Charge and Health Status Estimation of a Lithium Ion Battery in an Electric Vehicle Using Cell Balancing IOT Modelling Techniques

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Abstract— In Present scenario Internal Combustion Engines [ICE] is overcome by Electric Vehicles [EV] due to advantages like reduction in carbon-di-oxide [CO_2] emission, cost. Advancement in electric vehicles are extensively going on and one such concept is Battery management system [BMS]in Battery Electric vehicle. In Battery Electric Vehicle there are many types of batteries and from the literature survey Lithium Ion Battery can be concluded to be suitable as it is advantageous in weight, cost, energy density and many aspects. Battery may be overcharged or it may undergo faults. Hence a reliable management system is required to control the Electric vehicle [EV]. In this paper two battery charge estimation models namely, open circuit voltage and Kalman filter has been considered. From the simulation results obtained it is found that data retrieval is difficult in open circuit voltage method can be achieved using Kalman filter and found out to be satisfactory.

Keywords— Battery management system, Open Circuit Voltage, Kalman filter, State of Charge.

1. Introduction

Battery Electric Vehicle:

Battery Electric Vehicles, also called BEVs, and more frequently called EVs, are fully-electric vehicles with rechargeable batteries and no internal-combustion engine. In this paper Nissan leaf electric car has been considered since it has DC charging feature and monitors the charge status of the battery consistently and detailed analysis is as follows:

DC Fast Charging for Nissan Leaf

Battery Management System: In Battery electric vehicle Battery plays a crucial role. Battery could also be overcharged or it's going to undergo faults. Hence a correct management system is required to regulate the electrical vehicle [EV] and it's called Battery Management System [BMS]. to style Battery Management System several concepts, need to be taken care the most function of the Battery Management System is to stay any single cell of the battery. Charge status has got to be determined properly. If it's not determined and if the battery is overcharged then lifetime of battery may reduce. Hence to work out state of charge algorithms are developed. Among the algorithms, a Comparative charge status analysis during a Battery Electric Vehicle using Model based Method Technique and Book keeping Method is administered with suitable circuit model and simulation results are tabulated for an equivalent.

Lithium ion battery:

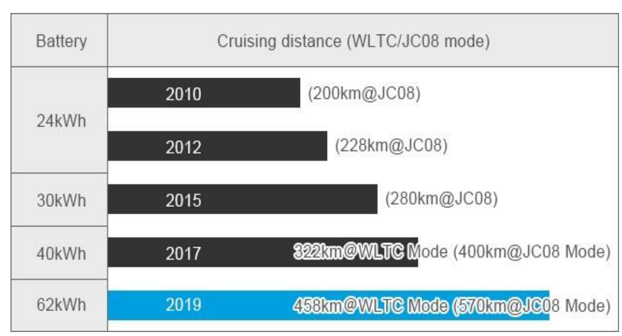

Fig 1: Lithium ion battery importance in Nissan Leaf Electric car

From fig 1 importance of lithium ion battery in electric car is shown. In May 2020 recent development says 62kwh battery with 80% charge can be achieved in 45 min and it can reach up to 680km and research is carried on the same [1][6].

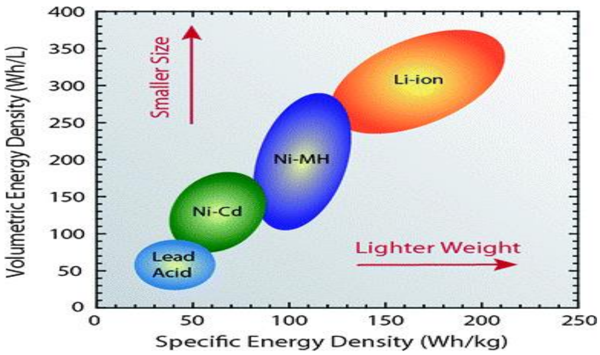

Fig 1.1: Characteristics of a Li-ion Battery

Section I gives detailed Introduction. Section II describes the description of state of charge. Section III describes the Methodology and Results. Section IV describes Conclusion and future Scope and Section V gives the References.

a) Open Circuit Voltage: In this method RC model has been built and simulated in Scilab. Simulation Results are compared with experimental results [7] and it is found that it is same and it is mapped with experimental results.

