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Optimal Charging Strategy of Electric Vehicle

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Abstract:
The increasing trend towards electric vehicle has paved a way to the development of charging system as it is the heart of EV. This paper aims to propose an efficient method of charging by determining battery State of Charge(SOC) and various electrical parameters. The experimental results of negative pulse charging method and battery with ultra capacitor is analyzed with change in Current and Voltage parameters which proved that ultra capacitor charging would yield Fast and Ultra fast Charging. This paper also presents the effective functioning of Battery Management system via CAN bus to show economical feasibility in the design

Keywords: *Electric vehicle,Charging system, SOC, BMS*

I. INTRODUCTION

The climatic changes due to global warming and exhausting nature of non renewable fuel sources have paved a way to the improvement of electric vehicle as it is the need of the hour[5].

Moreover, the recent growth of power electronics technologies have created a breakthrough for electric vehicles.

The development of Electric vehicles could even contribute to the welfare of the society by reducing the emission of global greenhouse gases as the consumption of energy for transportation is remarkably in rise[6].

The sprouting shift towards electric vehicles in the new era of pollution free transport mode needs a perpetual aid from charging station infrastructure.

On the other hand the greatest challenge in design of electric vehicle is the design of battery since efficient functioning of the vehicle and one-third of the vehicle cost lies on battery[1,3].

II. ELECTRIC VEHICLE CHARGING CLASSIFICATION

Charging Method	On-boar-d	On-board	On-boar-d	Off-boa-rd
Location	Residen-tial area	Residenti-al area	Public	Highwa-y
Electrical specificat-ions	1-Phase Voltage: 230V Current: 16A 3-Phase Voltage: 415V Current: 16A	1-Phase Voltage: 230V Current: 32A 3-Phase Voltage: 415V Current: 32A	3-Phase Voltage: 415V Current: 63A	Voltage: 500-700V DC Current: 100-125 A-DC
Charging time	1-Phase 6-8 hours 3-Phase2-3 hours	1-Phase: 3-4 hours 3-Phase: 1-2 hours	20-30 minutes	Less than 20 minutes

Table- I: Elucidation of Different Methods of Charging

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There are various ways to classify a charging station first and foremost way is to classify with regard to the charging action method, they are onboard charging and off board charging[5]. When charging is conducted inside the vehicle, it is on-board charging whereas in case of off-board charging - external charger is used to the charge vehicle. Second type of classification is based on its site, the charging can be carried out in domestic area, in common area or in freeway. Under the vertical of public place charging, stations could be in the form of fixed charging station (FiCS) or mobile charging station (MoCS). MoCS type is equipped with a truck-type vehicle having ample charging outlet to perform charging. When performing charging off-grid outside FiCS area, MoCS power source would be getting supply from energy storage equipment placed inside the MoCS. Charging in residential area uses 120/240VAC single phase with charging period 6-8 hours. if 400V-AC three phase supply is used instead of single phase the charging time is reduced to 2-3 hours both with 16 A. In case of current capacity of 32 A, the charging time is further reduced to 3-4 hours for single phase and 1-2 hours for three phase Charging. In public areas such as Fixed charging stations provides efficient charging with 20-30 minutes with 400VAC, 63 A three phase. The most efficient charging on highways with 500-700V direct current, 100-125 A DC has charging time of less than 20 minutes. Based on the above said criteria it would be easy for designing the charging station with right energy storage.

III. Energy Storage

The typical storage device used for storing energy is battery that generates electrical energy from the chemical energy by conversion. There are some types of batteries in market which are Lead-acid , nickel-zinc, nickel-iron, Nickel- cadmium[8,9]. The Lead acid battery is the cheapest of all but very heavy(weight) and it leads to various environmental hazards due to the presence of lead in it. The Nickel-Zinc battery is eco-friendly and on the contrary we should compromise on life cycle if it is the choice. The nickel-Iron battery has a consequence of heavy weight and high maintenance cost so it is not preferred. The Nickel-cadmium battery is not suitable for promising charging an discharging rates because of its memory effect and also presence of Toxic content in it whereas on the other it works better in rigorous working conditions. Finally while choosing the battery, certain parameters should be considered they are current rating in Ah and capacity in Wh. The best battery cell which almost overcomes the disadvantages mentioned in the above types is Lithium battery which possess good qualities such as less specific weight, high power density, precise energy, No memory effect, not hazardous, though it also possess disadvantages such as high production cost , requires protection circuit [5]. The advent of Lithium Ion battery served the purpose efficiently and also overcomes the disadvantages mentioned in the lithium battery.

