INVESTIGATIONS ON BATTERY CHARGING SYSTEM FOR ELECTRICAL VEHICLE APPLICATIONS

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***Abstract—**The electrical vehicles have become the research focus for the environment-friendly characteristics in recent years. As the core technology of the EVs, the battery technology influences the development of the EVs. The hybrid energy storage system can increase the life span of the batteries by improving their working condition, and how to shorten the charging time is also concerned. Two technologies are analyzed in this paper, and a control method for the fast charging of the batteries is proposed. Hybrid energy storage is utilized to maintain the stability of the system. At last, a simulation model is established in Matlab/simulink to test, and the results verified the validity of the proposed control system.*

1. INTRODUCTION

As global warming problem emerge and gasoline prices keep rising, electric vehicles attract more and more attention because of its clean and environmentally friendly features. As a solution to meet basic transportation needs, electric vehicles which equipped with energy storage device can also connect to the grid when they are free, so that a large scale of energy storage for grid power quality regulation forms. When the electric vehicle penetration rate reached a certain size, there will be a large amount of distributed energy storage to utilize. Distributed generation of new energy development will be promoted indirectly due to the large scale of available energy storage which improves the power quality.

There are two main bottlenecks in spread of electrical vehicles: one is the life time of battery. New materials are utilized to prolong the battery life and also increase the storage density to save weight and space. Besides the new materials, there are still some researches focus on how to form hybrid energy storage system to improve the battery operation condition; the other one is the charging time. Long charging time would influence the normal driving significantly. Some fast charging schemes and related devices are developed to shorten the charging time. Most of the researches need additional device to realize the fast charging scheme. The main drawback is that the additional devices increase the total cost and weight of vehicles.

In this project, a battery charging system which utilizes the hybrid energy storage system within the vehicles is proposed. The system can realize the fast charging control of battery without additional devices. Besides this, the terminal voltage of super capacitor can be controlled in a limited range, that would meet the energy manage requirement when the operation mode switch from charging mode to normal driving mode.

2. HYBRID ENERGY STORAGE SYSTEM

Among all the renewable resources, wind power have being widespread concerned from all countries for renewable energy projects. But it also has serious problem because wind speed is intermittent and fluctuates frequently, and that would influence the system stability significantly. Integrating energy storage system to the wind power system can enhance the stability and reliability of the whole power system. Many storage technologies have been proposed and testified for the validity. Such as battery, super capacitor, flywheel and superconducting magnetic energy storage (SMES). However, only one storage element can't enhance the system stability ideally. Characteristics of different storage elements are shown in Fig 1.

Several topologies and control strategies have been proposed that combine super capacitor to improve the condition of battery storage system, and they have already proved its validation.

There will be some requirements of supplying or absorbing high power for energy storage when vehicles accelerate or brake. High power should be avoid delivering to battery directly to save cycle lifes according to characteristics. Meanwhile, supercapacitor is suitable for dealing high power for high efficiency. The basic idea of an HESS is to combine supercapacitors and batteries to achieve a better overall performance.

3. FAST CHARGING SCHEME

Normal charging device usually take long time to charge batteries. This charging scheme is suitable for vehicles which have fixed and short route, such as city bus. But in daily life, the driving route is random. So that fast charging technology is needed to meet the user's needs.

A. Theoretic Principle

When the battery is charged, the electrons transfer from the anode to the cathode through external circuit. The transfer of electrons produces charged particles in the electrolyte. The cations and anions in the electrolyte form electric double layers that induce an overpotential imposed on the battery voltage to impede the charging process

and thus injure the charging efficiency. In addition, there will be formation of insoluble
In order to eliminate concentration polarization and increase the randomness of the crystal formation, pulse charging method gradually replace the traditional constant current charging. A proper ion and crystal diffusion time is provided between pulses in order to eliminate the potential of polarization and improve the efficiency. Typically, the pulse interval is set no more than one-tenth of a second, otherwise the charging time will be prolonged, and thus can not reach the fast charging purposes. Usually, the reduction of concentration polarization takes more than few seconds, so a further correction is made on the basis of pulse charging. A short-term negative pulse is added to the diffusion interval to accelerate the ion diffusion and increase the randomness of the crystal crystallization. The total waveform is shown in Figure 2, This charging method is also known as Reflex charging or Burp charging.