2. Description of State of Charge

State of Charge: The units of SoC are percentage points (0% = empty; 100% = full). An alternative sort of an equivalent measure is that the depth of discharge (DoD), the inverse of SoC (100% = empty; 0% = full). Fig 2.1 indicates the block diagram representation of various algorithms used to calculate State of charge.

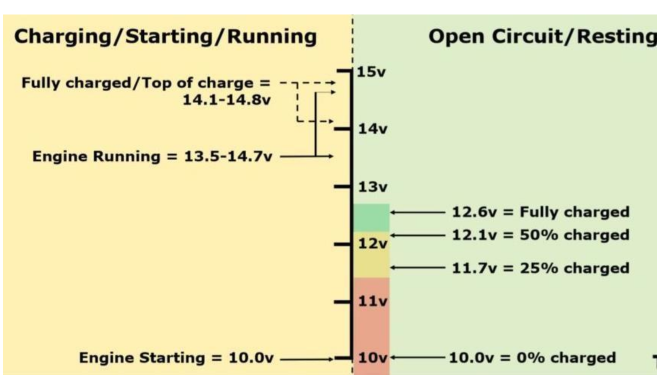

Fig 2: State of charge calculation in an electric car

3. Methodology and Results

Comparative charge status analysis in a Battery Electric Vehicle using Model based Method has been carried out with suitable algorithms and simulation results. Among various algorithms used to calculate state of charge, detail analysis of Kalman filter and Open Circuit Voltage is explained below:

STATE OF CHARGE	12V BATTERY	VOLTAGE PER CELL
100%	12.7V	2.12V
95%	12.6 V	2.10V
90%	12.5 V	2.08V
80%	12.4V	2.06V
70%	12.3V	2.05V
60%	12.2V	2.03V
50%	12.05V	2.00V
40%	11.90V	1.98V
30%	11.75V	1.95V
20%	11.55V	1.92V
10%	11.30V	1.88V
BELOW 10% DEAD	10.5V	1.75V

a) Open Circuit Voltage Method:

Open circuit voltage (OCV) **features a** considerable influence on the accuracy of battery state of charge (SOC) estimation. From the simulation model, consider RC network in addition with voltage source. State of charge is measured at output [5]. Voltage is measured at terminal 2 and total resistance is measured at terminal 1. Voltage and Resistance of the RC Circuit model has been developed using Scilab and has been indicated in fig 3.1. Open circuit voltage, Voc, internal resistances during discharging, Rdis, and charging, Rcha, are involved. The dependent variables considered for State of charge estimation includes:

Open circuit voltage (Voc),

Internal Resistance during discharge -Rdis

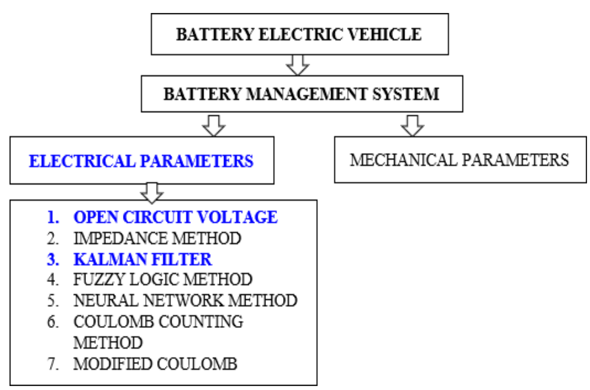

Fig 2.1: Block diagram of State of charge calculation in an electric ca

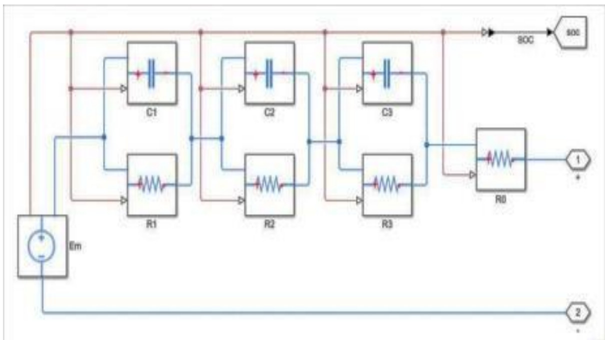

Fig 3.1: RC Circuit model of Open Circuit Voltage

The battery current and output voltage can be calculated as follows:

$$V_{..} - V_{l}$$

$$SOC = SOC_{ini} - \int_0^t \frac{I}{Q_b} d\tau$$

$$V_b = \frac{I\ ele, m}{I}$$

Here, SOCini is the initial value of SOC, and Qb refers to the storage capacity of the battery. From the developed RC circuit model and simulation has been carried out and results has been compared with existing paper[6] and mapped all parameters and it is shown in fig 3.2. Hence