IV. Battery Management System

As lithium ion batteries have limited safe operating area regarding temperature, current and voltage, it is necessary for the battery management system to have control over the batteries in a energy storage system[6]. To have efficient operation of electric vehicles, an effective Battery management system is necessary. Further improvement in the system which yields efficient results is that instead of passing the battery information through the battery control unit(BCU) it can be directly given to Controller Area Network (CAN) bus which in turn would improve the performance and saves cost.

The below figure shows the block diagram of battery management system where data acquisition (DAQ) plays a significant role for the effective operation of BMS. The battery cells provides information about electrical parameters to the DAQ which communicates about the state of battery charge using electric control(kind of electric control unit) and then state determination of parameters is done which provides interface to the user.

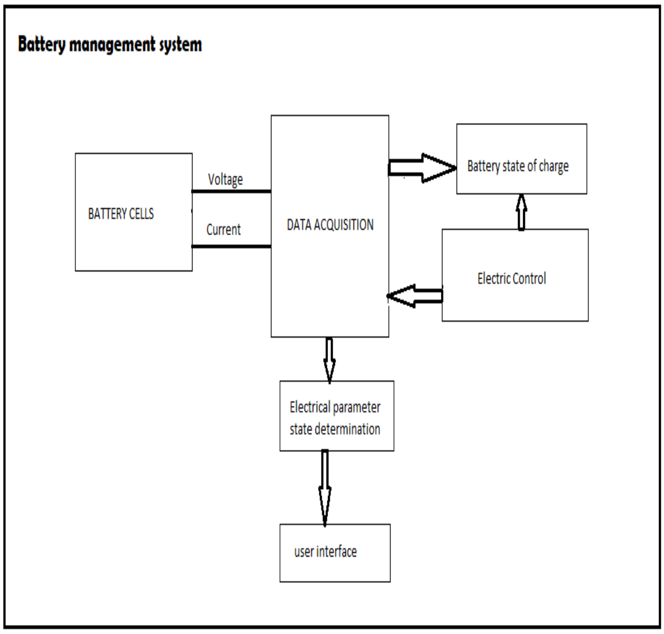

Fig.1- Block diagram of BMS

V. Charging Strategies

With the advent of EVs , the lithium-ion battery cells has been predominantly used because of its promising characteristics as discussed in the previous section. Nevertheless at the same instance, the method of charging the battery cells, plays a major role for the efficient functioning of the vehicle. There are many proposed charging strategies with the expansion of Electric vehicle, such as constant current, constant voltage, constant trickle, and steady current steady voltage battery charging strategies.

VI. Charging with Negative Pulse

During the process of charging, the polarization aspect seems to be imminent, due to electrochemical polarization, concentration polarization and ohmic polarization which has led to increase in the voltage and in turn reduces the efficiency of charging. So a strategy of depolarization charging has been proposed to avert the effect of polarization and in turn increase the efficiency of charging capacity. The internal polarization voltage of lithium-ion battery is nearly small, so charging by negative pulse control procedure has resulted to improve the charging speed of li-ion battery cells[5].

VII. Experimental Setup

The experiment was conducted as follows: (1) negative pulse charging strategy was adopted for charging the batteries; (2) Constant current up to 4.5V followed by constant voltage control method till current is less than 0.3A is proposed. The variation of voltage in the charging process was monitored by using Battery management system (BMS). Charging time shown below in fig 2

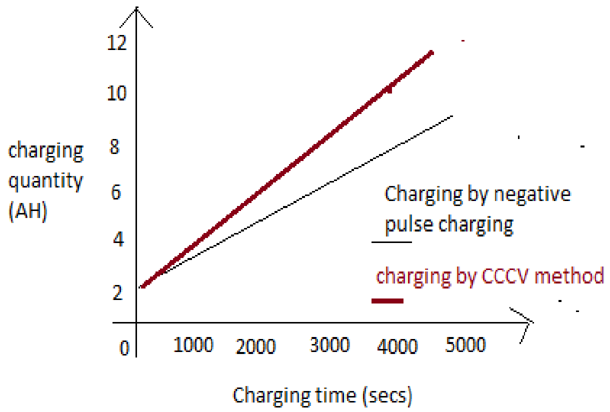

Fig.2 performance graph showing comparison of negative charging and CCCV method

From the performance graph, it is concluded that the charging rate is not so effective in negative pulse charging method.

