TMS320LF2407A-based digital charger for electric vehicles

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Abstract

First, the need of digital charger research was only presented. Particular attention was paid to the theory behind the shift-phase full bridge inverter and secondary rectifier that make up the digital charger's primary circuit. In this case, a control system circuit, software, and digital PID controller based on the TMS320LF2407A were developed. The results and technical parameters of the experiment were detailed. The charger's soft-switching, digital-control output is reliable and up to the task of handling the complicated charging methods required by today's batteries.

Introduction

With the ever-expanding EV market comes ever-increasing demands for specialized charging equipment to keep up with the ever-evolving specifications of power batteries that may be used in EVs. With the growth of digital technology and its accompanying advancements in DSP technology, the control sector is likewise facing a significant technical shift. Therefore, the theoretical relevance and practical worth of developing home electric car charging equipment [1] would greatly benefit from research into digital control technology of special charger electric vehicles. The digital charger's efficiency is determined, in large part, by the charging machine's lord loop. Inverter-type power is compact and high-quality, with a rapid reaction time thanks to its high operating frequency, and its diverse output characteristics are easily realized to accommodate a wide variety of charging strategies. As a result, the full-bridge with secondary rectification scheme is considered the primary charging circuit in this article. The fundamental layout of the primary circuit is shown in Fig.1.D1, D2 are rectifier diodes on the secondary side of the transformer, Lf and Cf are output filtering inductance and filter capacitance, and Vs is the DC voltage obtained from a single-phase or three-phase ac rectifier.

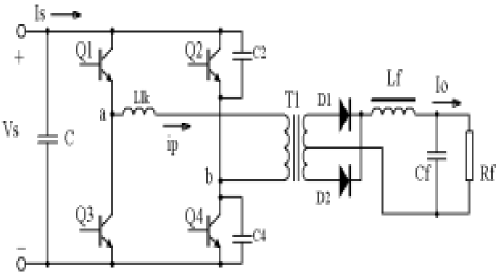


Fig.1 The main circuit schematic

Fig. 2 depicts the driving pulse timing diagram, which is almost identical to the conventional phase shifting control except that the dead time between Q2 and Q4 varies with duty cycle (as seen by the shaded portion). There will be additional lag time between Q2 and Q4 when the bus voltage is higher or lower than normal. Q4 and Q1 will both be opened at the same time throughout each half cycle, however Q4 will be shut off first. Q1 and Q3 make up the lagging bridge arms, while Q2 and Q4 make up the leading bridge arms [2].

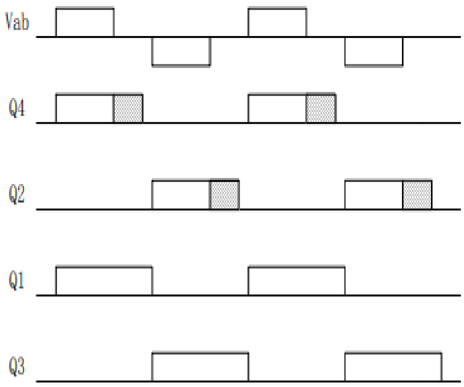


Fig.2 Driver pulse order of the main switch

Assume that Q1 and Q4 started off in the on position, and that C2 and C4 served as buffer capacitance for the zero-voltage-switching (ZVS) of Q4 at some point. In Q4, ZVS turn-off losses will be much reduced despite the persistence of trailing current. Reverse avalanche occurs when the reverse voltage supplied to Q2 surpasses 30V due to Llk (high-frequency transformer leakage inductance and line equivalent inductance). In this state, Q2 behaves as a zener diode. In addition to causing ip to weaken to zero, the transfer of energy (1/2Llkip2) from the avalanche to Q2 causes the avalanche to cease. Even though ip has just gone to zero, the voltage difference between b and busbar is equal to the IGBT reverse avalanche voltage, therefore only a little amount of current will flow backwards via Q1. It will facilitate Q1 composite electric charge storage, which will eliminate Q1 trailing current.Additionally, this allows Q1 to reach ZVS (zero voltage switching). Applying a negative voltage causes Q2 to open without loss when the voltage is at ground. After Q1 has been switched off, Q3 will be activated and enter a half cycle.

