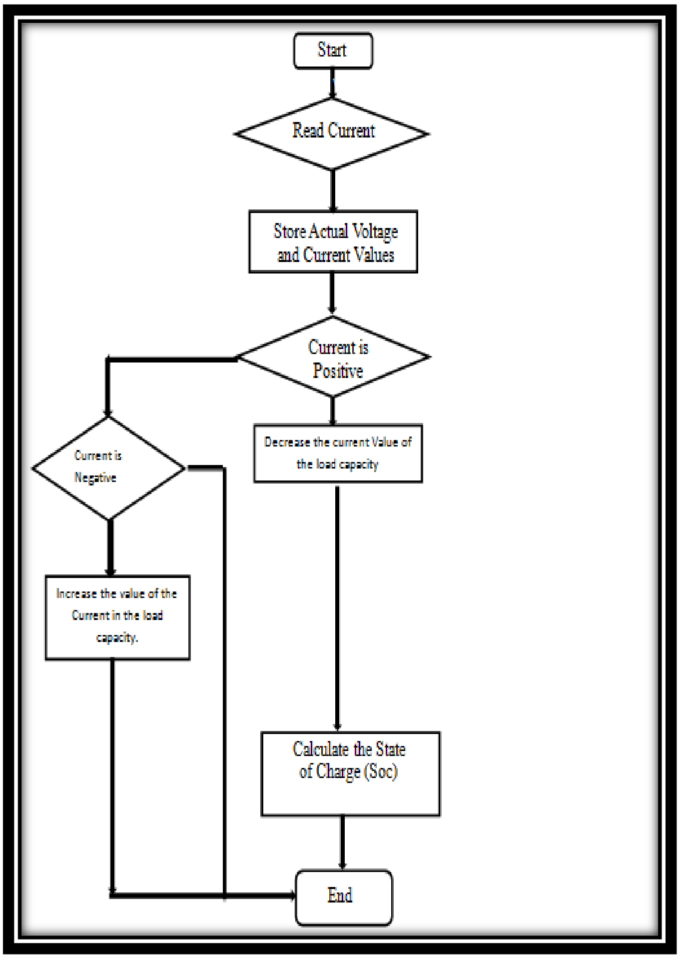


Fig.5. Flowchart to measure the SoC of the battery.

The point where the battery is considered to be fully discharged should be chosen based on the value at which this abrupt drop occurs. In addition to the points considered as the fully charged and fully discharged battery, a value for Ca must be stipulated. The choice of this value should take into account the battery charge capacity reported by the manufacturer in Ampère-Hour (Ah). Since it is only a value to be used to obtain the effective value of Ca, this first value must be oversized, and a value should be considered for each unit of Ah. In this paper, this value is five thousand. With the values set, the battery is discharged using a simple resistive circuit as shown in Figure 4. The battery discharge must be monitored to observe the moment when the sudden drop in the supplied power begins to occur. In addition to this measurement, it is necessary to perform the SoC measurement algorithm, with the stipulated value of Ca. To find the effective Ca value, it is calculated using the SoC value found and the Ca value stipulated above. Where Ca is the stipulated value and SoC is the value obtained with the battery discharge.

Thus, therefore, the discharge capacity of the evaluated battery is being found.

