A PROPOSED 46 kV 360 kW CROWBAR-LESS KLYSTRON POWER SUPPLY

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Abstract

A 46 kV 360 kW resonant power supply is described together with results showing its operation and performance obtained by computer simulations. The supply is suitable for use with klystron and inductive output tube (IOT) radio frequency amplifiers. The low stored energy and fast switch-off characteristics of the power supply result in less than 5 joules being deposited into a tube arc.

1 INTRODUCTION

Resonant converters have been in use for some years in high voltage power supplies. The availability of insulated gate bipolar transistors (IGBTs) with usable operating voltages in excess of 1000 V and switching currents greater than 1000 A led to this study in designing a low stored energy power supply.

A full bridge series parallel resonant converter topology was chosen as this is well understood[1] and offers some advantages over the purely parallel bridge configuration. Figure 1 shows the circuit schematic of the converter. The bridge is phase shift controlled resulting in a fixed frequency operation of the bridge and the ability to reduce the output voltage of the supply to zero if required.

2 RESULTS

The use of phase shift control allows the IGBT switches to switch without loss on one transition, the ON transition. As the phase shift is implemented switching losses are experienced in the OFF transition. These OFF transition losses limit the frequency of operation of the IGBTs in this mode. For these reasons the bridge frequency was chosen to be 20 kHz.

3 OUTPUT VOLTAGE AND RIPPLE

Figure 2 shows the variation of output voltage ripple with output voltage. As the bridge control is fixed frequency the output ripple is fixed at twice the bridge frequency namely, 40 kHz. As can be seen the ripple remains constant with variation of output voltage.

The amplitude of the ripple is a function of the filter and can be increased or decreased at the expense of power supply stored energy and response time. Figure 3 shows the current in the resonant inductor L and Figure 4 the output voltage ripple at maximum voltage.

