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# Performance Analysis of Lithium Ion Battery Based on State of Charge and State of Health for EV Applications

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**Abstract:** *Battery charging techniques are critical to enhance battery operation performance. Charging temperature rise, energy loss, and charging time are three key indicators to evaluate charging performance. It is imperative to decreases temperature rise and energy loss without extending the charging time during the charging process. There are different types charging strategies for li-ion battery like constant current (CC), constant voltage (CV), constant current constant voltage (CCCV), pulse charging and reflex charging. In the case of CC-CV charging temperature of the battery rises with the magnitude of the current being injected and cannot be regulated without any external cooling arrangement. Temperature regulated strategies are implemented through a discrete electrothermal model, which acts as a temperature estimator. The coefficient of the estimators corresponds to the battery parameters such as internal resistance and thermal time constants, entropy, etc. Batteries can be charged at a faster rate by injecting current at a higher rate than normal charging i.e. xC/10, where C is the capacity of the battery in Ah. In case of normal charging of the battery x D 1 and for faster charging x > 1. For example, if the battery capacity is 100Ah, then charging at 10A charging is normal and any injection more than this can be considered as faster charging. Normally, for a lead-acid battery x is equal to one, whereas for the Li-ion battery the value of x can be greater than 10. If the current is injected at the rate above the normal rating of the battery, it not only can cause accelerated battery degradation, but also leads to other issues such as overcharging, temperature rises, and over-voltage. To resolve the above issues and ensure safe operation, a proper battery charging strategy should be implemented. In this project we are developing temperature regulated pulse charging model for lithium ion battery, Whenever battery is charged fast its internal temperature rises which might result in thermal run away. In our model we are sensing the temperature of battery when battery is charged fast if battery temperature rises above the some maximum temperature then the input current is cut off and when battery temperature becomes normal then input to battery is given again. This process continues. Due to this battery life is increased and polarization is not form in the battery. For the same charging time as achieved with TRPC, TRPC results in almost double the expected life of operation and better SOH as compared to CC-CV and TRRC. We are trying to make temperature regulated pulse charging model for lithium ion battery..*

**Keywords:** State of Charge, State of Health, TRPC, Depth of Dischargec, Constant Current, Constant Voltage

## I. INTRODUCTION

Batteries are essential components of most electrical devices. They exist in various applications like cars, laptops, CD players, and other electronic appliances. Today, the battery is receiving a vast amount of attention as the most important energy storage device in Electric Vehicles (EVs) and the rapidly growing Smart Grid. For the EVs and HEVs, rechargeable batteries have been widely used as a power supply. Many types of batteries such as lithium-ion (Li-ion), lead acid, nickel-cadmium (NiCd) and nickel-metal hydride (NiMH), are being used but the Lithium-ion battery is focused, because of high energy density, environment friendly and has a long life cycle [1]. And also Lithium-ion batteries have some advantages such as lightweight, small size, wide operating temperature range, fast charging capability, long battery's life, low self-discharge rate, and no hydrogen gas release [2]. The lithium-ion battery has been the dominant type used in EVs due to high energy density, high power density, long life and environmental friendliness [1]. To enhance the performance of Li-ion batteries, researchers have developed different battery health indicators such as State of Charge (SOC), State of health (SOH), State of Function (SOF), etc.[3] The SOC and SOH are the parameters that cannot be measured directly. In order to

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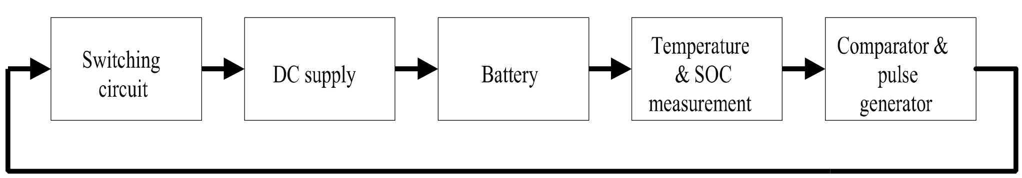
find the SOC and SOH of a battery, an estimation method is used. The most used SOC estimation method is Coulomb Counting. The Coulomb Counting method is a SOC estimation method by summing/integrating the electrical charge that enters or exits the battery.

SOC is a parameter that shows the state of the electric charge inside the battery while SOH is a parameter that shows the state of health of the battery [2]. The most commonly used definition of SOH of a battery is the ratio of fully charged/discharged capacity at present to the initial capacity, so capacity is the direct measurement for SOH estimation [4]. The SOC cannot be directly measured because Li-ion batteries store energy in a chemical form, and this energy cannot be directly accessed. Instead, the SOC can be estimated by different algorithms based on measurable battery parameters such as voltage, current and temperature. The battery can fully release its energy when it is first used and its SOH at this moment is supposed to be 100. Due to degradation, the available charge stored in a fully charged battery is expected to fall with usage, and thus, the SOH will decrease correspondingly. During long time utilization, the capacity and power capability of Lithium-ion (Li-ion) batteries are subjected to gradual degradation [1]. Thus, knowledge about the batteries state-of-health (SOH) becomes critical in practical applications (as is the case of electric vehicles - EVs), in order to ensure safe and reliable operation. Depending on the requirements of the application, the SOH can be related either to the battery capacity or to the battery internal resistance/power When SOH falls below a certain threshold and is supposed to not meet the usage requirements, the battery is defined as fault [5]. The SoH is analogous to the odometer which measures the distance that the intended vehicle travels. Precise calculation of the SoC and the SoH will prevent overloading or overloading of each cell in a battery pack. This prolongs the whole battery pack's useful life.