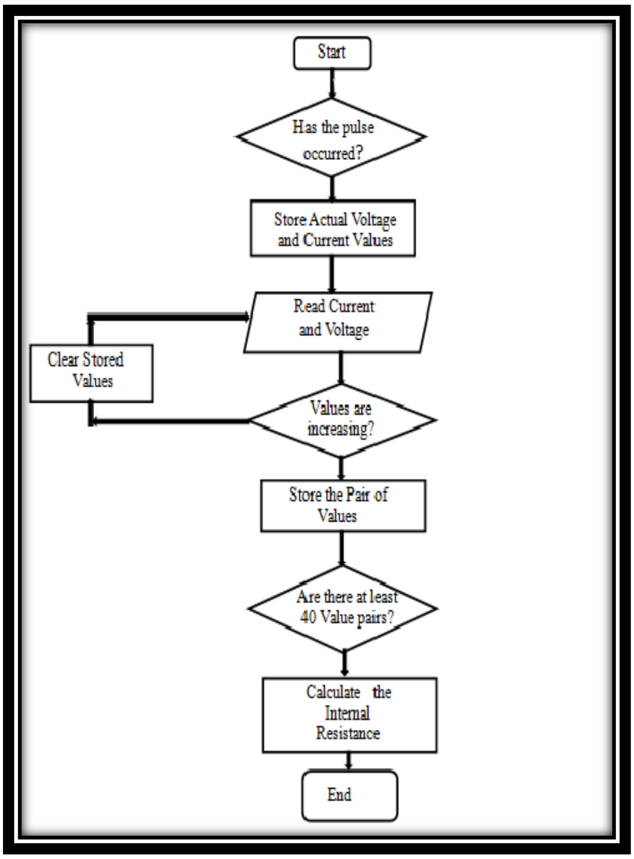


Fig.6. Flowchart to measure the internal resistance of the battery

Major Components:-

- Arduino UNO (ATMega-328)
- LCD (16×2)
- Relay

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

Arduino UNO (ATMega-328)

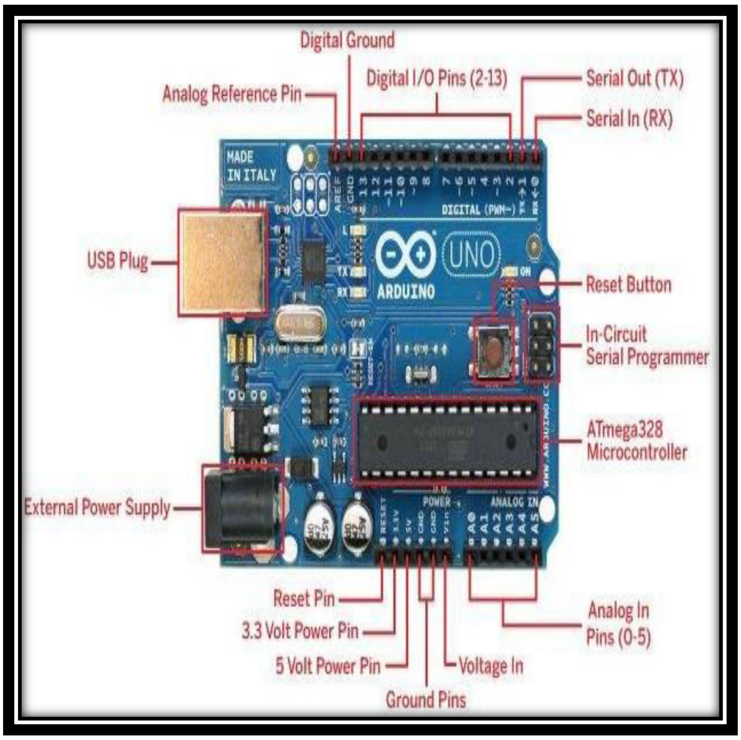
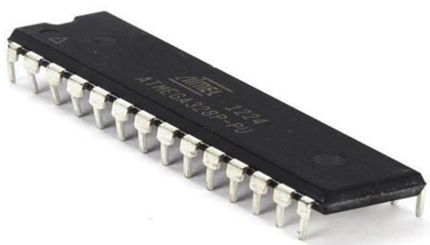
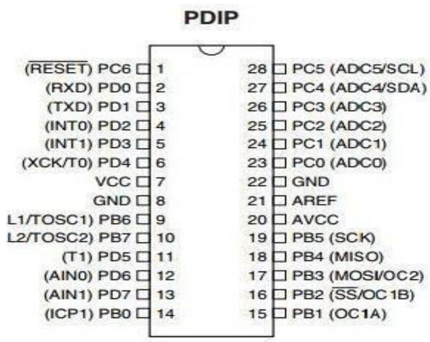


Fig.3.2.1 Pin out of Arduino Uno

AT Mega328:-





| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

3.2.3RELAY: -

When power flows through the first circuit (1), it activates the electromagnet (brown), generating a magnetic field (blue) that attracts a contact (red) and activates the second circuit (2). When the power is switched off, a spring pulls the contact back up to its original position, switching the second circuit off again.