B. Existing fast charger

The basic charger to realize the Reflex waveform is shown in Fig 3 . When S1 close and S2 break off, the positive current pulse flows from power source to battery. And S1 break off and S2 close, the battery is discharged to resistor load, then the negetive pulse is formed. The main drawback is that low efficiency of the total system.
There are some improved chargers to solve the efficiency problem, but everyone has its own problem. In, a proposed circuit makes use of only one active power switch to form the required asymmetrical bilateral pulses of Reflex charging. A resonant circuit which consists of one inductor and two capacitors extracts a negative discharging impulse providing a reflex current for the battery. While the amplitude and duration of the negative impulse is determined by the designed circuit parameters, the waveform of negative impulse couldn't change according to the SOC (State Of Charge) which would influence the accept ability of average charge current . author proposed a bi- directional Buck/Boost converter which can generate positive and negative charging pulse, and the amplitude and duration of negative pulse can be changed according to the requirement. In addition, the regenerative energy generated at the positive charging mode is feedback to the capacitor in series between the rectification bridge and filter capacitor through magnetic equipment, which would increase the total weight and size of EV. In addition also use a bi-directional Buck/Boost converter to charge and discharge the battery, and the feedback energy is delivered to
the DC bus directly. The configuration is quite simple and small size, but high feedback power in fast charging scheme will cause an over voltage problem to trigger protection circuits and turn-off the device. Over voltage is attenuated by using multiphase pulse-charging current scheme, du e to recycling energy from the negative pulse discharging being diverted to the next phase in the battery charging. But synchronous control in different phase isn't easy to realize, and the waiting time is quite long in single phase that would prolong the total charging time.

4. MAIN CIRICUIT AND CONTROL CONFIGURATION

The study object in this paper is electrical vehicle with hybrid energy storage device. Usually, the size and weight of fast charger is very large because of the high power. So that fast charger cannot be installed on the vehicle and they are assembled in special charging stations or charging poles. To prevent harmonic pollution, the fast charging equipment is connected to centralized storage in station to lessen the influence to main grid. DC/DC topology is adopted as fast charger for the billing convenience. Buck circuit is used in this paper to simplify the control mode to meet the charging requirement of different types of vehicles. The control object of buck converter is the DC bus voltage. The reference value is sent through communication line from chip on-vehicle to charging station. No matter what mode the converters on vehicles are working at, the external converters keep the same control strategy.
control mode of battery converter is changed according to the state of battery. Reflex charging is adopted in the fast changing stage. Constant voltage or voltage pulse charging scheme is adopted when the terminal voltage reaches preset value. The constant voltage technology is mature so that no concern about it in this paper. Main aim of super capacitor converter is also maintain the DC bus voltage. Terminal voltage fluctuation of super
capacitor is concerned. The super capacitor voltage is controlled to meet the requirement of vehicle accelerate or brake.
Power flow direction is analyzed in control design, as shown in Fig 5. When positive current pulse is controlled, station and super capacitor are supplying power to the battery. When negative current pulse is controlled, super capacitor is controlled to maintain the DC bus voltage. Buck converter in station can not receive the feedback energy because the unidirectional design. So the voltage of super capacitor can be adjusted by changing the current share ratio during the positive pulse peroid.