The TMS320LF2407A-Based Digital Control System Circuit

When a digital signal processor (DSP) is used as the controller for a switching power supply, not only are the problems caused by an excessive number of dividing elements, poor circuit dependability, and a complicated control circuit eliminated, but the inflexibility of a single, centralized controller is also mitigated. Higher frequencies, shorter instruction cycles, and an enhanced bus layout provide DSP potent data-processing capabilities. TMS320LF2407A, a newly added chip to TI's 24X family DSPs, is commonly used for digital control of motors and, with a little bit of programming and other circuitry, can charge electric vehicles digitally [3]. The logical structure of the control system is shown in Fig. 3.All of the control operations of the TMS320LF2407A-based control system are accomplished by means of an external circuit.

TMS320LF2407A generates limited dual polarity PWM control signal,and the control signal drives IGBT(on/off) after amplifying by an isolated drive circuit;

- ADC sampling circuit samples input signal, which has been processed by filter circuit,and input to CPU;

- After testing by bias magnetic detection circuit,TMS320LF2407A would catch the bias magnetic signal and process, if bias phenomenon appeared in power transformers; • Display and adjust settings through serial connection using SCI; Exchange data with external devices using a CAN2.0 controller.

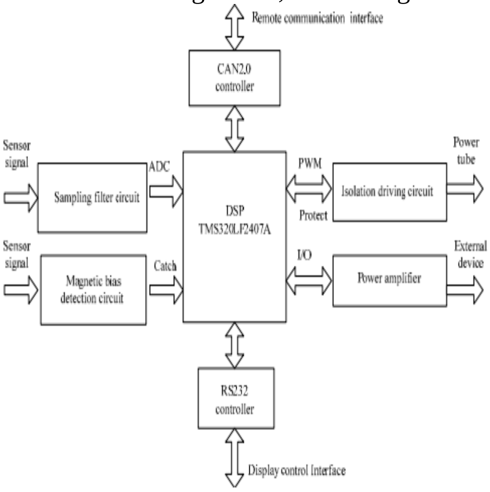


Fig.3 Frame chart of control system

Inconsistent devices, magnetic biasing that causes the primary side of the transformer to become saturated, full-bridge circuit straight-through that causes the primary side busbar to give the illusion of short-circuiting, overcurrent in the load of the vice side, and radiator overheating are all potential abnormal conditions that can arise while the power is on. Therefore, the abnormal situation may be resolved if the hardware circuit is built thoroughly and appropriate protection measures are implemented.

The Control System Software Design Process

The charging process as a whole is controlled and monitored by the control system, which also serves to actualize digital control throughout the charging process. C and assembly are both supported by the charging power control software. The control function must be realized, yet in a reasonable and straightforward manner. In order for the control system to accommodate the need for a stable and reliable high-power supply.

The Software's Overarching Design

The following are examples of the roles played by control software: sampling procedure; computer code uses the sample value to determine the output pulse width and then adjusts the PWM pulse width for the final product; It contains a CAN communication program, which allows it to receive control instructions and deliver the output current or voltage value, as well as a troubleshooting and protective function program. Figure 4 depicts the primary program flow chart and the first program of the control system software.

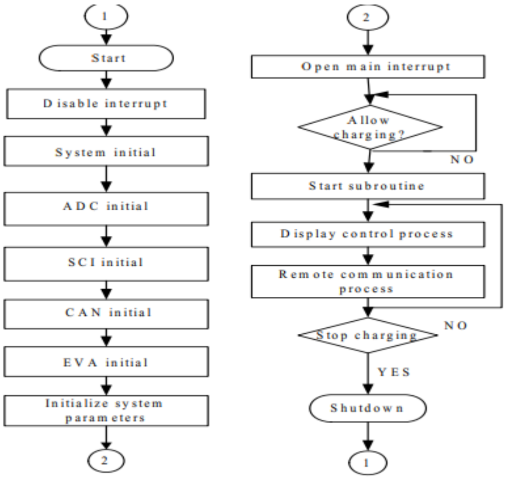


Fig.4 Main programme flow chart of control system

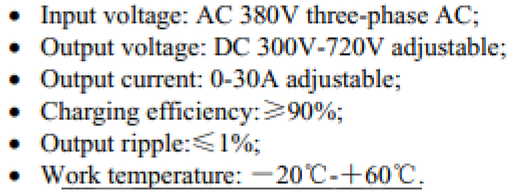
The software's operability may be enhanced by arranging processes like displaying content and controlling devices in the main program, rather than having those tasks performed in separate threads or via interrupts. Work that has to be processed often or urgently, on the other hand, is better suited to the interrupt method. The CAN communication software, in addition, makes use of the interrupt service routine for its own purposes. Methods and processes for charging may be determined and modified in light of the data obtained.

