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Resonant Converter Power Supply for Arc Welding Application

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Abstract: - Power Supply for arc welding requires reasonable low voltage and high current. Commercial power supply for arc welding could be made in smaller size with the same capability. One way is to decrease the transformer's size by increasing switching frequency. This would be achieved by incorporating switched mode power supply. The design of a resonant converter switched mode power supply is presented in this paper. Circuit simulation was done using Pspice software package. The results show arc welding power supply using resonant converter is feasible.

Keywords: - Resonant converter, Arc welding, Simulation

1 Introduction

Arc welding includes a group of welding processes that utilize heat from an electric arc to fuse metals together. The most widely used arc processes are shielded metal-arc welding which is commonly used for automotive frame manufacturing, pipeline construction and cast iron repair. Selection and adjustment of current is important in the shield metal arc welding process. The amount of current flowing across an arc is proportional to the heat in the weld joint. Traditionally arc welding power supply was using either an engine-driven generator or a transformer type of power supply [1]. However with the advancement in power electronics and microprocessor control, the use of switched mode power supply [2]-[4] has been made possible.

To achieve smaller size, lighter weight and faster transient respond of power supply for arc welding, the design of switched-mode power supply with high dc-to-dc resonant converter has been proposed in this paper. In application, such as welding power supplies, the load is isolated for safety reason, and the power supplies contains magnetic components such as isolation transformer and smoothing inductors. The size of the converter of these components is reduced if the frequency of operation of the converter is raised. Higher frequency of operation also allows a rapid respond to current fluctuation in the converter and results in improve waveform quality.

For this application, zero-voltage switching multi-resonant converter is used [5]-[8]. The zero-voltage switching multi-resonant technique utilizes to the highest degree all the major practices in a converter. In zero-voltage switching multi-resonant converter, the leakage inductance of the transformer and the parasitic and junction capacitance of the transistor and rectifier form a multi element resonant network in order to achieve zero-voltage switching of both the achieve switches and the rectifier. This allows the resonant converter to operate at very high frequencies with the most favourable switching conditions for all semiconductor devices.

2 Resonant Converter

The circuit diagram of a full bridge resonant converter is shown in figure 1.

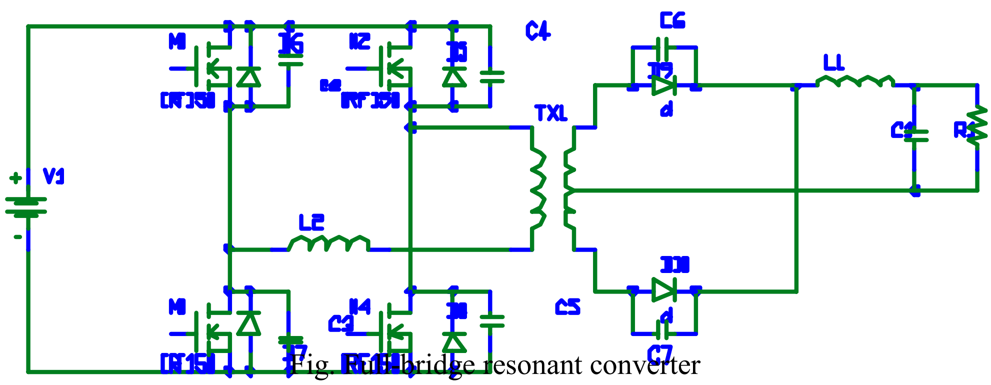

Fig. 1 Full-bridge resonant converter

There are four possible modes of operation of full bridge resonant converter. The modes of operation, which occur at heavier loads, are described in section 2.1. For the ease of explanation, the following points are assumed:

- The voltage drop across the conducting semiconductor devices is negligible
- The switching times of all semiconductor devices are zero.
- Switches Q1, Q2, Q3, and Q4 in figure 2 are identical.

2.1 Principles of Operation

Figure 2 shows the equivalent circuit of the full-bridge resonant converter in four topological stages while figure 3 shows the typical current and voltage waveforms.

