SMART Charger for Lithium-Ion Batteries with Temperature monitoring

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ABSTRACT

Electric Vehicle (EV's) is need of society to fight against pollution and to overcome limited resources of fossil fuels. This study has been undertaken to design and test the SMART charging of Electric Vehicle through an automated / controlled charger for Lithium-Ion batteries used in EV's. This design mainly focuses on charging of Lithium Ion battery with normal charge and fast charge without affecting battery life. Battery powered electric vehicles are popular due to its carbon neutral cleanliness, simplicity of operation and reliability and Pollution free or zero emission. Battery, energy storage devices stores energy, delivers energy (discharge) and accepts energy (charge) from external resources. In this design, used a 12Volt 2.2Ah battery having normal charge rate is C/4 which takes 4+ Hrs to charge up to 80%. By monitoring State of Charge (SoC) and Temperature of battery, amount of current pumped is increased by keeping temperature in between 35°C to 45°C which is normal temperature operating range for Li-Ion battery. Thus able to reduce total time required to charge the battery drastically.

Keywords :- Electric Vehicle (EV's), Lithium-Ion Battery, Buck converter etc.

I. INTRODUCTION

Battery powered electric vehicles are popular due to its carbon neutral cleanliness, simplicity of operation and reliability and Pollution free or zero emission. Battery, energy storage devices stores energy, delivers energy (discharge) and accepts energy (charge) from external resources. Different energy sources for electric vehicle are chemical batteries, ultra-capacitors or super-capacitors, ultra high speed flywheels and fuel cells.

Battery failure and low life are two major limiting factors for high speed vehicles. Electric vehicle with single charge can travel up to few kilometres and needs recharge. The practicality of electric transportation awaited the discovery of batteries which gave higher electrical output and could be recharged effectively, light in weight and less in cost. Once that cost of battery falls, the cost of electric car would be equivalent to (that of) an internal combustion car. So the challenge lies in making a breakthrough in battery (technology).

At certain levels risk is associated in adaptation of electric vehicles, which include charging infrastructures or charging station adoption risk. Even though electricity supply is readily available everywhere, but lack of safe charging stations of Electric Vehicles is still a far away from reality. EV charging can be done at THREE levels Normal charge at home for short distance, Normal/Quick charge at work or shop place for round trip and Quick charge at called pathway charge for long distance travel.

This paper aims to answer the questions of how a Electric Vehicle (EV's) can be charged FAST and efficiently by monitoring State of Charge (SoC) and battery temperature with corresponding policy suggestions. **This paper introduces concept of battery charging of an Lithium Ion battery of an electric car with an intelligent / SMART charging system.**

II. PROBLEM DEFINITION

Pollution from human activities is changing Earth's climate. Fossil fuel is an exhaustible source of energy and major factor contributing in pollution; hence there is a need for alternative solutions for combustion engine operated vehicles. Electric cars are more energy efficient and the electricity needed for these cars can be produced from renewable energy. Carbon monoxide, nitrogen oxides, and hydrocarbons are released when fuel is burned in an internal combustion engine and when air/fuel residuals are emitted through the vehicle tail-pipe[2]. What we can do to reduce pollution from vehicles and engines is drive less, drive wise, choose fuel efficient vehicles, don't idle or go for Zero-emission vehicles that include battery-electric vehicles, plug-in hybrid-electric vehicles, and hydrogen fuel-cell-electric vehicles. EV's are cheaper to run because of low rates of electricity than petrol, Zero harmful emissions, nearly 100% recyclable batteries and it reduces noise pollution. Below image depicts Solutions for transportation air pollution, emission reductions, can lead to cleaner air, better health and can control climate change.

