Design and simulate open loop control system for generates regulated DC high voltage.

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Abstract

In many applications like Pulsed load systems that need to be high voltage dc power supplies with no EMI, better regulation and better switching characteristics. High voltage (HV) power supplies are most used in air borne applications, industrial, laser based systems and medical. In our case high voltage power supply are used in RF and plasma generation. This paper presents the design and simulate of the power supply with 3KW power and 1 kV output voltage. For the designer of power supply converter has half bridge with the topology of switched mode power supply (SMPS) based which switching frequency is 10 KHz. This paper covers the single phase supply, half bridge inverter, High frequency transformer, full bridge rectifier, feedback loop control and some electronics component. For making the low cost of power supply, in feedback section designer should use OPAMP, IL494 and IC555 for controlling the duty cycle of the inverter.

Keywords

Zero voltage switching (ZVS), Zero current switching (ZCS), Feedback loop control, switched-mode power supply (SMPS), LLC resonant converter.

Introduction

Every dc power supply has main two stages which is rectifier and voltage regulator. The voltage regulator is sub-divided into two categories i.e. linear regulator and switching regulator. In linear regulated power supply transistor use as control element and amplifier use to provide an error signal while switching regulated power supply are use in high frequency which is controlled by feedback loop system for regulating output voltage. For taking tight regulation of high frequency inverter and high voltage in one power supply is a challenging issue. Duty cycle ratio is control by feedback loop control system. For regulation of dc voltage source phase shift Pulse width modulation (PWM) control is most preferred. In the Phase shift PWM control the duty cycle that senses the error generated between the reference voltage and output voltage coming out from feedback loop control system.

In SMPS topology, the single phase supply is first rectified and then filtered by capacitor bank that produce an unregulated dc supply. The unregulated dc voltage is directly fed to the half bridge inverter or high-speed switching section which contains electronic switches (IGBT or

MOSFET) connected as a chopper. The electronic switches have fast-switching characteristic with ZVS and ZCS. The switching frequency has variable pulse width and its range between 10 KHz to 200 KHz.

These electronics switches are switched on and off to intermittently apply the unregulated voltage is fed to the primary of the step up HF transformer. The output of the step up high frequency transformer is fed to the full bridge rectifier and then smoothed by the output filtering capacitor bank.

The main objective of the paper presenting is to design of high voltage dc supply (1kv) that include chopper and high frequency transformer. This paper also includes the design of feedback loop control system for control the duty cycle ratio.

The traditional ac supply has 230 V and 50Hz which cannot be generate the plasma at atmospheric pressure. So, this ac supply is first rectified, inverted, step up using high frequency ferrite core transformer, and once again rectified and filtered by capacitor to get the required level of dc voltage.

Switched mode power supply (SMPS) based configuration is most suitable for half bridge inverter to reach the level of 1 KV and 3000 W power.

