Research and design of control strategy for on-board charging system in electric vehicle

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Abstract: In the process of design of electric vehicle control system, the response of each control node in the charging process is analyzed, then the control strategy of the charging process of vehicle on-board charging system is studied and designed according to the electric vehicle on-board charging system structural characteristics, with reference to the national standard of the electric vehicle conduction charging system. Based on the simulation technology of Simulink/Stateflow, the logic simulation model of vehicle on-board charging system control process was established. By changing the input data of the model, the transformation of the running state of the main control system between different state objects and the output control signal to carry on the simulation verification via observations. The simulation results show that the control logic of charging system is correct and practically useful.

Key Words: On-board charging system, Control strategy, Modeling, Simulation

1 INTRODUCTION

In today's world, environmental pollution is serious; the petroleum resources are decreasing day by day. The emission of motor vehicle pollutants has occupied a large proportion of urban air pollution. Electric vehicles as the green environmental protection and zero pollution transport, has great superiority in the market. As an important form of power battery energy supply device, electric vehicle on-board charging system is one of the indispensable subsystems of electric vehicle; it has important practical significance to the popularization of electric vehicle [1].

On-board charging control system is an important part of the design and development of electric vehicle high-voltage power system, its control technology is one of the key technologies of electric vehicle development [2]. In the electric vehicle charging process, the on-board charger receives the vehicle control Module (VCM), battery management system (BMS) issued a directive and make judgments to achieve the charge of the entire process of control, At present, pure electric vehicle production is limited, domestic and foreign research on the mechanism of electric vehicle charging control system is mostly on the car charger independent of the circuit design, voltage / current control precision and response characteristics, power factor correction (PFC) , On the vehicle charging process control and fault control is rarely discussed [3]. As for the OEMs: the vehicle charging security, stability, efficiency, adaptability of the charging program is their considerable concern.

Pure electric on-board charging system control strategy development and design aims to: Under the premise of the existing vehicle charging system structure, by collecting the plug, pull the charging gun action signal, and through the CAN bus, BMS, VCM and OBC and other nodes to communicate, to control the charger safe high voltage power, and at the same time in the process of charging, and strive to accurately diagnose the vehicle fault and quickly make the appropriate treatment [7]. Along with the big trend in the development of new energy vehicles, on-board charging system development is essential.

2 On-board charging system operating principle

Electric vehicle on-board charging system structure diagram shown in figure 1, VCM as the core of the vehicle main control unit, in the charging process, through the hard line or CAN, etc. with AC charging pile (station), BMS, OBC, PRA (relay device) exchanging information, according to the information received, judge the state of each control unit, to make reasonable and safe instructions to control the coordination of various components, safe work; BMS as an important device to connect the energy management of vehicle power battery, monitors the dynamic data such as voltage, current and temperature of the battery in order to prevent overcharge, over discharge and overheating, and other phenomena damage the battery, affecting its cycle life. At the same time BMS through CAN communications involved in car charging process, can effectively guarantee the safety of vehicle charging.

OBC's function is to convert the AC voltage into DC high voltage, to charge battery. OBC monitors the input, output voltage, current, temperature and internal operation state in real-time, timely protection against over-voltage, over-current, under-voltage, over-temperature and other faults. PRA is a group of relays, VCM through which control the power battery high-voltage circuit on-off; CC connection confirmation function: through the way of electronic or mechanical, response the state of vehicle plug connected to the vehicle and/or the power supply plug is connected to the charging device, CP control guidance

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function: used to monitor the interaction between electric vehicle and electric vehicle power supply equipment [8].

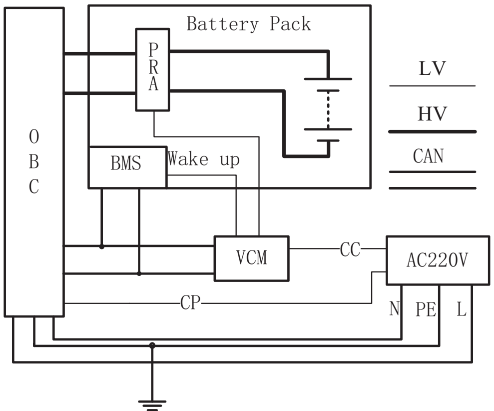

Fig.1 On-board charging system structure

There are three kinds of electric vehicle on-board charging mode, due to the national standard should not use the charging mode 1 of the electric vehicle charging, Here only a brief introduction to the charging mode 2/3, the specific reference to the national standard[8][10].