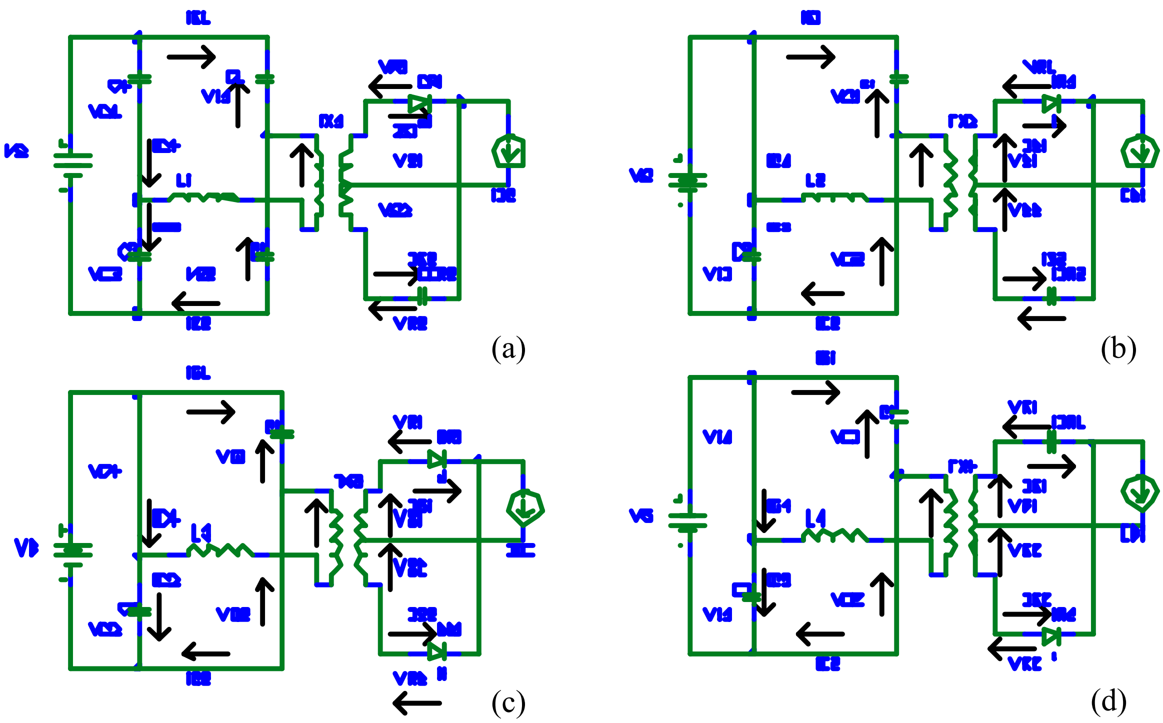

Fig. 2 Topological stages: (a) Switch-mode, (b) Rectifier-capacitor discharging mode, (c) Inductor discharging mode, (d) Rectifier-resonant mode.

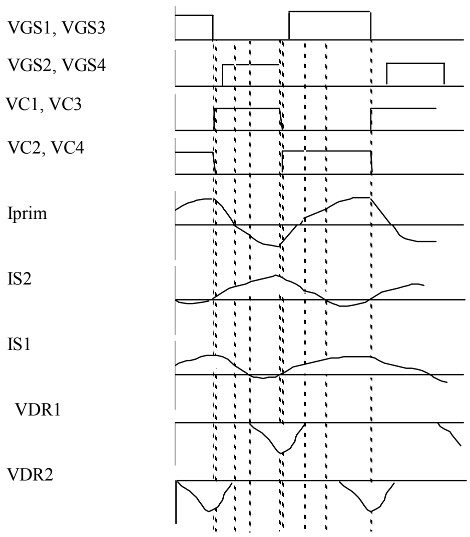

Fig. 3 Voltage and current waveforms

2.1.1 Switch-Mode

When the transistors Q1 and Q3 are on, capacitance CDR2 and inductor L resonant. At t=T0, Transistor Q1 and Q3 are turned off. Since rectifier DR2 is still reversed biased, the equivalent circuit of the converter is as shown in figure 2(a). During this stage, capacitance C1 and C3 are being charged in a resonant manner toward the supply voltage, whereas C2 and C4 are being discharged. The stage terminates at t=T1 when the voltage Vc2 becomes zero, subsequently, transistor Q2 and Q4 should be switched o to achieve a losses turn-on.