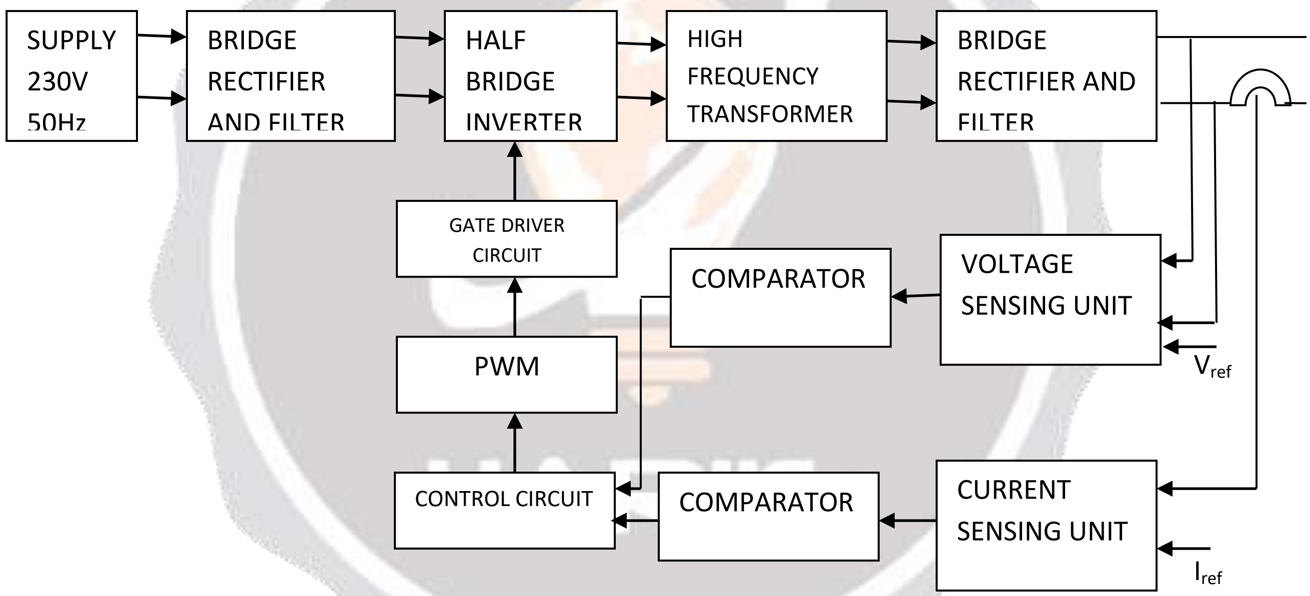

Fig. 1 Block diagram of high voltage power supply

Design Specifications

Table 1 describe power supply Parameter specifications.

Parameters Specifications

Input voltage (V_{in})	230 V(ac), 50 Hz
Output voltage (V_0)	100-1000V(dc) variable
Output current	3.0A continuous
Max. pulse width	35%
Average power	3KW
Switching frequency (f_s)	10KHz
Ripple voltage	1%

Table 1 Design specifications

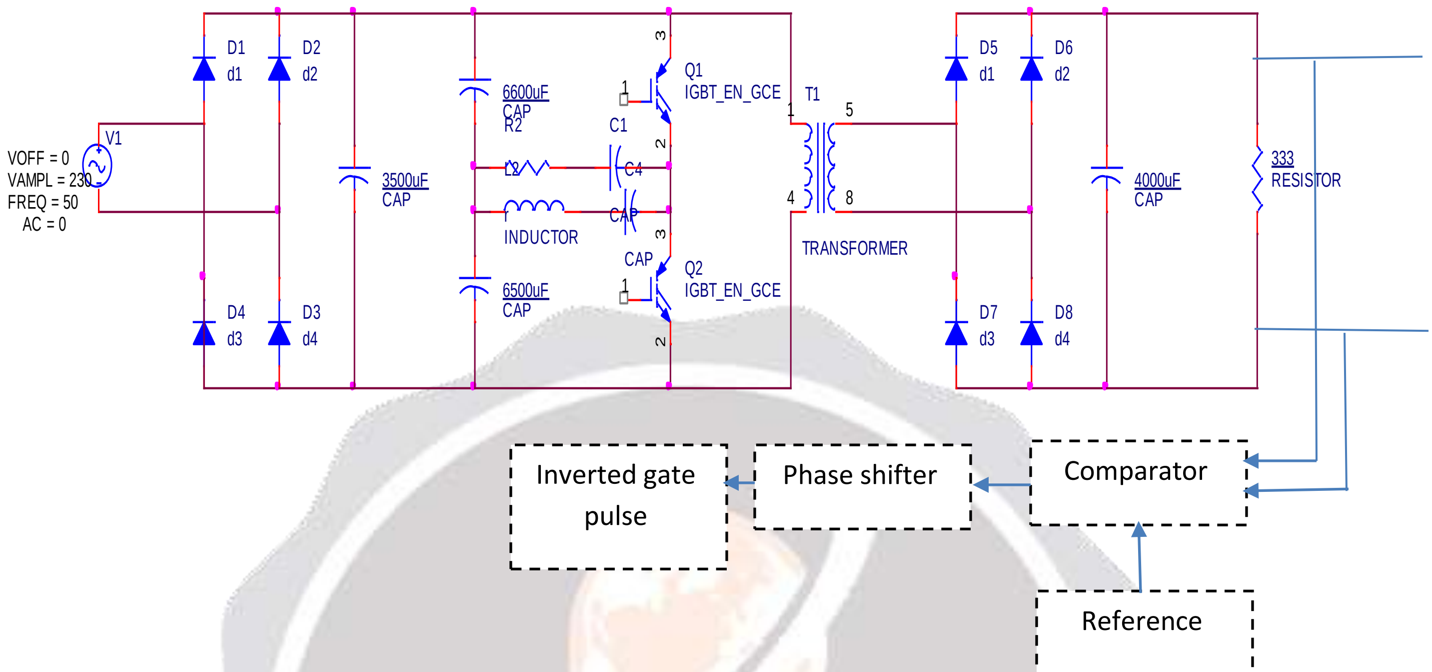

Fig. 2 power supply circuit

Design of Power Supply

For the development of regulated power supply, selection of the topology has some following factor are considered like isolation between input and output, input voltage at transformer and peak current at IGBT. To design the power supply of 3000W some parameter are specified that are shown in Table 1 and Fig. 2 shows that the designed block diagram of regulated voltage source.

