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Design of Non-Isolated Bi-directional Converters with Fast charging Schemes for Plug-In Hybrid Electric Vehicle

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Abstract—Due to price,pollution and environmental impact, use of gasoline must me considerably reduced by splitting the work of engine,this can be done by electric motors shared with internal combustion engine in Plug-In Hybrid Electric Vehicle.So for charging PHEVs there is a need for charging station for regular usage, this will be designed by using Non-Isolated Bi-directional converter with three modes of control scheme.The outputs are obtained from matlab/simulink software.

Index Terms— Plug-In Hybrid Electric Vehicle,State of Charge,Battery Management System.

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1 Introduction

Due to various economic,political and environmental reasons,the introduction of Plug-In Hyrid Electric Vehicle(PHEVs) into the streets is probable.Their introduction will require extra facilities such as the charging stations.In order for PHEVs to be able to penetrate the market their recharging time should be comparable to conventional once.The usual trend in charging PHEV batteries is that the Battery Managment System(BMS) gives various orders and information signals with charger characteristics.But this could result in a dangerous situation if the BMS happens to fail for some reason so fast charging scheme for PHEVs has to be designed.

Based on modeling the important characteristic of the battery and then identifying suitable model parameters these models are effectively used during the decision making in the battery charging process. When we consider an intelligent charger or charging in general, understanding the characteristic of the batteries to be charged is indispensable.

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Knowing the capacity of the batteries to be charged also needs considerale attention.However there are comparatively only few cars on the road.Thus finding any tangible information on this topic is not easy,thus we need to find an alternative solution.To that end there are three most noticeable bodies working on EV related issues.These are USABC,EPRI and MIT.Based on this it is possible to evaluate currently available battery types for xEV use.

2 DIFFERENT BATTERY SCHEMES

EPRI's analysis suggests the performance goals for an all PHEV is achievable by current Nickel-Metal Hydride technology but the goals of the USABC and MIT are beyond even current Li-Ion technology capabilities.In any case,it is clear that lead acid, nickel-cadmiun(Ni-Cd) and sodium-nickel chloride(ZEBRA) technologies are not likely to achieve goals for even the less ambitious PHEVs.In contrast,Li-Ion battery technologies hold promise for achieving much higher power and energy density goals.

Thus,it appears that while NiMH could be used for lower performance PHEV designs only a chemistry with the energy and power density capabilities of Li-Ion can meet USABC goals for PHEVs with all electric range [1].Thus in this thesis,focus is given only to Li-Ion and NiMH batteries.in the following sections we will briefly look at the state of the art NiMH and Li-Ion batteries and charging related issues.

Compared to other battery chemistries,the primary advantage of NiMH is its proven longevity in calendar and cycle life and overall history of safety [2]. However,the primary drawbacks of NiMH are limitations in energy and power density and low prospects for future cost reductions.As it has reached its maturity there is little room left for improvement in power and energy density or cost.Thus NiMH batteries could play an interim role in less demanding blended-mode designs,but it seems likely that falling Li-Ion battery prices may preclude even this role.

Fig. 1. Shows how voltage,temperature and pressure vary as charging progress [3].The voltage spike up on initial charging then continues to rise gradually through charging until full charge is achieved.Then as the cell reaches overvoltage,the voltage peaks and then gradually trends down.

Since the charge process is exothermic,heat is being released throughout charging,giving a positive slope to the temperature curve.

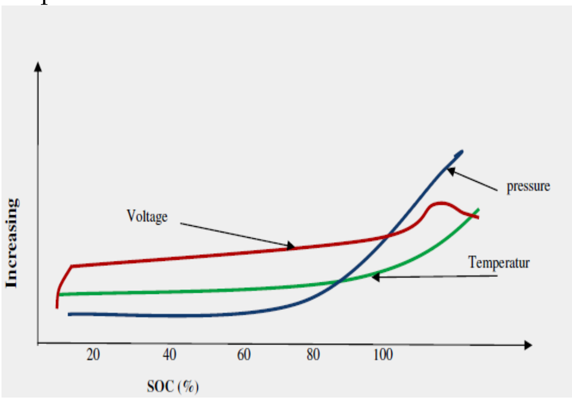

Fig. 1. NiMH cell charging characteristic

In contrast to NiMH,Li-Ion technology has the potential to meet the requirements of a broader variety of PHEVs.Lithium is said to be vary attractive for high energy batteries due to its lightweight nature and potential for high voltage,allowing Li-Ion batteries to have higher power and energy density than NiMH batteries.Also a reduction in Li-Ion cost relative to NiMH is anticipated [1].However,Li-Ion batteries face drawbacks in longevity and safety which still need to be addressed for future automotive applications.

