The Design of Charging Circuit of Pulse Laser Power Supply

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Abstract

In this paper, we design and produce a kind of charging circuit for high power pulsed laser power supply based on series resonant technology. This paper introduces a high voltage pulse power supply charging circuit using series resonant converter as charging circuit,The design uses IGBT as the hardware circuit of power devices.

Keywords

IGBT,Charging circuit,Acceptor resonance,Pulsed laser power supply.

1. Introduction

This paper introduces a high voltage pulse power supply charging circuit based on series resonant converter, Starting from the basic charging circuit, a detailed description of the LC resonant circuit. In depth analysis of the working principle of high power pulse laser power supply charging circuit. The technical specifications of the pulse laser power charging circuit are as follows: 220V AC power supply to the energy storage capacitor is 4000 F charge, the charging voltage of 2S is up to 1000V, the voltage stability is + 0.8%, and the ripple is less than + 1V.

2. LC resonance principle

The research of the resonance phenomenon has important meaning, on the one hand, it has been widely used, on the other hand, in some cases, the resonance failure occurs in the circuit.

As shown in Figure 1, for the LC series circuit, under the excitation of sinusoidal voltage, the circuit operating state changes with the frequency of changes.

$$Z(j\omega) = R + j(\omega L - 1/\omega C) \quad (1)$$

When the ω change of inductance with frequency is proportional to the change. With the change of capacitance frequency curve as shown in figure 2.

When $\omega = \omega_0$, appear $I_m[Z(j\omega)] = 0$. That is $\omega_0 L - 1/\omega_0 C = 0$. This is the LC resonance condition.Q is the quality factor of the resonant circuit, $Q = u_L(\omega_0)/u = \omega_0 L./R = 1/\omega_0 C$, $Q$is greater than 1, then there is greater than x $u_L = u_C$, When $Q >> 1$, it is shown that the inductance and capacitance at both ends of the inductor and capacitor are significantly higher than the voltage of U when the resonance or near resonance occurs. The following talk about the type of LC resonance.

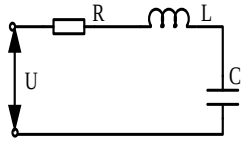


Figure 1 Series-resonant circuit

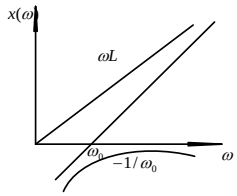


Figure 2 Capacitance with frequency change curve

3. Circuit design

Charging circuit is the core circuit of the whole pulse laser power supply system. It is directly related to several important technical parameters of laser power supply, for example, charging voltage, charging efficiency and precision.

Circuit design requirements:

(1) 220V alternating current to the 4000uF capacitor charging 1000V in the 2s, and then through the 4.75mH inductive discharge.

(2) Each step of the foot switch, the circuit to complete a charge and discharge process. Or set the timer, repeated charge discharge process. Constant current source charging is the best high power charging circuit, because the general power supply is close to constant voltage source, so we use the constant current converter and then charge.

3.1 Design of charging circuit:

We use the IGBT with high input impedance, the control circuit is simple, fast switching speed and heat stability of IGBT half bridge series resonant inverter is used as the charging circuit are introduced according to the needs of the design. The circuit is shown in Figure 3. Among them off 220V AC after rectifier voltage is C1=C2, 2E, when the circuit is in static (i.e., IGBT1 and IGBT2 are off), they divided into two equal parts that is E, each IGBT on the anti parallel a high-speed diode D1, D2 play the role of continuous flow, in addition, parallel with RC IGBT absorption circuit is used to limit the voltage rise rate of switching elements. Inductance L1 is a loop resonant inductor, which limits the flow rate of current rise, the resonant capacitor C3 and the high frequency transformer T1 in series, the secondary output of the transformer after the full bridge rectifier to the energy storage capacitor C4 charging.