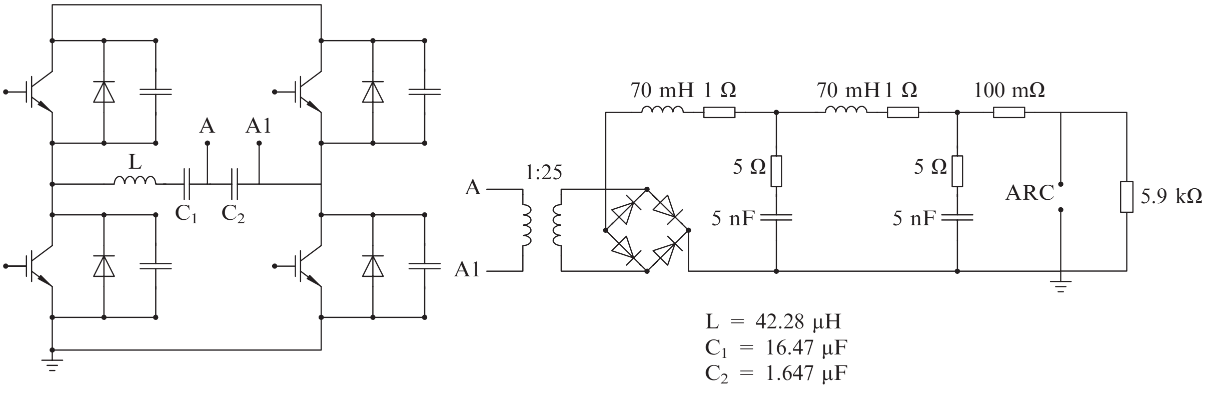

Figure 1: Power Supply Schematic

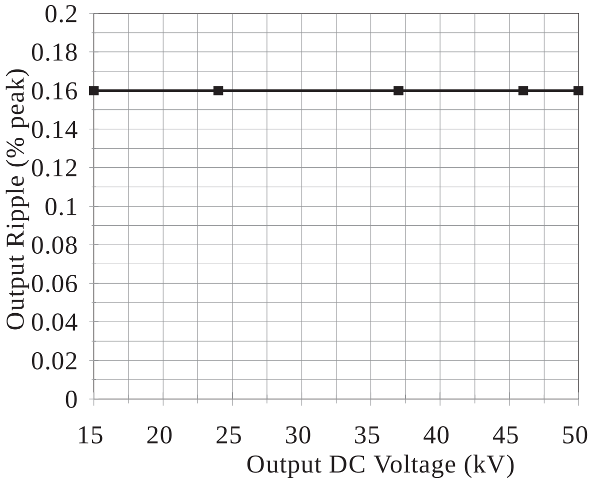

Figure 2: Variation of Output Ripple Voltage

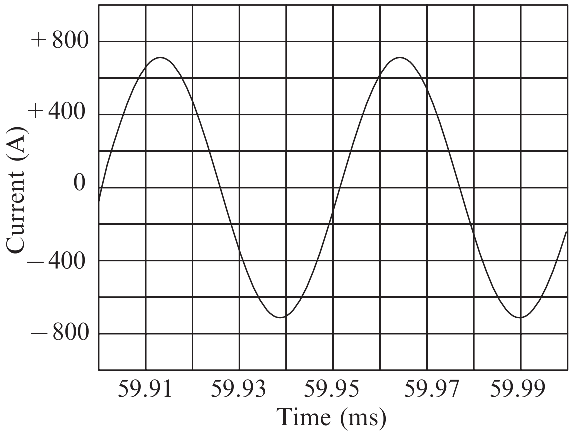

Figure 3: Resonant Inductor Circuit

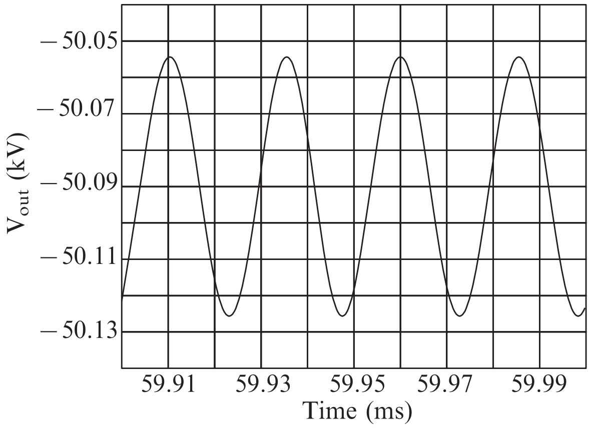

Figure 4: Output Voltage

4 STORED ENERGY

The energy in the power supply is stored in the resonant components, the transformer leakage inductance, capacitance and the smoothing filter. With the power supply operating at the maximum voltage of 50 kV the stored energy is calculated to be 33 joules. A klystron arc in vacuum has been assumed sustains a constant voltage drop of 50V, and has been modelled as an ideal zener diode. Figure 5 shows the predicted energy deposited due to a klystron arc. It shows that most of the energy is deposited in the resistances of the inductors and interconnecting cable, only 2.5 joules is deposited by the arc. It has been assumed that the cable is short and not of a co-axial type, which in itself causes different problems.

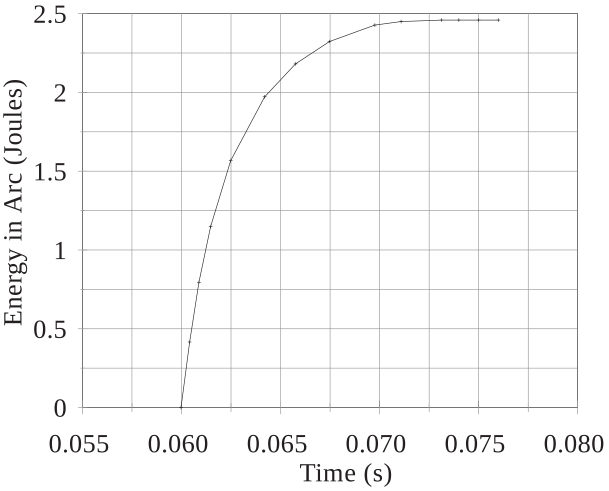

Figure 5: Energy Deposited in Arc

5 EFFICIENCY

Figure 6 shows the projected efficiency of the converter with varying output voltage.

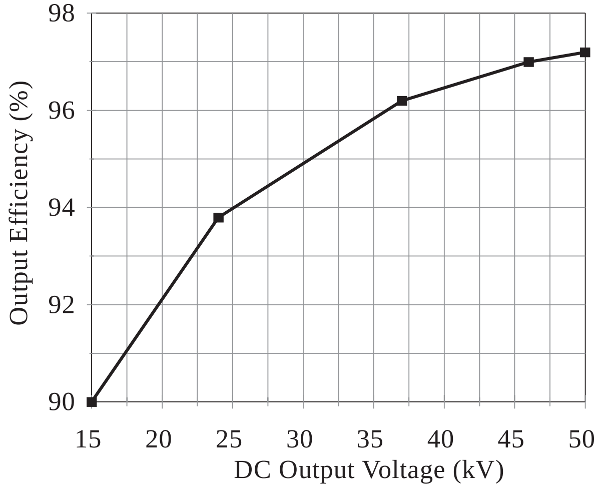

Figure 6: Power Supply Efficiency

To reduce harmonic generation and provide active power factor correction close to unity it is proposed that a Sinusoidal Rectification System[2] is used to provide the 1000 V required by the converter. The efficiency of these units is in excess of 98% and this will result in an overall unit efficiency varying from 95% to 88% over an operating output voltage of 50 to 15 kV.

6 UNIT SIZE

The use of Litz wire rather than foils, together with nanocrystalline transformer cores will result in low loss and a compact transformer. The transformer, rectifiers and smoothing filter will be in a oil tank so reducing the unit size. It is proposed that the power supply will be two 19-inch free standing rack units, one for the converter DC feed and power factor control unit and one rack for the high voltage converter.

7 CONCLUSION

A compact low component count power supply has been presented. Computer simulations show that overall efficiencies of 95% are attainable with low stored energy. Additionally the proposed unit will achieve close to unity power factor and meet current and future regulations regarding harmonic generation.

REFERENCES

[1] J S Przybyla, “High Power (>100kW) Converters in High Voltage DC Power Supplies and Capacitor Chargers”, IEE Pulse Power Symposium, 1998.

[2] R Jones, Product Development CEGELEC Industrial Controls, UK, “Sinusoidal Rectification for Harmonic Elimination- The Technology Explained”, IEE Colloquium June 1993: The Three Phase Pollution & Recent Developments in Remedies.