2.1 Modes of charging

The three modes of charging

1.Trickle charging

2.Fast charging

3.Constant mode

In general Li-Ion batteries are charged using constant current/constant voltage [4].But the charge rate and the voltage limit differ for different batteries from different manufacturer.

As for the charge rate it can vary from 0.2C to 6C or more depending on the model type.A typical constant current/constant voltage(CC/CV) is shown in Fig.2. Li-Ion batteries exhibit a good charge acceptance in wide temperature range but the actual charging temperature range differs with in different battery chemistries.some of the points mentioned in the discussion of NiMH batteries concerning temperature equally apply here.

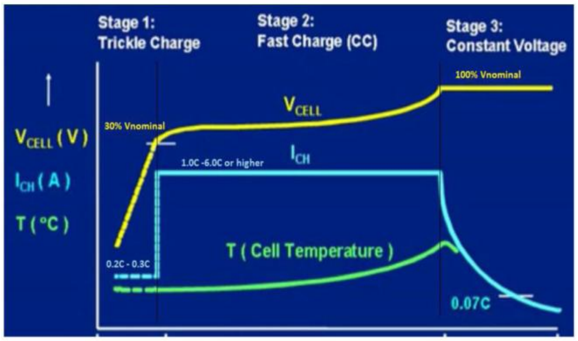

Fig.2. Li-Ion Charging Characteristic

In Trickle mode of charging,battery will charge slowly upto a nominal value and after reaching that level it will charge in fast charging mode after that when battery is fully charged it will operate in constant mode fig.2. shows these three modes of charging.

Finally as a concluding remark to this battery section,battery type most likely to be used for high range PHEVs is Li-Ion battery while NiMH could be used for lower power PHEV designs.Charge monitoring is done by using voltage and temperature measurement.While change in temperature slope could be used to trigger charge termination in NiMH,this is not the case in Li-Ions,charge terminationin will be facilitated by SOC measurement from the BMS.

3 SIMULATION

There are a wide variety of converter topologies which could have a variety of options to choose ranging from single phase [5] to three phase [6],[7],[8],[9],[10]. On the other hand the three phase converters can also be used for battery charger application.To begin with the battery charger for EVs it has two parts:the AC/DC and DC/DC converters.Mainly in the AC/DC side soft switched [6],[8] or hard switched [6],[7],[10] or two levels with two/three levels [8],[9].

The charger circuit Fig.3. consists of a hard switched three phase AC/DC converter preceded by LCL filters,and followed by a DC/DC two quadrant buck/boost converter with LCL filters.LCL filters choosen for their better filtering performance and lower inductance requirement compared to first order filter(L-filter) [7].

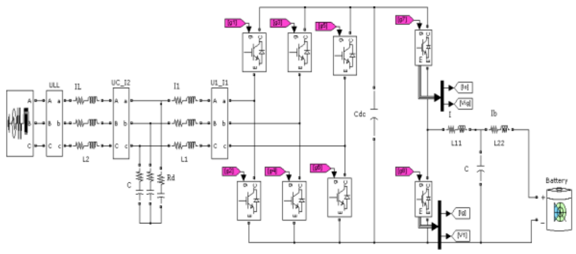

Fig.3. Overall charger power circuit simulink diagram

The AC/Dc converter has the values for components and the LCL parameters are selected based on the procedure described in [11].Valuable information on setting the DC link voltage can be found in [12],[13] provides a simple expression on selecting the value of the DC link capacitor.

DC/DC buck-boost converter is shown in Fig.4. as this converter is used in this power circuit.The values for filters are selected as same procedure in LCL filter.

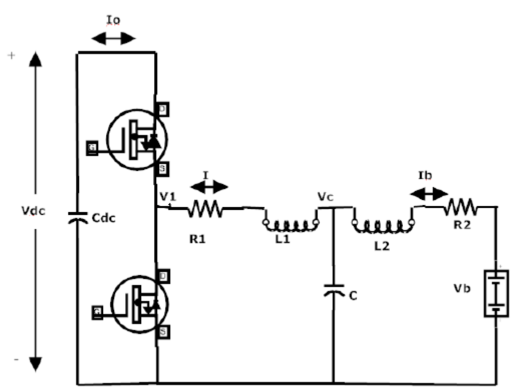

Fig.4. DC/DC buck-boost converter

4 SIMULATION RESULT

The outputs obtained after the simulation of all blocks in MATLAB software,the results of this simulation gives the Active Power in Fig.5. Reactive Power in Fig.6. Voltage graph in Fig.7. and Current graph in Fig.8 and State of Charge in Fig.9.