2.1.2 Rectifier-Capacitor Discharging Mode

In this stage, CDR2 continues to resonate with L. Due to a negative voltage across L, the primary current decreases and CDR2 continuos to discharge. The stage terminates t=T2 when the capacitor voltage across CDR2 becomes zeros and diodes DR2 becomes forward biased.

2.1.3. Inductor discharging Mode

During this stage, both rectifier conducts so that the primary voltage is zero and a negative voltage is applied to L. As a result, the primary current decreases with a constant rate. The stage terminates at t=T3 when the primary current becomes -Io/N and rectifier DR1 ceases to conduct.

2.1.4 Rectifier-Resonant Mode

At t=T3, CDR1 starts resonating with inductance L. This stage ends when switch Q1 and Q3 are turned off and a new conversion cycle is initiated. If switch Q2 and Q4 stay on for a longer time, the rectifier voltage may oscillate for several cycles. In this particular mode of operation, the dc voltage-conversion ratio shows undesired positive-slope characteristics. To avoid this mode of operation it is necessary to limit the on-time to approximately one half of the resonant period of the rectifier voltage. As a result, the full-bridge resonant converter operates typically with limited minimum-switched frequency.

2.2 DC Characteristics

Figure 4 shows the dc voltage-conversion ratio as a function of the conversion frequency. These characteristics are plotted with two parameters specified: Ion = 4ZnI0/(NVs), the normalized output current, and Xc = CDR/(N^2 C), the ratio of the capacitance across the rectifier reflected into the primary (CDR/$(N/2)^2$) and the resonant capacitance of the primary (C).

The minimum conversion frequency must be limited to ensure that the operating point of the converter does not go into positive-slope region as shown in figure 4.

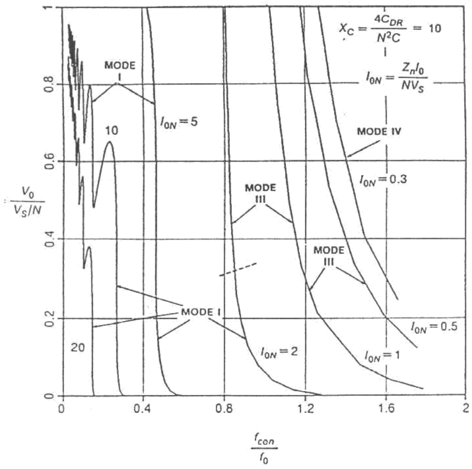

Fig. 4 DC voltage conversion ratio Characteristics for Xc=10

3 Circuit Design and Description

The proposed specification design of the switched mode resonant converter power supply for arc welding as following:

- Input voltage = 220V
- Output voltage = 50V
- Load current range ≤ 100A
- Switching frequency = 20Khz
- Duty cycle = 50%

The design consists of two major parts, main converter and controller. The main converter part consists of transformer, switches, rectifier and filtering. Controller's part uses Pulse Width Modulation (PWM) method. A sawtooth voltage and input reference voltage were needed for PWM method [9], [10]. Both of the voltages were then to be compared using a comparator. Signal would be ON if the reference voltage is within the sawtooth voltage region. On the other hand, OFF signal if it was outside the voltage region. Design of PWM method using sawtooth generator did not have certain duty cycle. The duty cycle might change as the output voltages was increased or decreased. To avoid the uncertainty of the duty cycle a hysteresis was implemented at the comparator. Therefore less variation was maintained in the duty cycle.

Sawtooth generation was done using IC 555.The technique using p-n-p transistor to give a charging of 200μA. Resistor R1 and R2 fix the base voltage of the Q2n2907A to a voltage of excess of

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2/3 Vcc. With the value given for R1 and R2 the voltages across the R3 can be adjusted to have 200µA. For this case, R1, R2 and R3 are 6K2, 39K and 6K8. As a result, capacitor is charged with constant current. The voltage across the capacitor rises linearly and could be defined by mathematical equation: dV=Idt/C. Where dt is time taken for the voltage across the capacitor by the dV volts. Putting variable capacitor can vary frequency. In this case, frequency of 20 kHz is done using C=1.5nF.