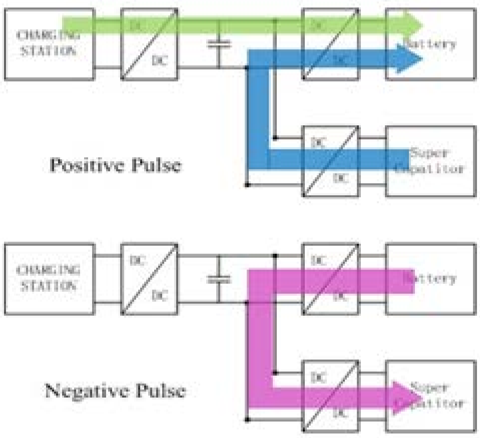


Figure 5. Reflex charging power flow

A logic comparison block is added to super capacitor converter control to fulfill the two functions mentioned before. When the input current from charging station is lower than a threshold value, super capacitor converter is controlled to maintain DC bus voltage as shown in Fig 6.

When the input current from charging station is higher than a threshold value, station charger can maintain DC voltage around reference value.

A hysteresis comparison of super capacitor voltage is carried out: if the voltage is higher than VHI, which means the energy stored in super capacitor is higher than control requirement. Then the super capacitor is controlled as normal voltage control to release energy to DC bus; if the voltage is lower than VLO, which means the energy stored in super capacitor is lower than the control requirement. The output current is set as 0, as shown in Fig 7. In this case, the super capacitor only absorbs energy and releases no energy. The voltage of super capacitor can be controlled in a certain range.

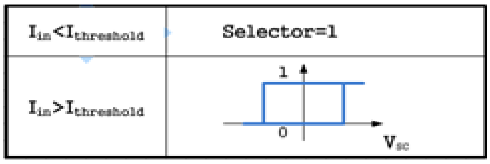


Figure 7 Logic decision of super capacitor converter

5. SIMULATION RESULTS

A simulation model is established in MATLAB/simulink to testify the validity. The control aims are: Reflex charging, maintaining the DC bus voltage at 300 V and limiting of the super capacitor in the range of 135-140 V.

The comparison threshold value of input current from charging station is set as 10A. When the input current is higher than 10 A, charging station could maintain the DC bus voltage alone, so that the super capacitor is controlled to maintain its own voltage as the logic decision mentioned before. When the input current is lower than 10A, the DC bus voltage is out of control when only external station is utilized to maintain it. In this case, the super capacitor is also controlled to maintain the

6. SIMULATION DIAGRAM:

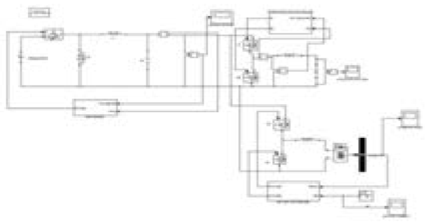


Figure 8 SWITCHING PULSES:

7. PULSE FOR SWITCHS:

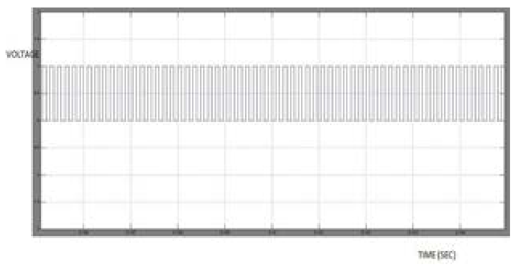


Figure 9 PULSE FOR SWITCH S1 & S2:

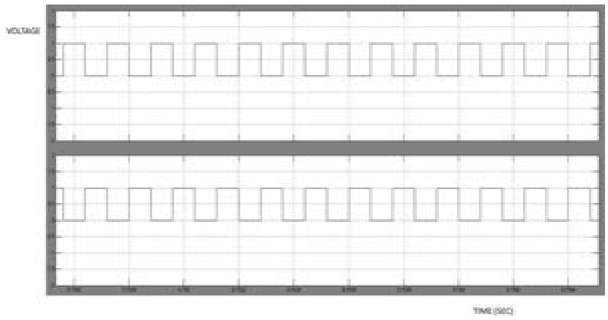
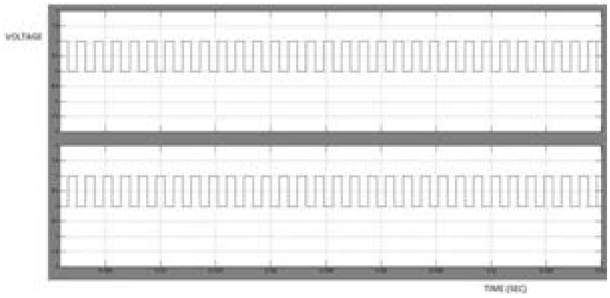