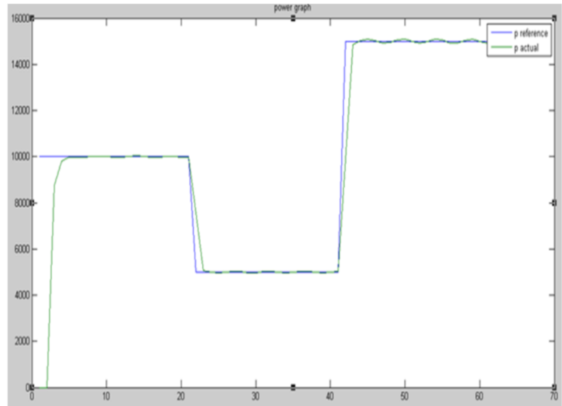

Fig.5. Active Power

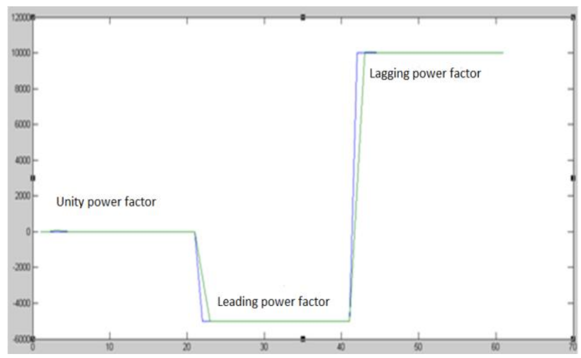

Fig.6. Reactive Power

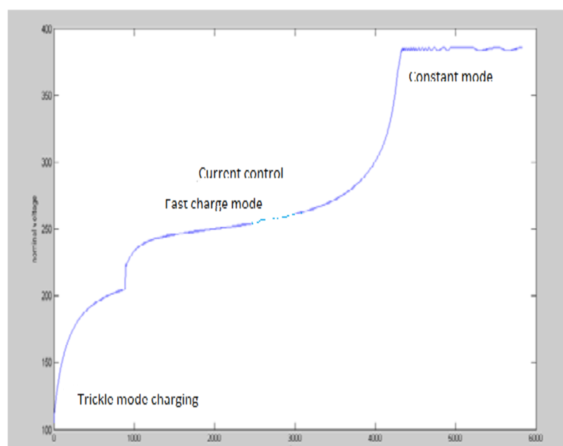

Fig.7. Voltage graph

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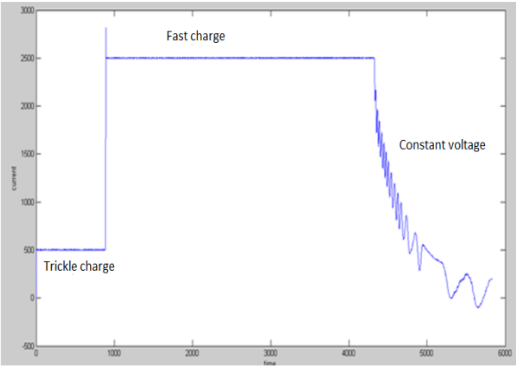

Fig.8. Current graph

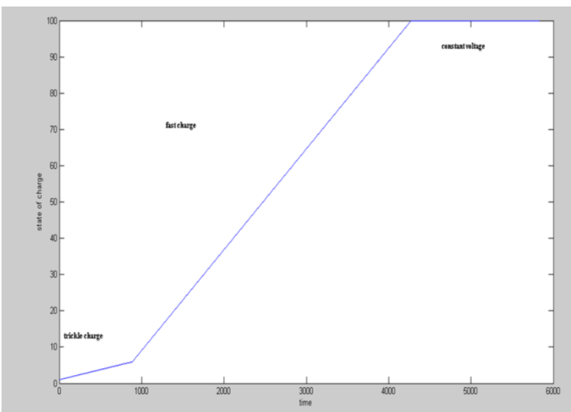

Fig.9. State of Charge

5 CONCLUSION

Various future works based on improving this work or using the same concept to apply it for other similar areas could be proposed.To improve this work and to make it practical the following things need to be done.Carry out laboratory experiments to understand and decide the effect of measurement noise,the best prediction sample time and the nature of temperature rise.

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