Li-Ion Battery Modeling using Kalman filter

To improve the model reliability, unlike the general equivalent Thevenin model, extra RC branch is added as shown in Fig. 3.5.1. These blocks shown in the figure were created in Simulink Simscape Language to define the custom components as text files. The texts include complete parameterization, physical connections, and equations represented as a couple of causal implicit differential algebraic equations. The mathematical relation method is easy to implement. However the initial value cannot be stored and hence data retrieval is found out to be difficult when state of charge has to be calculated.

Table 1: Simulation result for a Nissan leaf electric car lithium ion battery identified RC model

From Table 1 Simulation result for a Nissan leaf electric car lithium ion battery identified RC model is compared for a 12V battery. It is found that Nissan leaf electric car has used Level 2 charging and experimental and simulation results is same and it is validated.

b) Kalman Filter Method:

This method is complex but data can be stored and data retrieval is also possible but has few errors like

Battery Model and Parameter Identification of Kalman filter

Consequently, the renewable energy technologies have gained more attention and derived **the utilization** of more electric vehicles. Lithium- ion batteries **are becoming** popular in both renewable energy systems and electric vehicles **because of** their high power and energy density. Therefore, accurate battery models are vital to **the planning** and simulation of hybrid/electric vehicle propulsion systems. Modelling and batteries are a toilsome task **due to** their complex electrochemical structure and nonlinear characteristics. [3] Accurate real-time SOC estimation reporting to drivers **is additionally** difficult. This work addressed these challenges using extended Kalman filter (EKF) algorithm and a two-RC-block equivalent circuit shown in figure 3.5. This battery equivalent circuit model **is meant** in Matlab Simulink using the Simscape Language. Then, an algorithm with the EKF approach is developed **to reinforce** the SOC estimationhas been obtained as a result from experimental work as explained in [1] .