Input Section Design

The input section includes source of supply, MCB, fuse bank, rectifier, current limiter resistor and a filter capacitor. The input supply is applied to the circuit via switch and fuse. Capacitor is initially short circuit so, for less current flow put here current limiter. The rectifier and the filter capacitor provide a stability of dc voltage to the next section. In an inverter section IGBT are used to get fixed output voltage. The electrolytic capacitor was used to reduce the nose or ripples. The capacitor filter 3500µF, 400V was selected from Eq. (1).

$$i = C\frac{dv}{dt} \quad (1)$$

Where, i is current out from rectifier is about 3A, C is capacitor, dv is voltage fluctuation about 1% (10V) and dt the time (1/f) for which the input capacitor supplies the energy to the converter assumed 100µs.

Inverter section design

In an inverter section to reduce the transformer size the operating frequency is selected about 10KHz. By using power IGBT switching loss of voltage is reduce in half bridge inverter. To reduce the switching loss or to prevent short circuit ZVS and ZCS are used mean the maximum duty cycle of the inverter that can never goes up to more than 45%.
As shown in fig.1 two capacitors which have equal value and that provides DC bias to balance the inverter voltage. By using Eq. (2) we can find the switching frequency of 10 KHz.

$$fs = \frac{1}{2\pi\sqrt{LC}} \quad (2)$$

Where, fs are switching frequency.
Here we have only one equation and two unknown parameter. So, by choosing the value of capacitor is 0.2µF, get 1.4mH inductor value.

Transformer design

To improve the power density high frequency transformer is requires in high voltage power supply (HVPS). At high frequency the hysteresis loss is much higher than the eddy current loss. In air gap core leakage inductance is more and for smaller core size the leakage inductance is low hence core without air gap is selected. In transformer close coupling is necessary between primary and secondary to reduce the leakage inductance. Generally ferrite core is used in switching regulator.

The size of the transformer is designed by area of product (A_p) is given by Eq. (3)

$$A_p = \frac{p02[1.41+\frac{1}{n}]}{4kfkwJBmfs} \quad (3)$$

where P_{02} is the secondary side VA; η, the efficiency of the transformer; K_f, the form factor; K_w, the window factor; J, the current density; B_m, the maximum flux density; and f_s is the switching frequency.

Output Rectifier Section Design

In the output section, we can use many types of rectifier or diode is used. In high frequency rectifier many of fast recovery diodes are used. In this diode the recovery time is in terms of nano second which is very low. ZVS, ZCS and fast recovery time at rectifier stage is used for EMI is reduce. The important characteristic of diode is rating and for fast recovery diode has rating of 1000V. In fast recovery diode Forward voltage drop is about 0.9V to 1.5V.