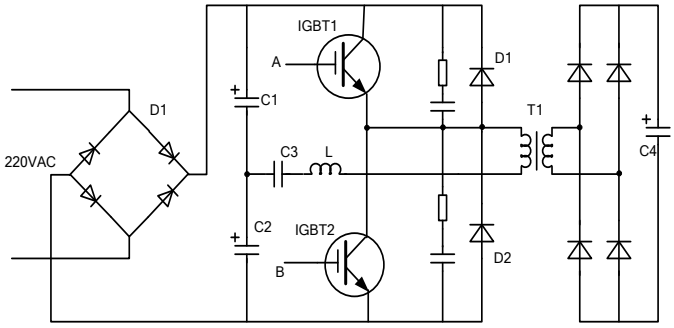


Figure 3The charging circuit of half bridge inverter IGBT

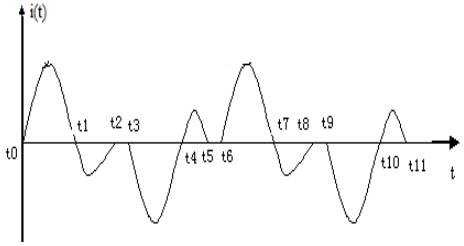


Figure 4IGBT inverter current working waveform

The waveform of the circuit is shown in Figure 4.At t0 time, A points to receive the trigger signal, IGBT1, power through the IGBT1, the transformer primary, C3, L to C2 charging, the current forward flow, its value from zero gradually increased, IGBT1 belong to the current conduction, L and C3 resonance. At T1 time, the current zero, the voltage at both ends of the capacitor C3 gradually reduced, T1 to T2 between the moment, turn off IGBT1. Due to the diode D1 conduction at this time, IGBT1 is a zero voltage turn off. At T2 time, the current to zero, D1 natural shutdown. T3 time, IGBT2 triggered by the trigger, the circuit began a resonant cycle, T4 time current zero, diode D2 continued to flow. At T4 to T5 time, IGBT2 zero voltage turn off, T5 time D2 natural shutdown, T6 time cycle ends.

AS can be seen, in an inverter cycle, a total of four stages.

(1) IGBT1 during the t0-t1, the power supply to the C3 charge.

(2) During t1-t2, D1 conduction, C3 to power feedback energy.

(3) During the t3-t4, IGBT2 conduction, the power supply to the C3 reverse charge.

(4) During t4-t5, D2 conduction, C3 to power feedback energy.

Bridge rectifier D1 bridge module selection, the maximum current is 50A. Filter capacitor C1 and C2 for the pressure 450V, capacity 2200uF of the two electrolytic capacitors. To provide inverter with more than 300 DCvolts.

In inverter, LC series resonant network is a very important part, the parameter L and C selection is the key of the series resonant charging circuit. The half bridge inverter, the resonant frequency of f_0 is two times the switch on-off frequency of f_s. Then the power required by the charging circuit, using the formula $P_0 = 1/2 \cdot CV_2 f$ that can determine the value of the resonant capacitor *C*, so that the formula $f_0 = 1/2\pi.\sqrt{LC}$ to determine the parameters *L*. In the actual design should take into account the selected switching elements of the current characteristics and charging voltage, according to the formula *L* reasonable choice of *C* ,and so that the whole circuit to work in the best state, to achieve the required charging performance indicators. In the actual design should take into account the selected switching elements of the current characteristics and charging voltage, according to the formula $IL = V/2/2\sqrt{L/C}$ reasonable choice of L, C and f_s, so that the whole circuit work in the best state, to achieve the required charging performance indicators. Because of the theoretical value in the specific circuit there are many factors that do not calculate, can only be adjusted through experiments, and finally select a more suitable L and C values, it can not only guarantee the normal operation of the circuit, but also provide the energy we need a harmonious vibration frequency. The inductance value is 20mH, the capacitance value is 0.33uF, the resonance frequency is 60kHz, because there is leakage inductance in the circuit, so the theoretical calculation value and the experimental value have a certain gap.

3.2 Design of control circuit

Control circuit is mainly to produce a variety of signal unit circuit. The main single crystal oscillator, voltage comparator, a single trigger circuit, multi harmonic trigger circuit, delay, voltage regulators, etc.. These unit circuits can be combined to complete the charging network control, discharge network control, voltage regulation and other functions. In this paper, from the single crystal tube, NE555, TL494 devices to design and control signal generation circuit, the use of a dedicated driver chip IGBT driver EXB841.

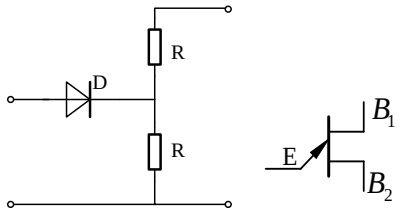
Single crystal oscillator:

The function of the single crystal oscillator in the circuit is to produce a tunable pulse, which can be replaced by a pedal, and is an important circuit unit for automatic charging.

