Journal of Electronic Research and Application

Research Article

Research on PTC Heater Control Technology for New Energy Vehicles

Zhu Jun[1], Nofan Lei[2*], Xijun Yang[3]

[1]Shanghai Rujing Electronic Technology Co., China;

[2]Shanghai World Foreign Language Academy, China;

[3]Shanghai Jiao Tong University, China

Abstract: PTC heating is the new energy vehicle heat management system of the main heating mode, this paper a detailed analysis of the basic working principle of the PTC heater, the design of the PTC heater hardware control system and software control system, with MALTAB simulation of the control system model.

Publication date: November, 2020

Publication online: 30 November, 2020

****Corresponding author:*** Nofan Lei, leinuofan@icloud.com

1 PTC heater basic principle

PTC is the abbreviation of Positive Temperature Coefficient, which means positive temperature coefficient, referring to the semiconductor material or components with large positive temperature coefficient. The term PTC is usually used to refer to a positive temperature coefficient thermistor, or PTC thermistor for short.

PTC thermistor is a typical temperature-sensitive semiconductor resistance, beyond a certain temperature (Curie temperature), its resistance value with the rise of temperature is increased stepwise. Ceramic PTC is a semiconductor ceramic sintered from barium titanate (or strontium, lead) as the main component, with a small amount of rare earth (Y, Nb, Bi, Sb), host (Mn, Fe) elements, and glass (silicon oxide, alumina) and other additives.

Ceramic PTCs have a small resistance below the Curie temperature, and above the Curie temperature the resistance increases by a factor of 1,000 to 1,000,000 (Figure 1).

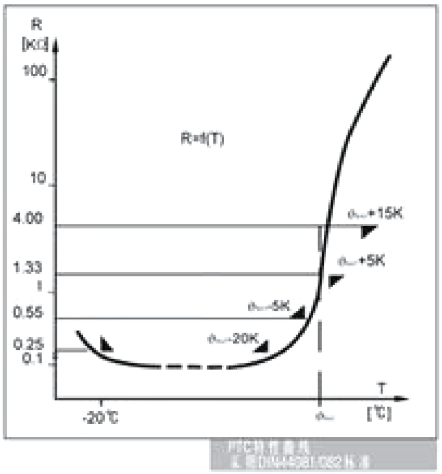


Figure 1. PTC heaters have low thermal resistance

PTC heaters have low thermal resistance, high heat transfer efficiency, is an automatic constant temperature, energy-saving heaters. The special feature is the safety feature, any situation will not occur similar to the phenomenon of resistance wire red, which causes burns, fire and other safety hazards.

2 PTC heater in the application of new energy vehicles

In a conventional car, the core energy source is fuel, powered by a conventional engine. The thermal management system of the traditional car, when cooling, is through a mechanical compressor driven with the engine belt to achieve the refrigeration cycle, when heating, is through the engine generated hot water cycle.

New energy vehicles, the core energy is generated by the battery system, there is no traditional engine, the battery system of new energy vehicles is the key to determine the mileage of the vehicle, due to the existence of the battery system performance of low temperature deterioration characteristics, the need to control the temperature of the battery system, compared to the thermal management system of traditional vehicles, the thermal management system of new energy vehicles and the difference is that the management object extends from the cabin to the thermal management of the battery, the second is that its function extends from simple cooling to the heating and insulation function.

The thermal management system has two operating states, cooling mode and heating mode. In the cooling mode, the compressor's cooling cycle generates cool air to cool the cabin and battery. In heating mode, the PTC heater generates heat to heat the cabin and battery. With the development of heat pump technology, heat pump compressor can run in heating mode, in the normal temperature environment, the heat pump compressor first run heating, in the lower temperature when the PTC heater auxiliary heating.

3 PTC heater control system design and implementation

3.1 Main parameters of the control system

The PTC is a resistive heating device with a rated operating voltage of 350 V. The controller receives control signals from the air conditioning master box and adjusts the PTC output power in real time. The water pump conveys heat to the battery through the water medium to complete the heating. The controller has a diagnostic function to cope with the failure mode under special circumstances and to protect its own module and the whole vehicle power system.

Main technical parameters of the control system.

(1) Working voltage of PTC controller: 9V-18V

(2) Working voltage of PTC heater: 200V-450V

(3) Maximum power: 6000W

(4) Overheat protection of the heating element: 120 degrees ± 2 degrees

3.2 Control strategy of the control system

3.2.1 Basic process of PTC control

Sampling the bus voltage and current and calculating the feedback power of PTC1 and PTC2.

Accept the power instruction of LIN bus and the feedback power of PTC1, calculate the current power instruction of PTC1 and PTC2, and make PI adjustment according to the power instruction and power feedback to get the required IGBT duty cycle.

Control the MCU output PWM and control the IGBT switch to make the feedback power match the given power.

3.2.2 PTC control power instruction distribution principle

When the feedback power is less than xx KW, all power commands are assigned to the PTC1 power command and the PTC2 IGBT is disabled from turning on, reset the PTC2 PI regulator, and if the feedback power exceeds xx KW, the excess portion of the power command is assigned to the PTC2.

3.3 Hardware design of the control system

A block diagram of the control system and includes the following components.

(1) Power supply module: converts low-voltage voltage to 5V, 15V, etc. required by microcontrollers and drive circuits.

(2) IGBT drive: processing the PWM signal output from the microcontroller to drive the IGBT.