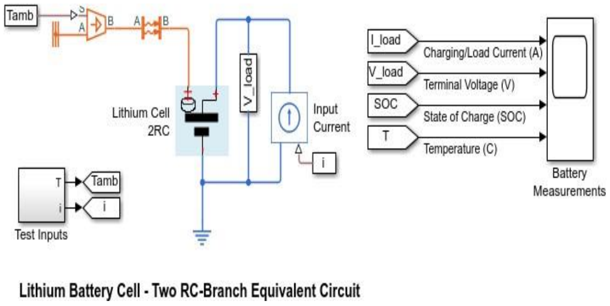

Fig 3.5.1. Two RC Branch Equivalent circuit model

the soc output voltage is explained in fig3.5.3

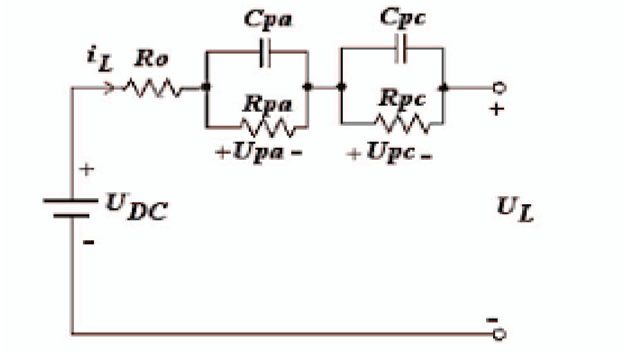

Fig 3.5.2: RC Thevenin Model

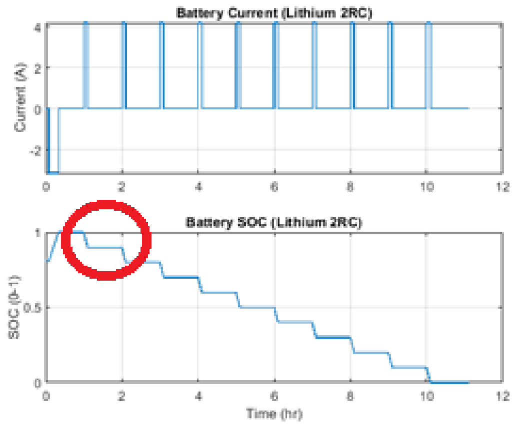

Fig 3.5.3: RC Thevenin Model

The state of charge estimation using Kalman filter method and its equivalent battery model has been shown fig 3.6. The Extended Kalman filter is a method for predicting the future state of a system based on the previous ones and convenient form for online real time processing. It consists of two equations. The expressions of matrices and vectors are the same as [1]. xk is the system state matrix and one of the matrix values represents SoC. Therefore, xk captures the system dynamics. Input of the system is uk which is a control variable matrix and known or can be measured.

$$xk + 1 = A \times xk + B \times uk + wk$$
$$yk = C \times xk + D \times uk + vk$$

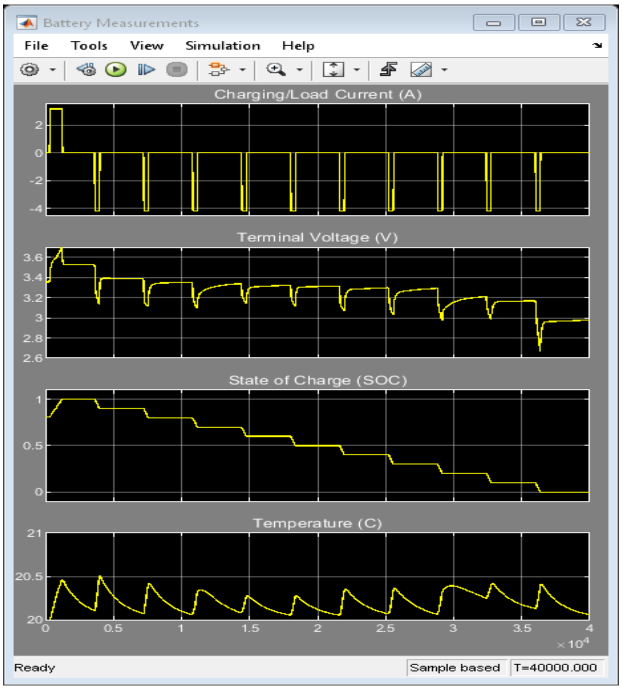

Fig 3.7.1 Theoretical results of Kalman filter

fig 3.7 and 3.7.1 indicate the Compare the simulation results with research paper results and found out to be same[7].Maximum SOC error is found out to be 1% from the simulation results as per fig 3.7.1 and it proved to be successful implementation of Kalman filter technique.

IMPORTANCE OF IOT IN ELECTRIC VEHICLE

Description of IOT: A system with IoT will definitely streamline the performance of EV charging and looks the impacts. IoT will improve the city planning and makes the city life easy. Internet of Things (IoT) signifies the network-based interconnection of daily usage entities. It is termed as a selforganizing wireless linkage of devices aimed at the interconnection of everyday objects. deployment of energy storage devices in the distribution grid will help expedite this process and improve system performance [4]. Bulk energy storage has been used for decades in the utility grid and now the integration of renewables is creating a need for more distributed storage.

Fig2: Importance of IOT

Delivery operations in traffic and pollution : Urban logistics and delivery services are one of the main issues troubling every big and small city in the country. According to data by MDS Trans modal Limited, these delivery services represent between 8 and 18 percent of urban traffic flows. Hence, online delivery services will reduce the capacity of the roads by 30 percent in the coming years due to the increase in the number of online delivery companies and the rise in demand by the consumers. The movement of these vehicles in rush hours, which are already congested by private transport, have a high impact on congestion and urban environmental quality. They are also responsible for about 20 percent of CO2 emissions in urban areas.

The role of IOT in EVs: A new segment that has joined the delivery services segment is electric vehicles. **Methodology: Case a) Node-Red** The estimation algorithm was implemented in the Node-Red environment. Node-Red is a graphical means for connecting various hardware appliances, Application Programming Interfaces (APIs) and real-time facilities together– to equip the Internet of Things. The lightweight runtime is built on Node.js, taking maximum benefit of its event-driven, nonblocking model [15].

