Research on the Key Technology of Electric Vehicle Driving and Charging Fusion DC-DC Converter

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Abstract. Taking STM32F407ZE as control core and using PID control method, a model of electric vehicle driving and charging fusion device is presented. The system can automatically switch battery charging mode and motor drive mode, and the key technology of DC-DC converter is studied deeply. The system model of bidirectional DC-DC converter is designed and manufactured. In order to simulate the three operation states of the bidirectional DC-DC converter, the performance of the system is tested under three operating conditions, and the feasibility of the system is verified. It provides a theoretical basis and design reference for the bidirectional DC-DC converter of electric vehicle driving and charging fusion device.

Introduction

The main causes of the new energy car development are the main problems of energy shortage, environmental pollution and climate change. In 2014 by the end of the country during the two sessions comprehensive national power grid of charging infrastructure construction, we will break industry monopolies, and is the background of the national power grid to delegate, country to vigorously develop the electric car industry, demand by 2016 electric cars cumulative volume to reach 500000 units, 2 million units in 2020; Speeding up the promotion of new energy vehicles is a big deal. One of the main problems restricting the development of electric vehicles is the price of electric cars generally large volume, high [2] (generally for three times the price of the same kind of car), one of the reasons are: (1) to improve the electric vehicle power and battery life, the electric car battery charger and power source motor drives for two parts, are separated; (2) in order to realize the electric car quick charge, at present the mainstream of the charging way is high voltage large current fast charging, charging quantity of heat is very big, need very large heat patch [3]; The power battery packs also need a lot of space to accommodate multiple parallel connections. This leads to large and expensive electric cars. This paper studies the variety of the electric car battery charging device, the electric car motor drive device structure and material, this paper proposes a new, small volume, light weight and the battery charger and motor drives the fusion of vehicle dynamics model, and the key technology of DC - DC converter to do the research. The proposed model will greatly reduce the cost and reduce the volume, and can be applied to the dc motor drive, hybrid electric vehicle and other equipments.

The Overall System Scenario Description

The whole system model including the double DC - DC topologies can be realized at the same time (step-down transformation and transformation of pressure), two-way DC - AC topology can be realized at the same time, the three-phase rectifier and three-phase inverter), measurement and control circuit, power battery, auxiliary power supply, etc., measurement and control circuit of STM32F407ZE as core controller, data processing and the corresponding function switch, realized the switch between power battery and motor drives.

Overall system structure is shown in figure 1, power battery charging mode, the closed switch S1 and S3 and S2 disconnect, two-way switch to the step-down DC - DC system state, two-way AC - DC
switch to the rectifier state, three-phase alternating current (AC) after bidirectional AC-DC rectifier through the two-way DC-DC system after decompression for constant current charging the battery pack, in the process of charging for real-time sampling current voltage sampling circuit, system sampling values calculated and displayed, when more than threshold voltage on both ends of the battery pack, system startup as the overcharge protection, stop charging; When closed switch S2 and S1 disconnected, two-way switch system to boost DC-DC system state, two-way AC-DC switch to inverter, power battery discharge after bidirectional DC-DC system booster bidirectional AC-DC inverter to drive motor, eventually driving electric cars.

Figure 1. Electric car drive and charging device fusion system structure block diagram.

The main core of the whole system is a bi-directional dc-dc system, which has a high voltage difference and a large current in the power pack. In electric cars to stop charging status when the two-way DC-DC will be in a state of decompression, in decline or brake electric cars, electric opportunity can feed in turn to the battery, so that the double DC-DC in step-down state, so the double DC-DC system is a state, has been repeatedly switch design must consider the system all the running status [4].

Bi-directional dc-dc Structure Analysis and Design

Synchronous Rectifier DC Transformer

In this paper, the voltage of the electric car power battery pack is raised or decreased by using the Buck/Boost two-way DC convertor, which is closed by controlling the closing of the switch tube. As shown in figure 2, the circuit diagram shows that in the positive-boosting work, control S1 remains in the lead state, S2 pulse width modulation; In the process of reducing pressure, keep S2 shut off, S1 pulse width modulation. During the working period, S3 and S4 are always closed, and S1 and S2 are always closed in the same way. The bi-directional dc-dc converter not only works on the battery energy charging system, but also can be applied to the battery discharge booster system [5].

Figure 2. Buck/Boost two-way DC converter circuit diagram.

Drive circuit design: IR2110 is the IR of high power MOSFET and IGBT dedicated drive integrated circuit, the circuit chip, small size, high integration, fast response, driving ability is strong, with undervoltage blockade, and its low cost and easy to debug, and is equipped with external protection blockade port [6]. For the Buck/Boost bi-dc converter circuit, which consists of four
Bi-directional dc-dc System Control Theory Analysis and Calculation

The Coefficient of Proportionality and the Calculation of the Integral Coefficient

This design adopts the control algorithm for PID control algorithm, the system voltage by measuring current, by regulating the function of PID controller to achieve a constant value of charging current and the proportion of the PI regulator of the dynamic response is faster than pay no lag (), integral part of the system to eliminate poor net [7]. The calculation of the ratio and integral controller coefficients is as follows:

\[ u(t) = K_p[e(t) + T \int_0^t e(t)dt] \]

In this case, the KP is the proportionality coefficient, the Ti is the integral coefficient. The sampling period of the single chip machine is T, and the input method can be approximate:

\[ u(t) = K_p[e(t) + TT \sum_{j=0}^1 e(j)] = K_p e(t) \sum_{j=0}^1 e(j)T \]

This system adopts its incremental control algorithm, which is based on the principle of recursion:

\[ u(k - 1) = K_p e(k - 1) + K_i \sum_{j=0}^1 e(j)T \]

The incremental is:

\[ \Delta u(k) = u(k) - u(k - 1) = K_p [e(k) - e(k - 1)] + K_i e(k) \]

Ways to Improve Efficiency

1) use IR2110 to drive the MOSFET, which increases the switching rate and improves the efficiency of the system.