3.2.4 Load (12v 200rpm DC motor):-

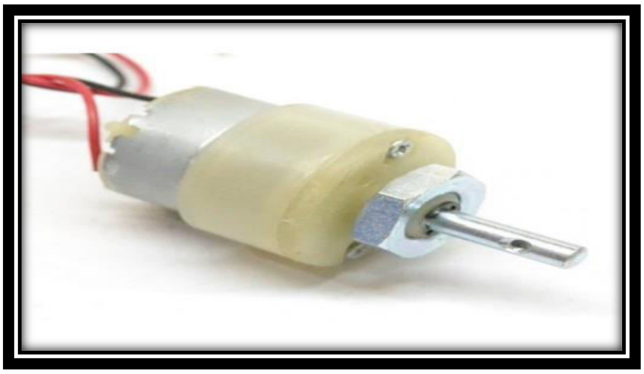


Fig No.3.2.4Load

200 RPM 12V DC geared motors widely use for robotics applications. Very easy to use and available in standard size. Also, you don't have to spend a lot of money to control motors with an Arduino or compatible board. The most popular L298N H-bridge module with onboard voltage regulator motor driver can be used with this motor that has a voltage of between 5 and 35V DC or you can choose the most precise motor diver module from the wide range available in our Motor diver's category as per your specific requirements.

3.2.5Adaptor:-

Fig No.3.2.5 Adaptor

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

An AC adapter, AC/DC adapter, or AC/DC converter is a type of external power supply, often enclosed in a case similar to an AC plug. Other common names include plug pack, plug-in adapter, adapter block, domestic mains adapter, line power adapter, wall wart, power brick, and power adapter. Adapters for battery-powered equipment may be described as chargers or rechargers (see also battery charger). AC adapters are used with electrical devices that require power but do not contain internal components to derive the required voltage and power from mains power.

3.2.6 IC 7805: -

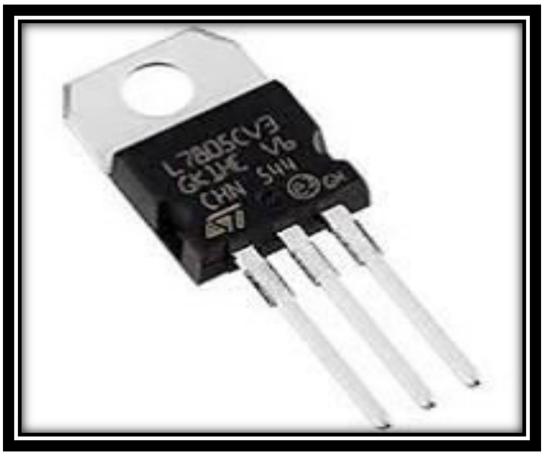


Fig No.3.2.6 IC 7805

IC 7805 is a 5V Voltage Regulator that restricts the output voltage to 5V output for various ranges of input voltage. It acts as an excellent component against input voltage fluctuations for circuits, and adds an additional safety to your circuitry. It is inexpensive, easily available and very much commonly used. With few capacitors and this IC you can build pretty solid and reliable voltage regulator in no time. A Circuit diagram with pin out is given. It also comes with provision to add heat sink.

3.2.7 IC7812:-

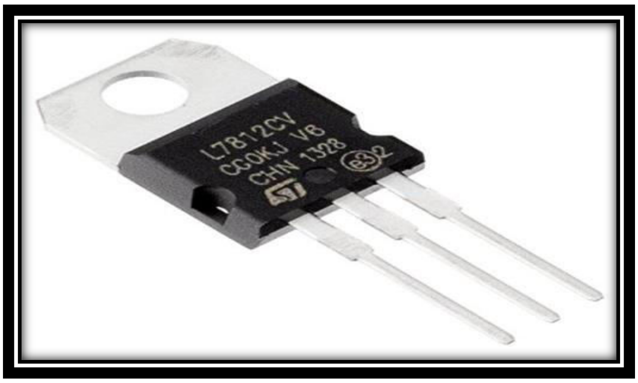


Fig No.3.2.7 IC7812

7812 is a 12V Voltage Regulator that restricts the voltage output to **12V** and draws 12V regulated power supply. The 7812 is the most common, as its regulated 12-volt supply provides a convenient power source for most TTL components.