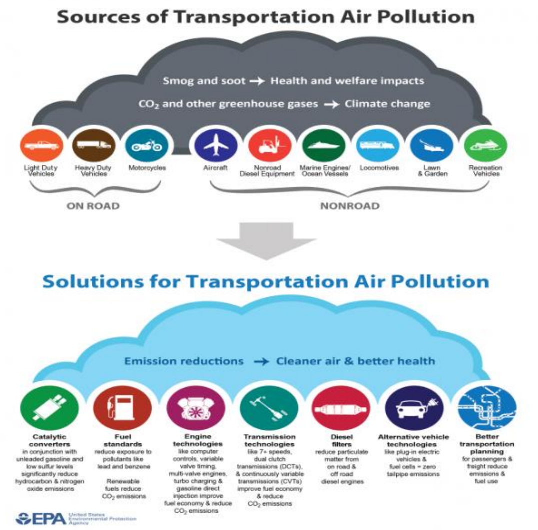

Fig. 01 Source and Solution of Transportation Air Pollution (Source: EPA)

The electric cars have some drawbacks such as the long charging time and short range of operation. The average charge times for an electric vehicle to refuel i.e. to recharge battery is varying with battery type and charger type. Basically there are TWO different types of charging i.e. AC charging and DC charging. Battery operated EVs can run for 5 years or 1,00,000 miles before fully disintegrated. Where as Plug-in hybrids and hybrids have a longer life span due to continuous recharging from the internal combustion engines and batteries.

III. PROPOSED SOLUTION

Unlike conventional petroleum driven internal combustion vehicle, BEV is propelled by a large electric motor, which is powered through a rechargeable onboard battery system (as seen in Figure 2). There are several different types of batteries that have been implemented in battery electric vehicles.

Fig. 02 Chasis of Mahindra Reva (Source: http://www.pluginindia.com/blogs/visiting-mahindra-revas-green-factory)

Lead Acid Batteries (LAB) and nickel metal hydride (NiMH) batteries are mature battery technologies used in early electric vehicles. Lithium Ion (Li-Ion) batteries are now considered to be the standard for modern battery electric vehicles. There are many types of Li-ion batteries that each has different characteristics. Li-ion batteries are excellent in retaining energy, with a self-discharge rate (5% per month) that an order of magnitude, lower than NiMH batteries [3].

Why lithium-Ion over Lead Acid Batteries

Below table depicts, why Li-Ion batteries have replaced over Sealed Lead Acid Batteries (SLAB) even though they are costlier. Li-Ion cells and batteries are not as robust as some other rechargeable technologies. They require protection from being over charged and discharged too far. In addition to this, they need to have current (Amp) maintained within safe limits.

Table 01 Comparison of Lead Acid and Li-Ion Batteries.

Details of Comparison:	Lead Acid	Li-Ion (Cobalt)
Nominal Cell voltage	2.0v	3.7v
Voltage operating range	1.8-2.1v	3.2-4.1v
Wh/kg	35-40	140-150
Wh/liter	70	400
Size of a 1 kWh battery	14 Liters	2.5 Liters
Weight of a 1 kWh battery	25kg, 55lbs	6.7kg, 14.8 lbs

In Battery operated Electric Vehicle (EV's) time required to recharge the batteries is more, more expensive than the combustion engine cars due to cost and life span of battery. The batteries provided are quite heavy increasing the net weight of the car. Actual charge rate is limited by battery chemistry, infrastructure and other factors.

By considering all above factors this paper proposes a SMART charger by monitoring State of Charge (SoC) and Temperature of Li-Ion battery while charging. Proposed methodology is as below

1. Monitor State of Charge (SoC) of battery, if it is in between 60% to 80% start pumping current with 1.5C rate.
2. Monitor temperature, when it's closure to 45°C step down to 1C and then to 0.5C.
3. As temperature falls below 40°C again charge with 1.5C and so on, till it reaches to 80% of capacity.
4. Only charging to 80% in order to maximize battery life: "*Long life mode*".

This methodology reduces time required to charge Li-Ion battery drastically, one of the major limiting factor in Electric Vehicles.