Assumption had been made that the output voltages from the power supply always 50V. The input reference voltage was supplied from the output voltage from the power supply. Input reference voltage and sawtooth voltage were then to be compared using comparator. LM 324 was used as the comparator. Signal would be ON when input reference voltage within sawtooth generator. On the other hand signal would off when it was outside the saw tooth generator voltage.

Four switches (IRF150 : Q1-Q4) were used for the circuit. Voltage shifting were used at the Q2 and Q4. This is done as they required more or less than 220V for activation. When shifting occurred, Q1 and Q3 were isolated. Dc voltage with high frequency from output switches was then shifted to the transformer. A linear transformer was used for this purpose. Modification the value of the primary inductor and secondary inductor was done, the ratio was approximately 100mH: 8mH. Output voltage was approximately 50V. Rectify was done to convert all negative voltage into positive voltage. Four diodes were used. Filtering was also done for output load. Capacitance and inductor are employed to the circuit. A complete circuit design for the converter and controller is shown in figure 5.

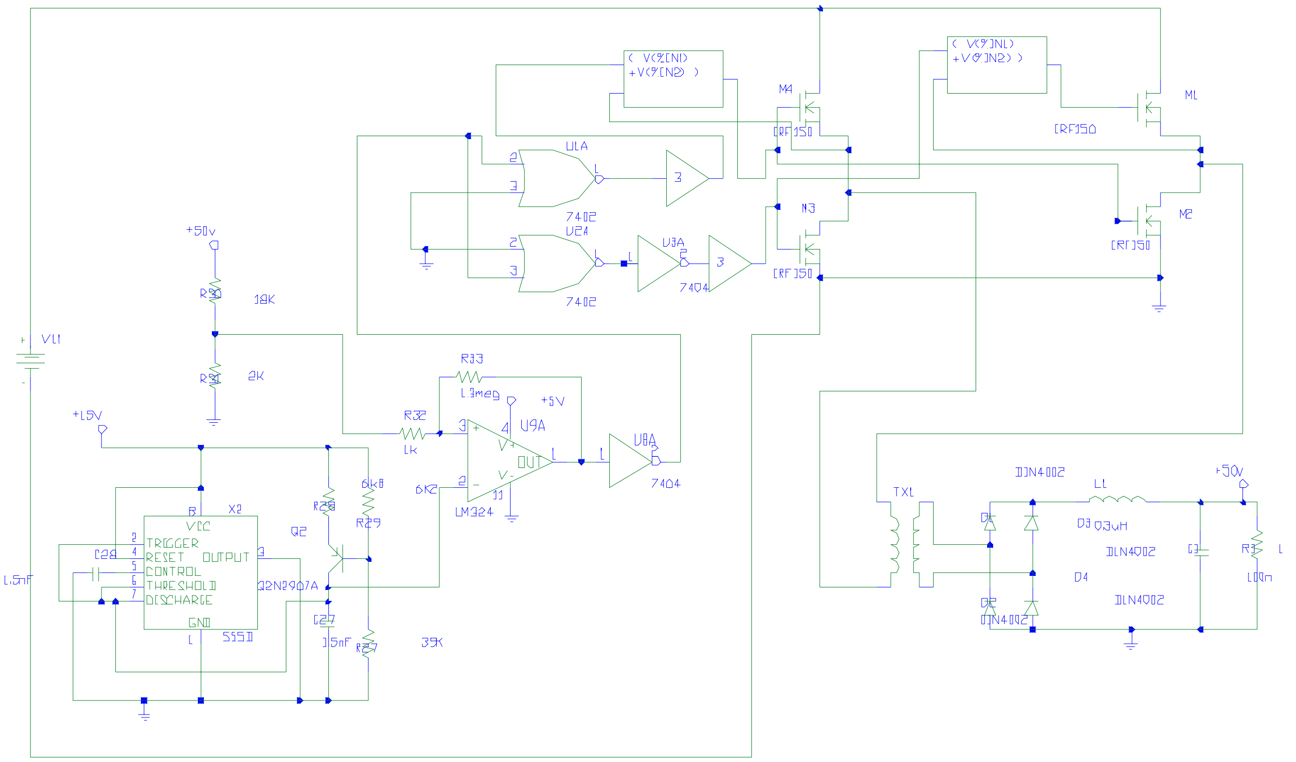

Fig. 5 Resonant converter and controller circuit