Figure 10 PULSE FOR S3 &S4:



BUS VOLTAGE:
BATTERY CURRENT:

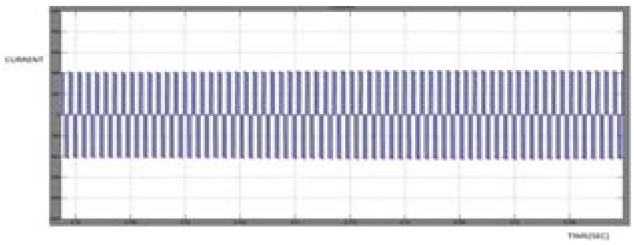


Figure 15 DC bus voltage.

There still is a potential benefit that a ll control blocks need no change even the electrical vehicle disconnects from the charging station.

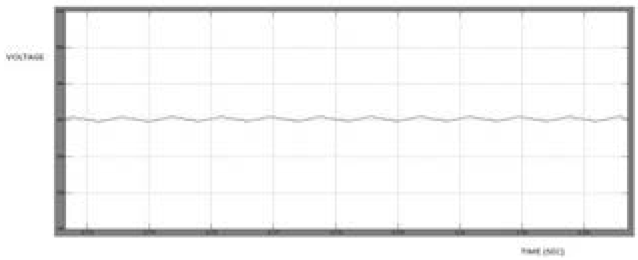


Figure 12 SUPERCAPACITOR VOLTAGE:

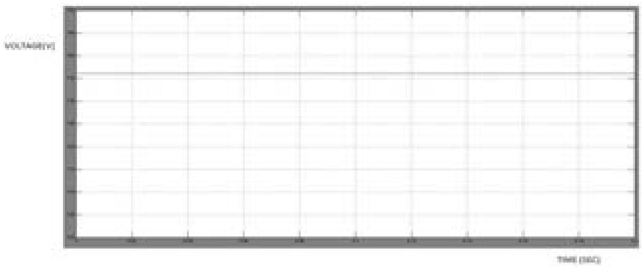


Figure 13 REFLEX BATTERY CURRENT:

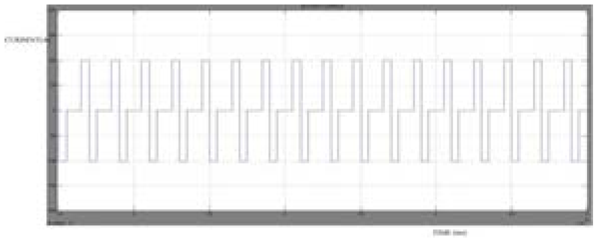


Figure 14

The simulation results are shown in Fig 8. DC bus voltage is maintained around 300 V although the current pulses cause voltage boost at short time. The battery current is controlled as the Reflex charging waveform to realize the fast charging. All the duty cycle and period are adjustable, but this part is not concerned in this paper. Besides, the super capacitor voltage is controlled in the range of 145-155 V. All the control aims are implemented in simulation model.

8. CONCLUSIONS

A Certain investigation for the battery charging system is proposed in this project to meet three goals: the first is reflex fast charging control of battery; the second is satabilization of DC bus voltage; the third is limitation of the super capacitor voltage. All these three goals are testified the validity in simulation model. And the parameters of the Reflex charging scheme could be modulated according to the actual condition. Furthermore, the influence of control parameters and the stability issue of these converters should be discussed in further study.

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