A Quick Overview of Digital PID Controller Design

PID control's many benefits stem from its straightforward design and tunable settings. As a result, it became standard in the field of continuous system control. The controlled variable's deviation is calculated using proportional, integrative, and differential methods, with the resulting values being combined linearly. Since digital PID control is an example of sampling control, it uses sampling time deviation to determine the values of the control variables. Therefore, precise direct calculations of the integral and differential item are not possible for type (1). As a result, the control law formula for this system is as follows, and the incremental proportional integral derivative (PID) method is used. The controller's reaction time must be quick because of the high frequency the charger needs. The increments of the controlled variable at time i, in this case the PWM pulse width, are denoted by ui. Tape (2) demonstrates that incremental algorithms only need to save the deviation of the first three iterations, using little storage capacity and having little system impact. When errors in calculations or a lack of accuracy first become apparent, the resulting cumulative error is negligible. In addition, the system's reaction time may be slashed since it remembers its state from the last time it was restarted. Additionally, the method prevents the output value from fluctuating excessively due to incidental variables, which considerably improves the system's dependability. The PID controller's settings in this setup were found by experimentation and fine-tuning, yielding good results in the end. Each sampling interrupt requires a computation, and the sampling period of the system is the switching cycle of the main circuit, from which the output pulse-width of the subsequent cycle may be determined. In the interrupt management procedure for the ADC, the PID algorithm was embedded.

Outcomes of Analyses and Technical Specifications

Charger, electric vehicle (EV) power battery (Ni-H), pure resistance load, personal computer (PC), and test equipment (digital oscilloscopes) make up the whole of the experiment system. The principal side voltage (Up) and current (IP) waveform test results are shown in Fig. 5.Up and IP are the ideal principal voltage and current in the waveform. Because power switches operate at ZVS (Zero Voltage Switch) and ZCS (Zero Current Switch), the primary voltage and current do not show as current peak and voltage peak like conventional hard switching. Fig. 6 displays the output response curve of the system. From the graph, we can deduce that the system only needs half a second to double the output voltage from 200 to 500 volts. This demonstrates the system's benefits, which include a fast reaction time, little overshoot, and excellent, consistently precise results. The following are examples of Charger's technological parameters:



- Input voltage: AC 380V three-phase AC;
- Output voltage: DC 300V-720V adjustable;
- Output current: 0-30A adjustable;
- Charging efficiency:⩾90%;
- Output ripple:⩽1%;
- Work temperature: －20℃-＋60℃.

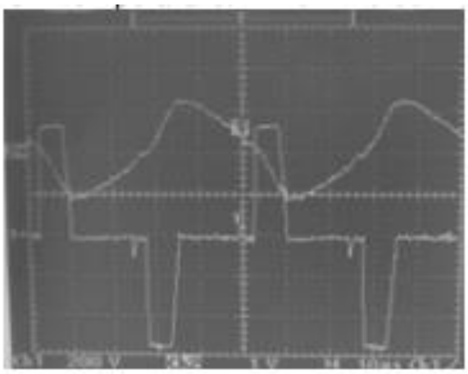


Fig.5 Waveform of power transformer prior current and voltage

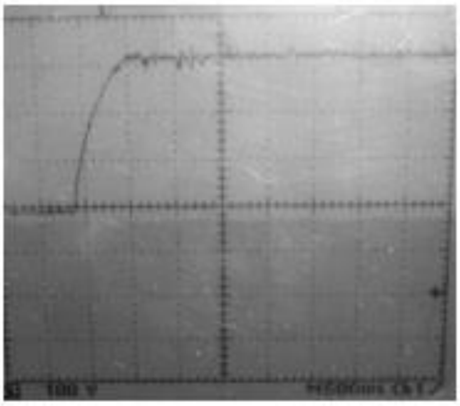


fig.6 Response curve of system set value

Conclusion

Soft switching is used in the digital charger for electric vehicles, which increases the charger's efficiency and dependability. Because it uses a digital processing chip and digital control technology, the control system has great real-time performance and an outstanding control function, and it can meet the complicated charging needs of a variety of battery types and powers. The gadget is modular in design, so it can interact well with both humans and electric vehicles.

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