IV. DESIGN ARCHITECTURE OF SMART CHARGER

Power is what gives the car acceleration and maintains a car at a given speed. Mechanically power is the product of torque and rpm, so while torque can be multiplied through gearing (by lowering rpm), power is independent of gearing.[1]. The electrical power is Voltage x Amps = Watts. Technically there is no difference between power produced by an Internal Combustion Engine or an electric motor. Energy is what gives an electric car range. It is the product of power and time (E = P x t) or the product of voltage and amp-hours. Energy is stored in the batteries as chemical energy and is converted to kinetic energy by the motor to make the car move. The measurement used for measuring total electrical energy in a battery pack is called Watt-Hours (Wh). Watt-Hours is a measurement we can use to figure out how much energy we have, i.e. how long can we sustain a given level of power.

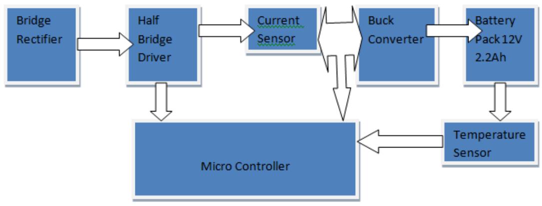

Fig. 03 Block diagram of SMART Li-Ion Charger

1. AC Level 1 Charging 230V AC 50Hz charging from 0.55A outlet (~0.12kw) (Normal Charge mode)
2. AC Level 2 Charging 230V AC 50Hz charging from 1.1A outlet (~0.25kw) (Moderate Charge mode)
3. AC Level 3 Charging 230V AC 50Hz charging from 2.2A outlet (~0.5kw) (Fast Charge mode)
4. AC Level 4 Charging 230V AC 50Hz charging from 3.3 A outlet (~0.75kw) (Fastest Charge mode)

SMART charger operates with above FOUR levels with monitoring SoC and Temperature of Battery, to charge battery efficiently and reduce time, a major concern in transportation vehicles. It communicates with the Li-Ion Battery controller, which specifies current levels that vary during the charging. The charger meets those levels by dynamically adjusting its output voltage.

V. TEST RESULTS

During test at different levels time required to charge Li-Ion battery reduced drastically, as mentioned below with temperature. These results achieved by keeping battery temperature in between 40°C to 45°C with continuous monitoring of SoC and Temperature.

- AC Level 1 Charging 230V AC 50Hz charging from 0.55A C/4 outlet with approximately ~0.12kw of energy with Normal Charge mode takes 4+ hours to charge battery.
- AC Level 2 Charging 230V AC 50Hz charging from 1.1A C/2 outlet with approximately ~0.25kw of energy with Moderate Charge mode takes 2+ hours to charge battery.
- AC Level 3 Charging 230V AC 50Hz charging from 2.2A 1C outlet with approximately ~0.5kw of energy with Fast Charge mode takes 1+ hours to charge battery.
- AC Level 4 Charging 230V AC 50Hz charging from 3.3 A outlet with approximately ~0.75kw of energy with Fastest Charge mode takes ½ hours to charge battery.

VI. CONCLUSION

India is the land of opportunity for any kind of new technology. Electric Vehicles is one of the future technologies, which have entered India very recently. "Electric vehicles are costlier than conventional ones, but they are the need of the hour as they reduce pollution".

In this design, used a 12Volt 2.2Ah battery having normal charge rate is C/4 which takes 4+ Hrs to charge up to 80%, tested during stage-I. During stage-II of testing it is tested with FAST charge rate of C/2 which approximately takes 2+Hrs to charge up to 80%. During stage-III of testing it is tested with FAST charge rate of 1C which approximately takes 1+Hrs to charge up to 80%. After successful testing, this charger is able to reduce charging time required to charge Lithium-Ion battery up to 75%

of its normal charging time without affecting life and health of a battery. This is achieved by using Buck converter operating at 30 KHz switching frequency with variable duty cycle controlled through ATmega microcontroller.

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