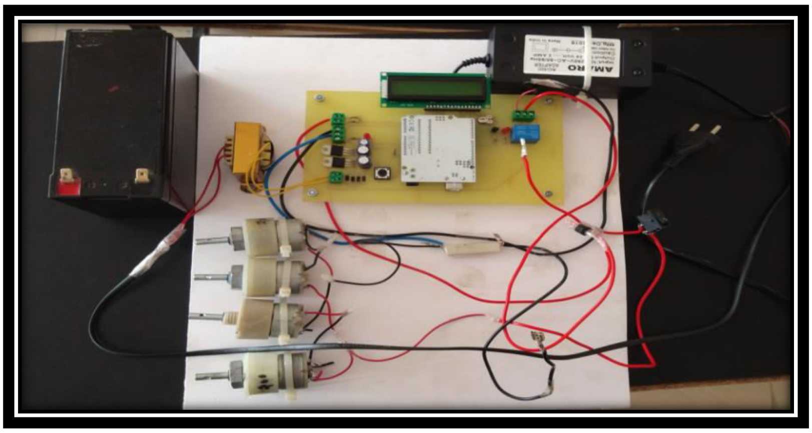
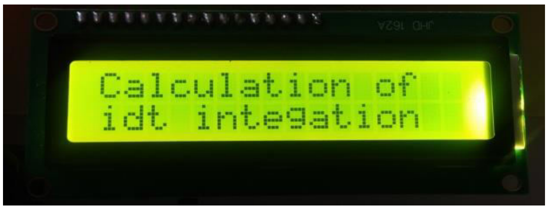


Fig.4.1 Hardware

VII. RESULTS

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||



| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

VIII. CONCLUSION

The main objective behind our project design and implementation of lead-acid battery SoC and SoH. The main goal was to describe carefully the procedure to design and implement the SoC and SoH estimators. The SoH is estimated through generating a pulse to the battery and monitoring its voltage and current. Then, the SoH is obtained by calculating the battery internal resistance. On the other hand, the SoC was estimated through the Coulomb Counting method. Experimental results showed the efficacy of the proposed estimation method. The proposed estimator can be applied in real-time applications. The SoH and SoC estimators are independent of the DC/AC converter used to process the battery energy. When there is current through the battery, independently of its direction, the SoC estimators keeps measuring and computing the value of the charge within the battery. On the other hand, the proposed estimator computes the SoH value in moments when the battery begins to be charged. Therefore, the design and implementation of SoC and SoH proposed in this project is an attractive solution for lead-acid battery applications.

IX. FUTURE SCOPE

The BMS manages batteries by controlling load environment, monitoring battery state and accordingly balancing the charging. Battery management system is useful for ensuring prolonged life of batteries, preventing battery damage due to overcharging and voltage fluctuations, managing optimal state of charging for the battery and facilitating BMS interfaces with host application to provide real-time information regarding battery health. BMS follows three types of topologies, which are distributed, centralized and modular. Distributed BMS has a single communication cable controller and battery; a cell board is installed at each cell. Centralized BMS has a single controller, which is connected to battery cells with the help of communication wires. Modular BMS has multiple controllers that handle certain number of cells and communicate with each other.
The report begins with an overview of the battery management system market. The global battery management system market is segmented on the basis of verticals into automotive, energy, telecom and drones. To understand and assess the opportunities in this market, the report is categorically split into three sections market analysis by vertical, topology, component and region.

REFERENCES

[1] M. H. Bollen, "Integration of Distributed Generation in the Power System",John Wiley & Sons, 2011.
[2] R. M. Dell and D. A. J. Rand, "Understanding Batteries Royal Society of Chemistry", 2001.
[3] D. Pavlov, "Lead-Acid Batteries Science and Technology A Handbook of Lead-Acid Battery Technology and Its Influence on the Product," Elsevier, 2017.
[4] C. Julien, A. Mauger, A. Vijh, and K. Zaghib, "Lithium Batteries Science and Technology",Springer, 2015.
[5] A. Chen and P. K. Sen, "Advancement in battery technology: A state-of-the-art review," in 2016 IEEE Industry Applications Society Annual Meeting, 2016.
[6] M. Alamgir, "Lithium Has Transformed Vehicle Technology: How trends in Li-ion battery technology have developed for vehicle electrification," 2017.
[7] M. W. Cheng, Y. S. Lee, M. Liu, and C. C. Sun, "State of charge estimation with aging effect and correction for lithium-ion battery," IET Electr. Syst. 2015.
[8] P. Du and N. Lu, "Energy Storage for Smart Grids: Planning and Operation for Renewable and Variable Energy Resources (VERs)", Academic Press,2014.