(3) HV sampling: sampling of high-voltage voltage.

(4) Current sampling: sampling the current on the PTC.

(5) IGBT temperature sampling: sampling IGBT temperature.

(6) PTC temperature sampling: sampling the PTC temperature.

(7) Drive voltage sampling: sampling the drive circuit power converted by the power supply module.

(8) LV voltage detection: comparing the LV with the reference voltage.

(9) LIN communication: LIN bus communication circuit.

3.4 Software design of the control system

The control system software framework.

3.4.1 Software application layer

(1) Input signal processing: processing of input analog, digital, LIN communication inputs, etc.

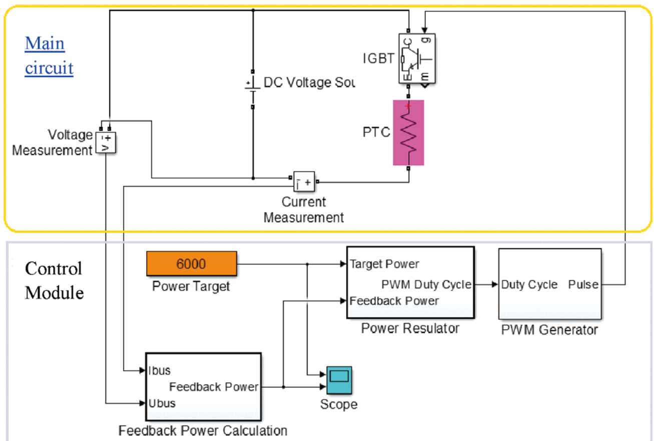
(2) Output signal processing: processing of the output PWM signal, GPIO signal, etc..

(3) State management: management of the system state.

(4) Power calculations: total PTC power estimates.
(6) Power control: calculate the PWM duty cycle based on the power command and calculated power.
(7) Diagnosis: diagnosis and protection of power, current, voltage, temperature, etc..
(8) Derating control: when there is an abnormality in current, voltage, etc., the power command will be derated.
(9) Diagnostic management: De-jittering of unidentified faults/protections and management of fault status.

3.4.2 Model Simulation of Control Systems

Matlab/Simulink simulation model

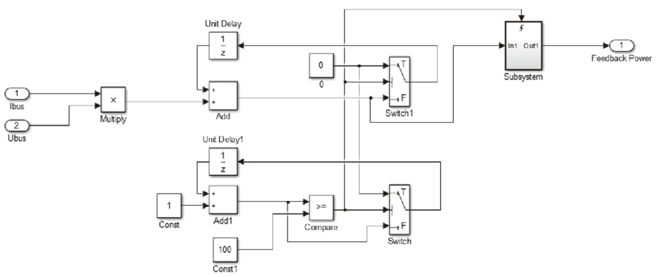


Matlab/Simulink Simulation Model - Power Calculation

Power calculation scheme: multiply the bus bar current by the bus bar voltage and then calculate the average power by accumulation.

$$P = \sum_{k=1}^{T/T_s} U_{bus} I_{bus}$$

model



Power control (PI control)

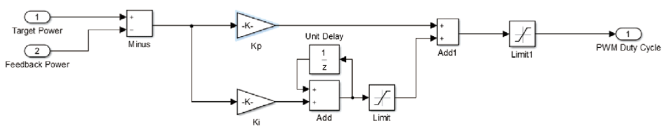
(1) Get power error

$$P_{error} = P_{reference} - P_{feedback}$$

PWM duty cycle by PI adjustment

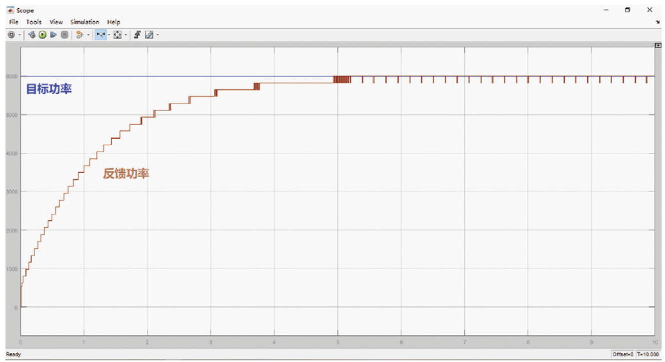
$$D_{PWM} = K_p P_{error} + K_i T_s \sum_{k=1}^{T/T_s} P_{error}$$

model



Simulation Results

The figure below shows the simulation results at a target power of 6000W.



4 Conclusion

PTC heater has the characteristics of small thermal resistance, high heat transfer efficiency and high safety, which is the main way to heat the thermal management system of new energy vehicles. Based on the PTC control principle, designed the PTC hardware control system and software control system, and used MATLAB to simulate and analyze the model of PTC control system to realize the control of PTC thermal management.

References

[1] Jun Y. Structural design of PTC plumbing heater for pure electric vehicles and its control system, Master's thesis, Huazhong University of Science and Technology, 2016

[2] Zhang RJ. Optimal design and experimental study of PTC heater based on comprehensive performance evaluation Zhejiang University of Technology Master Thesis 2018

[3] Tian FG, Guo HC, Li SY. Heating solution for pure electric vehicle cab, Automotive Electronics 2012(10)

[4] Song JJ. positive temperature coefficient thermistors and their applications household appliances 1998 No. 8