The user connects the charging device , CC signal is active, VCM wake up, determine whether the vehicle plug and vehicle socket is fully connected, VCM through the hard line signal to wake up BMS, through the CAN signal to wake up OBC (in the case of abnormal power reconnection using CP wake up), When the OBC wake up, detects the PWM signal on the CP to determine the CP in the connection state concurrent to VCM, VCM thus determine the vehicle into the charging mode 2 or 3. When the OBC confirms that the vehicle meets the charging conditions, the system can be charged in accordance with the pre-established charging strategy [9].

3 Control strategy design

In order to make the system control logic more intuitive, based on the signals in OBC communication with each node, the system control logic is modeled by using stateflow. According to the study and analysis of the charging process, the process is set to Sleep, idle, Ready, Working, fault these 5 working state. System control logic model shown in Figure 2.

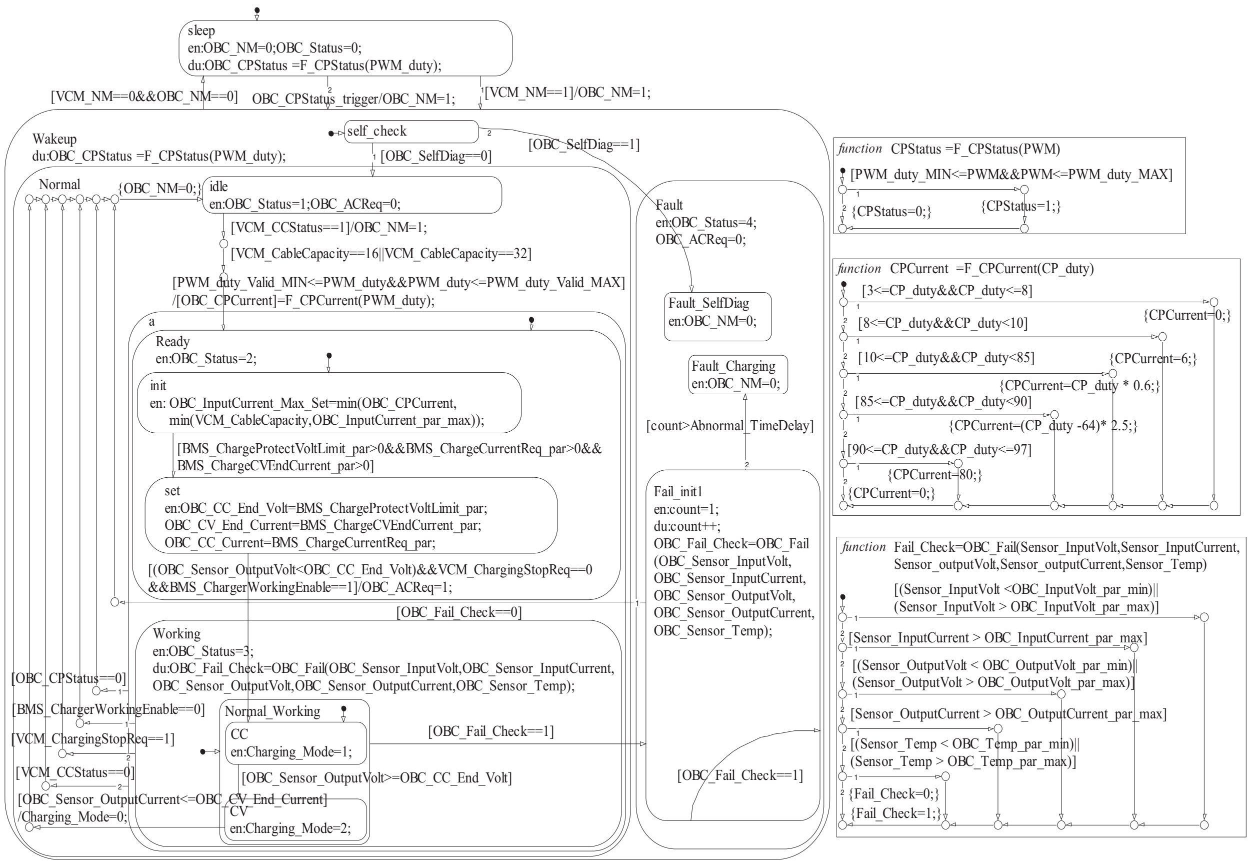

Fig.2 Logic simulation model of on-board charging system based on Stateflow

1. OBC is initially in the sleep state, the CP or CAN network wake-up signal (VCM_NM=1) is detected and will be awakened. After Waking up, OBC power on self-checking.

I. If the self-checking fails, OBC transitions to the fault state and reports the status via the OBC_Status message (OBC_Status=4).