This project is divided into two parts, i) effect of temperature regulated pulse charging (TRPC) on different Li-ion battery health indicators like maximum capacity, SOC, SOH. Also, the comparison of battery charging method i.e. Constant Current with respect to Temperature Regulated Pulse Charging. ii) Comparative study between reflex charging and pulse charging is carried out.

## II. SYSTEM OVERVIEW

Electric vehicles (EVs) and plug-in electric vehicles are in high demand due to zero contribution to air pollution. Mainly Li-ion, Ni-metal hydride, Ni-Cd, and Lead-acid batteries are used as a power source in EVs. Among these batteries, Li-ion batteries are characterized with higher energy/power density, lightweight, and longer life as compared with the batteries of other chemistry. However, there are some constraints such as, requirement of Battery Management System (BMS), issue of overcharging, and regulation to full charging to keep per-cell voltage stress to a lower level. Longer charging time is a major concern in the adaption of EVs. This issue can be solved through the concept of battery swapping or the fast charging of the batteries to reduce the charging time. Battery swapping requires a large infrastructural cost. Therefore, the more focus is on charging strategies to reduce time. Batteries can be charged at a faster rate by injecting current at a higher rate than normal charging. i.e. xC/10, where C is the capacity of the battery in Ah. In case of normal charging of the battery x is equal to 1 and for faster charging x is greater than 1.But if the current is injected at the rate above the normal rating of the battery, it not only cause accelerated battery degradation but also leads to other issues such as overcharging, temperature rises, and over-voltage. To resolve the above issues and ensure safe operation, a simulation model of fast charging of Li-ion battery using TRPC method is developed. The working of this model is explained below. The battery used in these simulations is LiFeMgPO4, which have the capacity of 40 Ah and rated output voltage is 12.8 V. This same battery is used while comparing pulse charging and reflex charging.




A block diagram of the control strategy of temperature-regulated pulse charging is shown in above Figure .The first block is switching circuit. It has two main functions, firstly it disconnect the dc supply when battery temperature goes beyond the pre-set limits which are maximum and minimum temperature limit and secondly it break the supply when SOC percentage of battery goes up to 95 percentage. Second block is DC supply block. To charge the battery at higher rate, higher voltage is necessary. So we use the 18 Volt as an input DC voltage. These input DC voltage is fed to Lithium ion battery .Which is of Lithium Iron Magnesium Phosphate (LiFeMgPO4) chemistry having a 12.8 voltage rating and 40Ah current capacity.

The output of battery is given to temperature measurement unit and SOC measurement unit. These measured temperature value then converted into voltage and give to the Schmitt trigger. Maximum and minimum temperature limits are already set in Schmitt trigger. Schmitt triggers output goes high when measured temperature value is beyond the pre-set limits and this high signal then converted into low by inverter and then fed to switch no. 2 and it turns on or off accordingly. Similarly output of SOC measured unit gives to the switch 1and it turns off when SOC percentage goes beyond 95 percentages.

## III. FUTURE SCOPE

Charging infrastructure for electric vehicles (EV) will be the key factor for ensuring a smooth transition to electric vehicles. Smart charging of EVs is expected to enable larger penetration of EVs and renewable energy, lower the charging cost and offer better utilization of the grid infrastructure. New rate designs, better smart metering and charging equipment technologies, and a charging infrastructure that is convenient and price competitive will need to be developed and implemented. While there are uncertainties around the commercial penetration of electric vehicles, a future scenario in which governments agree to substantially decarbonize their economies will involve partial electrification.

## IV. CONCLUSION

In the present work suitable fast charging strategy (i.e. TRPC) is proposed for fast charging of lithium ion battery. Two simulation models are developed, one is for charging the lithium-ion battery using trpc method and another one is for studying aging effect of lithium ion battery. From the second simulation model it is found that in case of constant current (CC) strategy battery capacity fades 8.34% more in comparison with temperature regulated pulse charging (TRPC). This is due the fact that resting time is provided in pulse charging due to which rate of rise of internal resistance reduces. From these results it is clear that TRPC charging strategy can be used for fast charging of lithium ion battery.

Also in this project comparison between pulse charging and reflex charging is carried out. Aging model and charging circuit are developed for both the strategies. With the help of simulation models it is found that pulse charging method is 10% faster than reflex charging. However temperature rise is more in pulse charging than reflex charging, also the battery capacity fade is more in pulse charging in comparison with reflex charging.

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