A single crystal tube (UJT) has an emitter and two base, as shown in Figure 5.

$$R_{BB} = R_{B1} + R_{B2}, U_{B1} = U_{BB} R_{B2} / R_{B1} = \eta U_{BB} \quad (2)$$

U_{BB} is a two electrode voltage, η is the partial pressure ratio. It is generally between 0.3 to 0.85.



(a)Equivalent circuit (b) Symbol

Figure 5Single crystal tube

The characteristic curve of single crystal UJT is shown in Figure 4-8. Among them, which corresponds to the voltage / current IP were known as the peak voltage and peak current, and u point corresponding to the voltage UV and current IV respectively for valley point voltage and current.Before a P-point, UJT in the cutoff region, only the leakage current flowing through, when the emitter voltage $U_E=U_D+\eta U_{BB}(U_D=0.7)$,UJT conduction launch very Eand base B1 for low resistance conducting state, dynamic resistance ,$U_E/\Delta I_E$ is negative, UJT into negative resistance region. When the emitter current I_E increases to a certain value, the emitter voltage $U_E$drops to the valley point V_O. If we continue to increase the change is very small. UJT into the saturated zone.

By the negative resistance characteristic of UJT, the self excited oscillator can be easily formed.When the power $U_{BB}$is switched on, it is charged by the resistance R to the capacitor C. C on the voltage U_C will be exponential growth. When $U_C=U_P$, UJT conduction, so C by UJT and resistance discharge. Get pulse output on R_1. When U_C is reduced to UJT, the $U_C=U_V$ cutoff. After that, the power U_{BB} and by R to C charge.Over and over again, to form an oscillation. Oscillation period T is expressed as:

$$T = RC\ln 1/(1-\eta) \tag{3}$$

So change the R or C value, you can change the oscillator cycle.

Using 555 to form a single steady state trigger

Here two single steady state circuit respectively complete the function of silicon trigger and delay.As shown in Figure 6

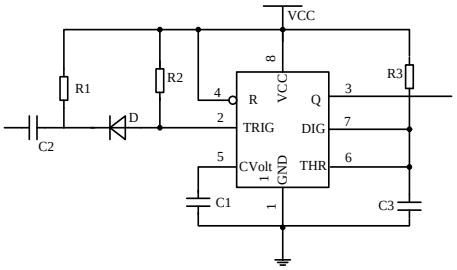


Figure 6555 constitute a single steady state trigger

At the beginning, the input signal is $V_1=V_{CC}$, so the comparator C_2, V_+ is greater than V_-, so the output high level.Power R through the resistance of C to V_{CC} charging, so that the V_1 potential rise.When V_1 is charged to more than $2V_{CC}/3$, is of comparator C_1, will appear $V_-$is greater than V_+, so comparator C_1 outputs low level, the NAND gate G_1 outputs high level, the output V_O for low level.At the same time, NAND gate G_1 output high level make T_D conduction, capacitor C by T_D discharge. When the discharge to less than $2V_{CC}/3$ comparator C_1 outputs to a high level, the capacitor discharges C to 0. This is the steady state.

When the decline in input signals V_1 along arrived., $V_1=0$, so that the comparator C_2 appeared V_- is greater than V_+, comparator C_2 output low level, NAND gate G_2 high output level, NAND gate G_1 output low level, so that the output V_O for high level. The circuit is triggered by a flip.

TL494 is typical of fixed frequency PWM control IC, it contains the control switch power supply all the required functions, can be used as the correct cream double tube type, half bridge, bridge type of switch power supply control system.

4. Conclusion

in this paper, based on the series resonance technology and high-power pulsed laser power supply basic charging circuit, constant-current source charging circuit and control circuit of signal. Including LC series resonant inverter charging circuit principle and design; The basic unit of the control signal circuit circuit principle and design; Design of technical index set is 220 v alternating current to the energy storage capacitor capacity is 4000 u F charging, charging voltage within 2 s for up to 1000 v, voltage stability plus or minus 0.8%, ripple is less than + / - 1 v.

Through the analysis of the actual test waveforms, can prove in this paper, the developed high-power pulsed laser power charging system has reached the technical indicators are proposed.

Reference

[1] Liang Zuo- liangLiang Guo-zhong. Laser power supply circuit [M]. Beijing: The Publishing House of Ordnance Industry, 1995.

[2] Ye Hui-zhen. Switching regulated power supply [M]. Beijing: National Defence Industry Press, 1994.

[3] WANG Zhao-an. Power electronic technology [M]. Beijing: China Machine Press, 2001.