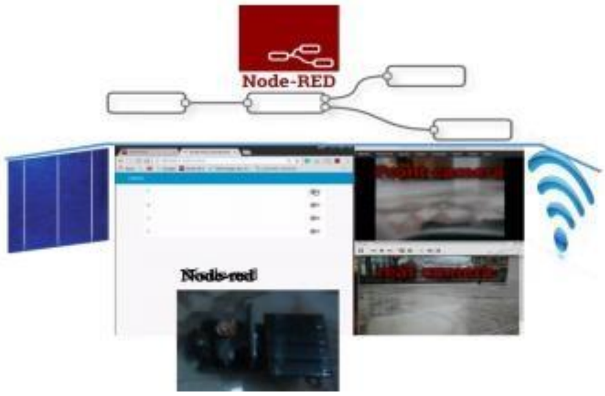

Fig 5: Importance of Node-Red in Electric Vehicle

Case b) MQTT (Message Queuing Telemetry Transport) is a messaging-based communication protocol that affords the lightweight network with an easy means to deliver data. The protocol is used for machine-to-machine. In publish/subscribe model, communication is straight from client to an endpoint. But the publisher (client sending message) and subscriber (client getting message) have no knowledge about the presence of each another. There exist a third element, known as broker, who is familiar with both the existing parties i.e., publisher and subscriber As MQTT delinks the publisher and subscriber, only the information about hostname/IP and port of the broker is sufficient in order to communicate with messages. Figure 6 shows a typical BMS framework incorporating the measurement of key battery parameters e.g., current, voltage, temperature etc., and performing necessary calculations/estimations to extract useful information about energy storage system i.e., State of Health (SoH), State of Charge (SoC), operating temperature range.

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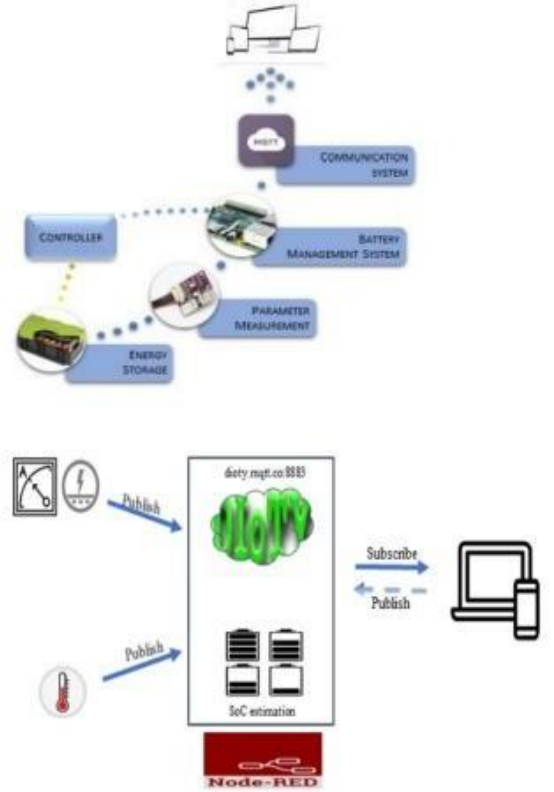


Figure 6 BMS hardware prototype at the block level.

The battery packs electrical parameters are measured using hall effect current/voltage sensors and after amplification, In [6] the paper explains the problem of charging a set of electric vehicles from photovoltaic power and rectified by “Maximum Variable Resource Allocation Problem” (MVRAP). In [7] & [8] an energy management algorithm that organize the optimal charging and discharging times of an electric vehicle battery has been introduced. In [10], they introduced charging rate compression (CRC) algorithm which decreases the problem-solving complexity in EVs. Implementation Electric vehicles are going to be the future transport. In order to increase the efficiency of the charging station and to reduce the charging time we made the charging station by utilizing the renewable and non-renewable energy to increase it’s efficiency and with fast charging are communicated with the processor Raspberry Pi 3 B interfaced through an 8-bit ADC. Users can view the value of SoC and operating temperature. The lifecycle of the battery pack can be augmented overall by the feasible formulation of battery charging, discharging, and sleep practices e.g., in the occurrence of SoC topping 10%, the discharge should be allowed and in the occurrence that it trips down below 10%, the discharge need to be stopped. When the SoC touches 95%, then the battery charging must be stopped. Cyclic full charge/discharge enhances the longevity of the battery pack. The operation should be ensured below the specified temperature to avert the risk of explosion of the battery.