4 Results

The above design was simulated using Pspice software package. Results are shown in figure 6, 7 and 8. It was found that actual output voltage from simulation was 50V at the frequency 20 kHz. Max loading could be achieved up to 60 Amperes. The actual output current was lower than the expected theoretical value. The most likely reason was that some specific type of components needed for the design was not available in the Pspice library. In addition to some of the assumptions made to simplify the design stage. These could be improved on by incorporating them in future design.

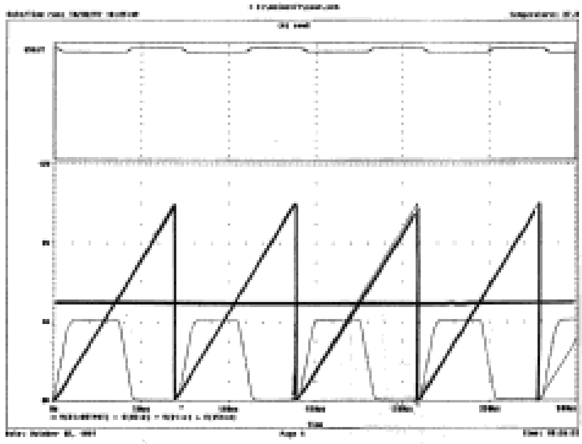

Fig. 6 Simulation waveforms for the controller

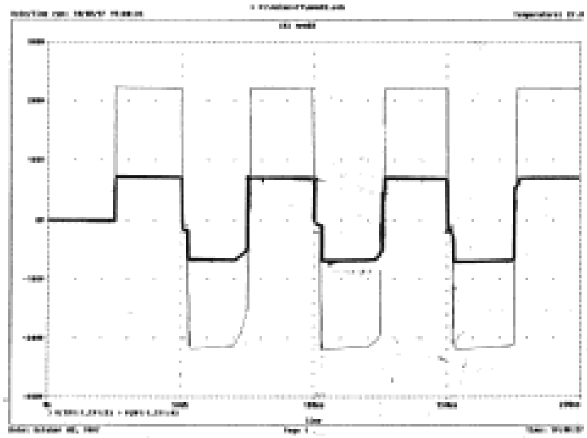

Fig. 7 Primary & secondary voltages

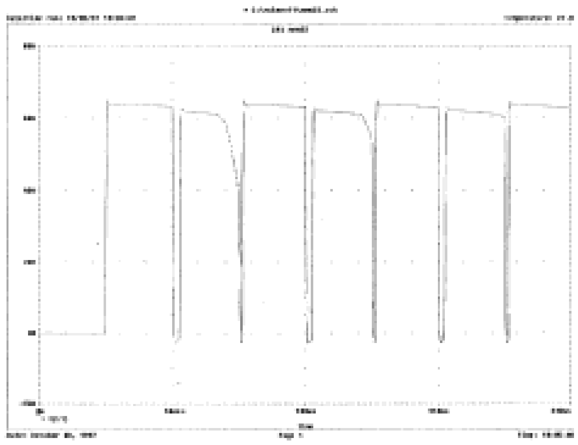

Fig. 8 Converter output current

5 Conclusion

This paper presented a method of using switched mode power supply resonant converter for arc welding. PWM was used for controlling the switches. Simulation had been done using Pspice software package. The result from the simulation was slightly different from the theoretical value because of some of the assumptions been made to simplify the design. However the paper proved that arc welding power supply using resonant converter is feasible.

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