Energy Storage System

An energy storage system(ESS) is developed in view to facilitate charging service for any kind of charging methods as discussed earlier. AC charger outlet and DC charger outlet are the basic two types of charger outlets. Fast or rapid (highways) charging is possible with DC chargeroutlet and it requires DC to DC converter. On contrary, charging with AC charger outlet will be very slow pace (residential, public) which requires an inverter.

The battery or ultracapacitor provides DC output which provides fast or rapid charging[4]. Slow charging is achieved by connecting batteryto an inverter. Optimization of combined energy storage is targeted withthe advancement of battery

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management system (BMS) [8].

Ultracapacitor (UC) is similar to that of normal capacitor in structure, but the only difference which has led to the selection of ultracapacitor for this application is that UC have elevated capacitance value & energy capacity with factor of more than 20 times than a regular capacitor. The promising characteristics of ultra capacitor which led to its selection includes repair-free operation, longevity in operation life cycle and unaffected by environmental temperature changes. Presently, there are basically three models of Ultra capacitors used in EV, they are: hybrid capacitors, electric double-layer capacitors (EDLC) and pseudo-capacitors[2]. Among them, power density is more in EDLC than in other types. Also, EDLC has low Specific energy density and its lifetime can reach upto 40 years, which is the longest among all. The Lithium–ion Battery is having exceptional chemical stability and thermal stability and also it has comparatively higher discharge current than other batteries hence it is preferred for our application.

Combined energy storage system

Fast and optimum charging with better voltage and current response is achieved with the combination of battery and ultra capacitor. Here we use Lithium – Ion as a suitable battery and Electric double layer capacitor (EDLC) as a suitable Ultra capacitor.

The following figure shows combined energy storage system where it consists of UC and bank of battery cells. The UC is connected to the DC to DC chopper circuit which in turn is given to the DC outlet. The battery is taken care by the battery management system which is controlled by the electronic control unit for optimum operation of the entire system. As output from the battery is given to the inverter and then fed to the AC outlet.

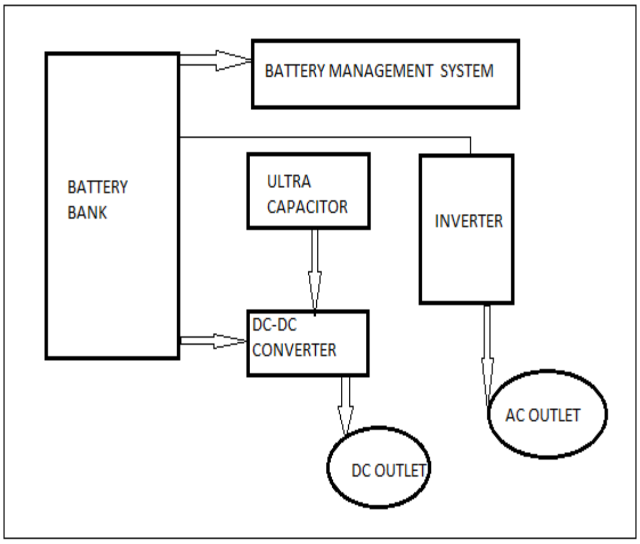

Fig.3- Combined Energy Storage System

VIII. Conclusion

In this paper, the different methods of charging strategies such as negative pulse charging method and energy storage system was analyzed. The battery management system was studied which operates with CAN bus for effective reduction in the cost. The experimental results of negative pulse charging method showed that because of low polarization voltage it couldn't progress the effectiveness of charging in lithium-ion battery. On the other hand the ultra-capacitor with lithium ion battery as a combined energy storage system has proved to yield ultra fast charging as compared to negative pulse charging method.

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