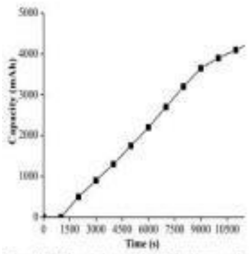


Fig. 4: Estimated capacity of battery packs

Fig. 5: Battery pack temperature across different platforms

1) Methodology: Data collection State of Charge (SoC) of a battery shows the remaining battery capacity and this value is expressed in percentage value (ranging from 0 to 100) [9] [10.SoC = Initial SoC − (current flowing (1) through battery/Nominal capacity of battery) The magnitude of current is constantly positive for the discharging process and it will be negative for charging process. 2) SOC calculation: Coulomb counting method which means counting the charge flowing into (or) out of the battery.

Ardinuo: Nowadays Electric Vehicle (EV) technology has grabbed great passion from the people. In [1] , inexhaustible energy generation appliances were supplied in the energy station. In [2] & [9], there are chain of charging stations supplied with an energy storage appliance and propose a system that allots power to them from the grid, as well as routes customers. In [3], the work power the vehicle to compute a routing policy that reduces their expected time of journey. [4] describes the fee scheduling problem in EVs at the microgrid scale. In [5] To reduce the computational demand during long control horizon, a nested optimization method is used to breakdown the joint OPF and EV charging problems. technology through wired or wireless modes to reduce the charging time. The charging station should have a separate battery pack from which the electric vehicles are to be charged by using DC to DC rapid charging technology through wired connection or wireless

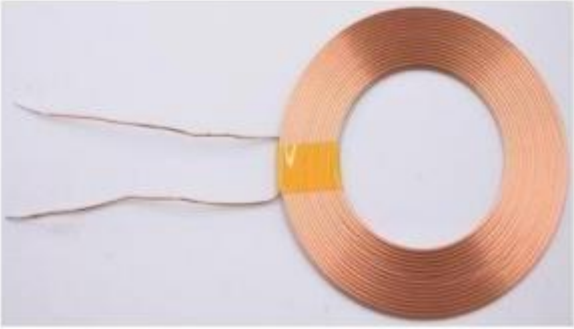


Figure 4. Coil Used For Wireless Charging

Using IOT all the details i.e power consumption, cost are updated in the charging station and thus the efficiency ofthe charging station is increased with reduced charging time. It's performance can be increased by installing charging ports or wireless charging pads in the parking of hotel, parks, theatre, malls and in traffic signals with renewable energy sources. We know that EV charging involves renewable energy generated from solar panels utilized by all manufactures today for industrial and domestic purpose. The estimation of energy generated can be predicted even though it is not as accurate and it is time-varying and limited. By considering the charging requirements for a particular vehicle and the expected power generated from the solar generation a local energy storage unit can be introduced. In order to automatically control the storage unit in vehicles, charging station provides sufficient flexibility. So that it can increase the stations introducing energy storage. Like our ordinary electricity bill, it can charge for the storage utilized per unit energy whether it is charged or discharged and by this, charging station can be benefited by making extra cost. Whenever energy state of the storage chargers changes, they exclude the installation cost of the storage and charge for the appropriate capacity of the storage to fulfill this task as an energy buffer. To make the entire vehicle as automated, power storage is in control by the charging station which decides when to charge or discharge the storage unit. Accurate value will be maintained by proper usage of storage unit, with the help of various monitoring sensors. Figure shows the block diagram of an electric vehicle charging system. The main part or the heart of the system is the microcontroller which controls the functions of the devices connected according to the requirement. Using the Ardino uno processor the proposed system is implemented with programming written in Embedded C. The figure 2 shows the different sensors used in the system. The three sources of input are solar panel [11], grid supply and battery bank. Mostly solar cells available in different voltages and current ratings and when it absorbs sunlight it generates electricity. Current sensor is used to measure the amount of current in a wire and generates a signal which is directly proportional to the current. The output signal is used to display the measured current using ammeter, or can be utilized for further analysis. Another important sensor is the Voltage Sensor which is mainly used to converts voltage measured into a physical signal and it is directly proportional to the voltage. The specialty is, it will measure the presence of a voltage without making metal contact. It is made of resistive voltage divider and that integrated resistors, embedded in a casted resin, which has very low inductance. The whole arrangement is in the shape of zigzag, together with the resin permittivity which acts as a capacitance. Radio Frequency Identification system [12-14] has two main parts, a tag attached to an object which is to be identified, and a Transceiver called as Reader. Organic Light Emitting Display is a LED in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current.In between two electrodes organic layer is present and at least one of the electrodes is transparent. The IOT module can be controlled from local Wi-Fi network or from the internet source. The ESP-01 module consists of GPIO pins which is programmed to turn ON/OFF. the LED or a relay through the internet. This can also be programmed by using an Arduino/USBto-TTL converter through the serial pins. Any operating systems can be used to write code and upload to the board such as Windows, Mac OS, and Linux. Here in this paper the coding is written in java , which is more suitable with any Arduino board.