Ⅱ. If the self-checking passes, OBC transitions to the idle status and reports the status via the OBC_Status message (OBC_Status=1).

2. When OBC detects that all of the following conditions are met, transitioning to the Ready state and reporting the status via the OBC_Status message (OBC_Status=2).

a. OBC detected the duty cycle of CP signal is in the effective range 8%-92%.

b. The VCM sends the charging gun connection signal is connected state（VCM_CCStatus=1） and the cable capacity（VCM_CableCapacity）is 16A or 32A.

3. OBC determines the maximum allowable operating current of the current power supply device through the duty cycle of the CP, Specific correspondences are shown in table 1.

Table1. Mapping relationship between duty cycle and current limit of electric vehicle detection [8]22

PWM Duty cycle D	Maximum charge current I_{MAX}/A
D＜3%	Charging is not allowed
3%≤D≤7%	5% duty cycle indicates the need for digital communication，And must be established between the charging pile and the electric vehicle before charging. No digital communication does not allow charging
7%＜D＜8%	Charging is not allowed
8%≤D＜10%	I_{MAX}=6
10%≤D≤85%	I_{MAX}=（D×100）×0.6
85%＜D≤90%	I_{MAX}=（D×100－64）×2.5 and I_{MAX}≤63
90%＜D≤97%	Reserved
D＞97%	Charging is not allowed

4. OBC compares the maximum supply current value, the rated input current value of the on-board charger and the rated capacity of the cable, and sets the minimum value as the current maximum allowable input current of the on-board charger; At the same time, OBC get the battery information from BMS, determine the battery maximum rechargeable voltage, the battery allows charging current, the battery constant voltage charge end current is greater than zero, And they were set for the on-board charger constant current charging voltage, constant current charging current, constant voltage charging end current.

5. When OBC detects that all of the following conditions are met, transitioning to the Working state and reporting the status via the OBC_Status message (OBC_Status=3).

a. Receive the charging work enable signal sent by the BMS is Enable (BMS_ChargerWorkingEnable=1).

b. Receive the charging stop request signal sent by the VCM is none (VCM_ChargingStopRequest=0).

c. OBC actual output voltage is less than the BMS request output voltage.

6. After entering the working state, OBC closes the S2 switch (Inside the charger, corresponding to the national standard S2 switch) to turn on the AC supply circuit. The OBC will output voltage current to charge the battery according to the command voltage current and combined with OBC state.

7. On-board charger in accordance with the set output current to the battery constant current (CC) charging; the battery voltage will gradually increase. When the battery voltage rises to the set value, instead of the constant voltage (CV) charging, during charging, the charge current will decrease as the battery voltage increases. When the charge current is reduced to the set value, indicating that the battery is full.

8. In the whole process, When it is detected that the duty cycle of the CP is not within the allowable charge range (duty: 3% to 97%) of the GB standard in the charging modes 2/3or VCM_CCStatus = 0（Disconnect）, the OBC jumps to the idle state.

9. When the charger is in the normal charging state, it will stop charging if it detects that one of the following conditions:

a. BMS_ChargerWorkingEnable = 0(Not Enable).

b. VCM_ChargingStopRequest = 1(charging stop).

c. Charger actual output current is less than or equal to the constant voltage charging end current.

10. OBC stop charging and transfers to idle state, while disconnect the S2 switch and send the Sleep request to the system via the network management message, when the condition is satisfied OBC enters the sleep state.

11. OBC monitors the input, output voltage, current, and temperature in real-time, timely protection against over-voltage, over-current, under-voltage, over-temperature and other faults. After OBC detecting the fault, close the high voltage output, disconnect the S2 switch, will report fault status via OBC_Status message and start the recovery time-out timer Count++. When the fault automatically restores within 30s, OBC returns to the idle state , enter the normal charging process; when the fault is not automatically restored in 30s, OBC sends Sleep requests to the system through network management messages. When the condition is met, OBC goes to sleep.

12. CP connection status, the charging device can provide the maximum working current calculation, fault are judged by the graph function.

4 Simulation verification

The control logic of on-board charging system is modeled in Stateflow environment, other input and output models are implemented in Simulink, combine the two together to build the simulation model of the system is shown in Figure 3.The transfer between the five states based on the designed control strategy according to the signals of VCM sleep enable, CC connection status, CP signal duty cycle, self-check status, charging cable capacity, BMS charge enable, VCM request to stop charging, the current voltage temperature signal of OBC.