Simulation output

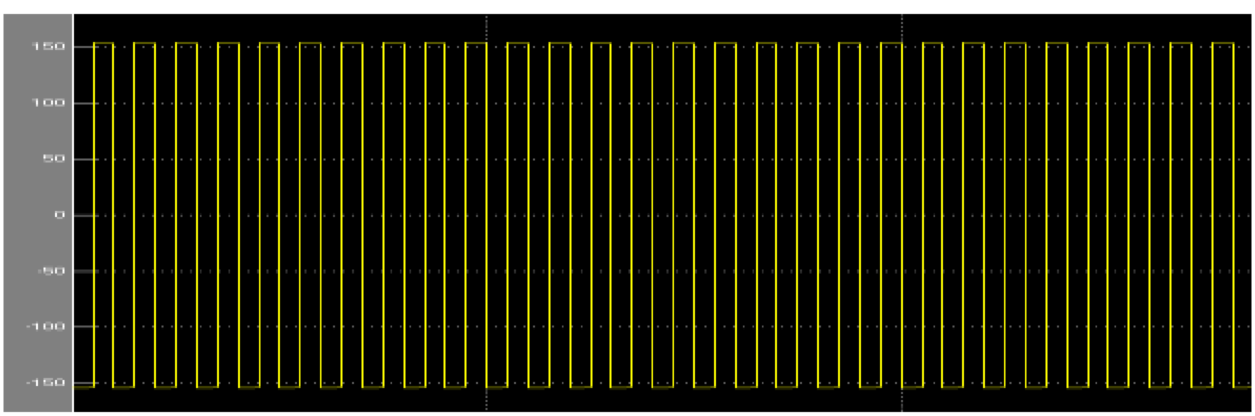

Fig. 3 output of the inverter with10KHz frequency

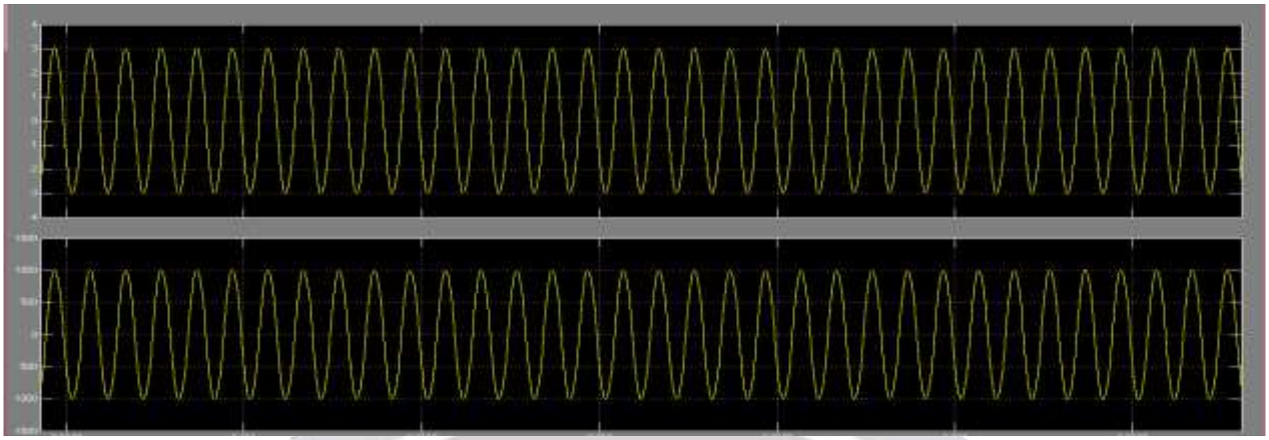

Fig. 4 Output of the high voltage and current of high frequency transformer

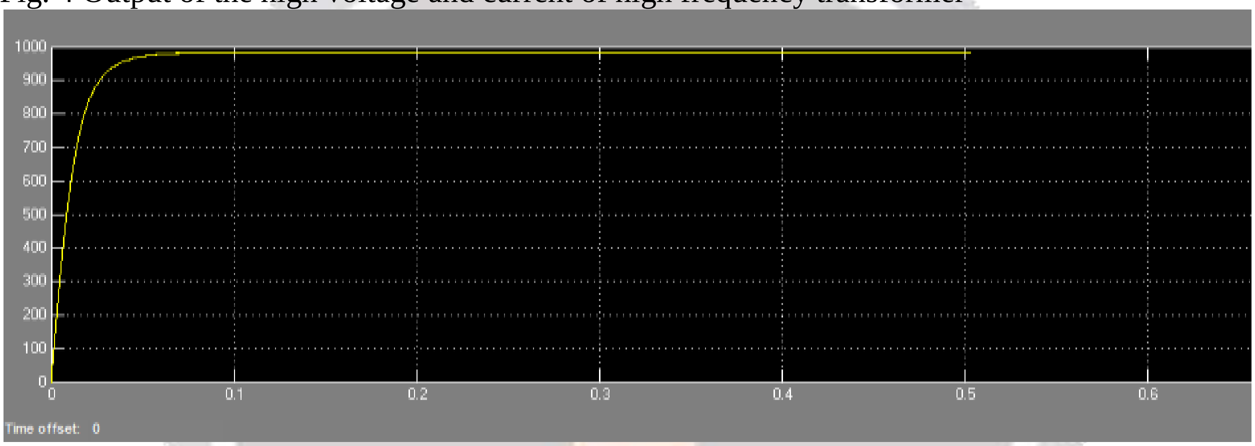

Fig. 5 Final output voltage of the power supply

Results

The design of the supply with 3 KW average power and maximum 1 KV output voltage. The simulated results of the power supply are given in this section. By using the Half Bridge inverter configuration, the power supply was simulated at output voltage of 310V. The results of simulation that indicate the proposed method performed as expected. The experimental waveform for the inverter output voltage or the voltage at the primary of the transformer for maximum duty cycle is given in Fig.3 for getting maximum output. By decreasing the duty cycle the output voltage is decreased proportionally. With different duty cycle the output voltage is different as shown in table 2. The waveform of the step up transformer is shown in Fig. 4. Fig. 5 is shown the final output of the power supply which is DC of 1000V with only 1% fluctuation mean the final output voltage is vary only 10V.

Duty cycle	Output voltage (V)
1%	75V
5%	240V
10%	400V
20%	470V
35%	1000V

Table 2. Duty cycle vs output voltage

Conclusion

This paper presents the design of a high voltage dc power supply with close loop feedback control system at 1 kV, 3000W with SMPS topology with 10 KHz switching frequency. The design present covers half bridge inverter, feedback loop voltage and current control with maximum 35% of duty cycle. The proposed method of closed loop control for high voltage dc power supply was studied under various line and pulse load conditions. The converter designed is simulated for the specifications mentioned earlier.

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