Figure 2. Front Panel Of Current Sensor, Voltage Sensor and RF ID Module

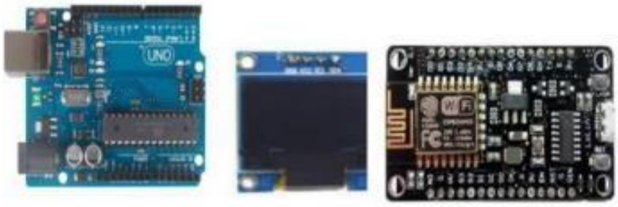
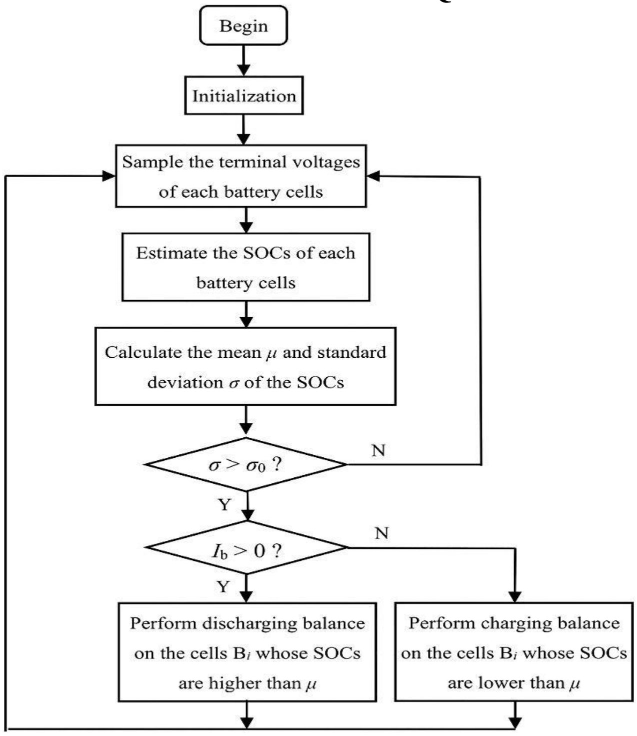


Figure 3. Front Panel Of Arduino Uno, OLED Display and Node MCU

CELL BALANCING TECHNIQUE



Active Cell Balancing During Discharge

The diagram below represents a typical battery stack with all cells starting at full capacity. In this example, full capacity is shown as 90% of charge because keeping a battery at or near its 100% capacity point for long periods of time degrades lifetime faster. 30% represents fully discharged to prevent deep discharge of the cells.

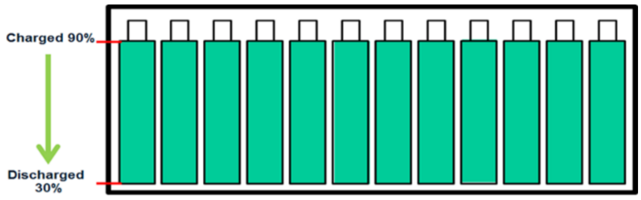


Figure 1. Full capacity.

Over time, some cells will become weaker than others, resulting in a discharge profile represented by the figure below.