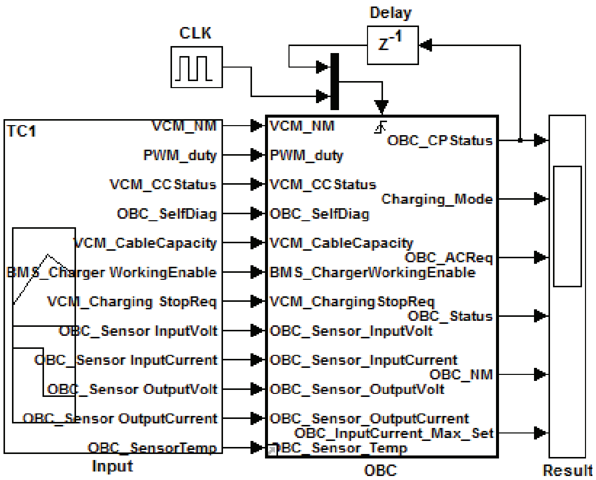

Fig. 3 system simulation model

In the process of implementing the simulation control strategy, the control strategy logic can be improved step by step through the simulation results. Simulation results in Simulink shown in Figure4.

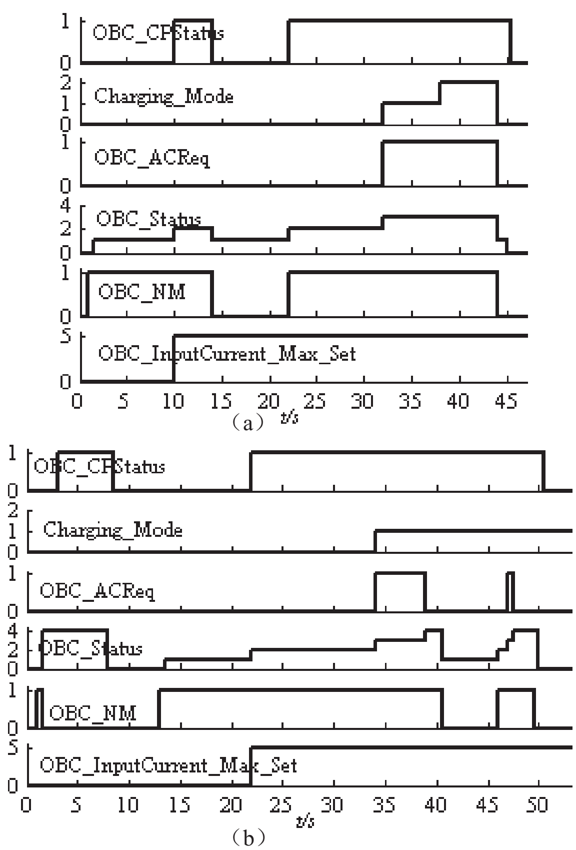

Fig.4 simulation results graph

As shown in Fig. 4a, the CAN network wake-up signal is valid at 1s, OBC wakes up passes self-check, enters the idle state, When all the input Condition CC Connection Status, Cable Capacity, CP Signal Duty Cycle are satisfied, the state transitions to Ready, and the maximum input current of the system is calculated; When input signal CP duty cycle is 0 at 14s, the system state transfers to idle, Then the state transition conditions are satisfied, the system transfers to the Working state and closes the S2 switch(OBC_ACReq), output high voltage charges the battery with constant current-constant voltage mode (Charging_Mode); charger output current from 4A to 1A is less than a preset charging cut-off current of 3A at 44s, the system transfers to the idle state, disconnect the S2 switch ,stop high voltage output and request sleep, VCM allowed to sleep at 45s, system status transfer to Sleep; Simulation results show the rationality of charging system control logic.

Fig.4b, the system self-checking does not pass, transfers to the idle state. At 48s the output current is 10A is greater than the threshold 5A reported fault, disconnects the switch S2, fault is not restored in 3s, the system issues a sleep request; At 39s the system state is Working state, input current is too large, the state transfers to fault, fault recovery within 3s, the system returns to the idle state, normal charging process. The simulation results show the rationality of the fault control logic of the charging system.

5 Conclusions

In this paper, the working principle of on-board charging system is analyzed and the control strategy is designed. Based on the system simulation software Matlab / Simulink / Stateflow platform, the Stateflow model of the charging process of the on-board charging system is established, and the control logic is verified by simulation. The results show that the designed control logic of the on-board charging system can meet the expectation. The control strategy combines the structural characteristics of high voltage power system of electric vehicle, which is advanced and practical. Simulation analysis of on-board charging system can effectively shorten its development cycle, reduce development costs and through a small amount of test validation, get the on-board charger system control logic; it is of some guiding significance to the development of electric vehicle on-board charging system.

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