2) reducing the grid series resistance of the switch tube, which can change the Angle of the control pulse before and after, prevent the shock, and reduce the shock voltage of the drain on the switch tube. At the same time, the static current of the switch tube is reduced by the resistance of the high resistance value between the cascade and the source level of the switch tube, and the static current of the switch is reduced.

3) according to the specific requirements to circuit winding inductance for system, combining with the theoretical formula and experience, choose the magnetic core and winding specifications, avoid magnetic saturation and reduce the copper loss and magnetic loss.
4) according to the demand of the circuit, select the suitable electrolytic capacitor, store the energy, and filter the ripples [10-12].

5) select the optimal integral coefficient of integral controller Kp, movement sensitive system, will speed up the calculation speed, Ki choosing appropriate proportion coefficient, the system stability is stronger.

**Bi-directional dc-dc System Software Design**

The software algorithm in this system is very important and very difficult, and the algorithm is very demanding. System software has four functions: system initialization, including the initialization of peripheral interface chips; Keyboard detection, current preset and step adjustment; Using PI algorithm for current and voltage adjustment, the dynamic adjustment of output current is realized. Implement the DA and AD transformations.

This design is designed for the PID adjustment. First try A/D sampling INA282 battery charging current value (as shown in figure 6 to AD sampling flow diagram), system error on data processing to get A relatively accurate sampling value, then this value is compared with preset the theoretical value, with the method of difference comparison, will get their difference by subtracting the measured values with the theoretical value, the difference compared with 0, respectively in different situations to adjust the duty ratio of PWM wave output, to achieve the objective of the constant current charging [13, 14]

**Data Testing and Analysis of Results**

Three commonly used while electric cars for the battery charging, of which the core is constant current charging process, for constant current charging, need to test current control accuracy and charging efficiency.

Under the condition of U2 = 30 v, the charging current control accuracy test, by charging current I1 of the adjusting range is 1 ~ 2 A test, adjust the step value is about 0.1 A, through the test, when set current changes, corresponding to the variation of charging current shown in the table below:

| Set the current /A | 1.000 | 1.100 | 1.200 | 1.300 | 1.400 | 1.500 | 1.600 | 1.700 | 1.800 | 1.900 | 2.000 |
|-------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Charging current /A | 1.067 | 1.091 | 1.281 | 1.388 | 1.492 | 1.592 | 1.685 | 1.796 | 1.891 | 1.992 | 2.091 |
| Control /% | 6.7% | 8.27% | 6.76% | 6.77% | 6.57% | 6.13% | 5.31% | 5.64% | 5.06% | 5.21% | 5.80% |

The table 1 shows that when the current set varying from 1 A to 2 A, step value 0.1 A change, charging current is changed, other conditions in certain cases, the current accuracy is above 5%.

Electric vehicles in the process of constant current charging, give priority to with high current, the simulation system set I1 = 2 a, under the condition of U2 = 30 v efficiency test, the converter input current, charging voltage value corresponding to the efficiency of each are shown in table 2 below, measured, converter charging efficiency up to 96.5%.

| The input U | Input current(A) | Charging voltage(V) | efficiency |
|-------------|------------------|---------------------|------------|
| 30V         |                  |                     |            |
|             | 1.58             | 22.8                | 96.5%      |
|             | 1.68             | 23.7                | 94.1%      |
|             | 1.78             | 24.9                | 93.2%      |
|             | 2.05             | 28.9                | 94.2%      |

In the system interrupt S1, S2 connect, connect the battery to work load circuit, namely the device mode set to discharge mode, in keeping the U2 = 30 + / - 0.5 V, U1 at the ends of the battery voltage, discharge current I1 corresponding numerical relations of converter efficiency shown in the following
table, after the test, the converter efficiency is as high as 96.4%, the basic to maintain a constant output voltage and current.

| U2/V      | I2/A | U1/V | I1A | efficiency /% |
|-----------|------|------|-----|---------------|
| 29.501    | 1.579| 21.021| 2.123| 95.8%         |
| 30.012    | 1.533| 19.456| 2.012| 95.3%         |
| 30.459    | 1.553| 19.581| 2.12 | 96.4%         |

Summary

This paper puts forward a model of electric vehicle driving and charging fusion device in combination with low efficiency and low economic benefit. This paper analyzes the key technology dc-dc transformation for electric vehicle drive and charging fusion, and designs a set of device model. At the same time, the reason of low battery efficiency is analyzed, and the improvement suggestion is proposed.

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