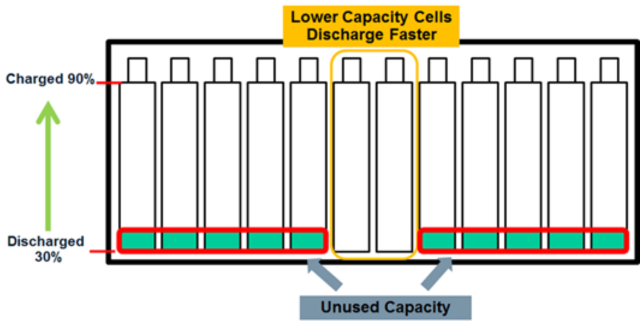
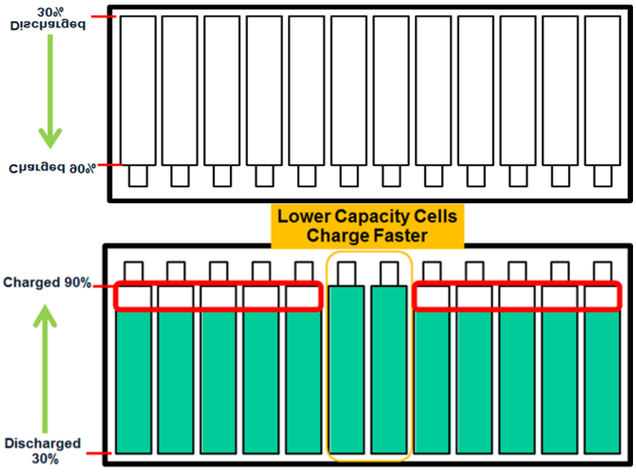


Figure 2. Mismatched discharge.

It can be seen that even though there may be quite a bit of capacity left in several batteries, the weak batteries limit the runtime of the system. A battery mismatch of 5% results in 5% of the capacity unused. With large batteries, this can be an excessive amount of energy left unused. This becomes critical in remote systems and systems that are difficult to access since it results in an increase in the number of battery charge and discharge cycles, which reduces the lifetime of the battery, leading to higher costs associated with more frequent battery replacement. With active balancing, charge is redistributed from the stronger cells to the weaker cells, resulting in a fully depleted battery stack profile.

Figure 3. Full depletion with active balancing.

Active Cell Balancing While Charging: When charging the battery stack without balancing, the weak cells reach full capacity prior to the stronger batteries. Again, it is the weak cells that are the limiting factor; in this case they limit how much total charge our system can hold. The diagram below illustrates charging with this limitation. Kalman filter and Open circuit voltage has been calculated mathematically with suitable battery model. In Open circuit voltage data retrieval is found out to be difficult. Hence to retrieve data Kalman filter has been implemented. In Kalman filter method for a Lithium ion battery model, the proposed improved Thevenin model has been implemented, and its parameter identification has been performed using the Extended Kalman Filter algorithm. Maximum SOC error is found out to be 1% from the simulation results.



4. Conclusion and Future Scope.

For monitoring the charge status suitable algorithms has to be implemented. In this paper, Comparison between Further an optimization model for maximizing the trade revenue for aggregator of EVs is presented aimed at facilitating smart charging to reduce the impact of increased penetration of EVs on grid. Internet of Things(IoT) based smartgrid has been developed to monitor status of batteries in smartgrid systems. The car user can easily check the health of his car battery and he can easily decide whether to take power from grid or to sell power to grid. The data stored in the Adafruit IO lasts for 30 days. For future work, handling of multiple users could be implemented so as to compare the status of different users.

FUTURE SCOPE:

Kalman filter is applicable only for nonlinear systems and it is hard to implement in linear system as there is no feedback compensation mechanism. Hence to overcome this issue of Kalman filter, other suitable algorithm like coulomb counting, fuzzy logic, modified coulomb counting method may be considered for reliable operation of a battery in a battery electric vehicle. In this paper we have proposed an electric vehicle charging station using IOT. In addition to the vehicles charged, it has to be updated automatically using IOT. Optimal solution will be attained when a charging station decides which arriving EVs to admit and schedule according to its charge capacity. For this, the uncertainty factor i.e the effect of solar energy prediction has to be determined. In order to avoid the charging time, the parking area itself can be utilized as charging station. Without making any contact with the vehicle, the charging can be done using mutual inductance of the coil which is the major advantage of this proposed system.

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