OPTIMUM DESIGN OF SINGLE SWITCH RESONANT INDUCTION HEATER

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Abstract

The availability of low cost power switching devices has opened up the application of induction heating for domestic cooking. This paper describes a single switch resonant inverter for this application. A performance index for the switch (output power / switch VA rating) is proposed. The operating point can be selected to realize the best switch utilization.

Introduction

In the application of high frequency induction heating, the cost of power switching device is the major element of the overall cost. The cost of the power switching device is related to its VA rating (blocking voltage * load current). It is therefore essential that the switches are put to the best use in any design. This paper describes a single switch resonant circuit for the application of induction heating. Selection of operating point to realize the best switch utilization is presented.

Single switch resonant inverter (SSRI)

Figure 1 shows the power circuit of the SSRI. R_p, L_p, L_m, R_s form the equivalent circuit of the induction coil and the vessel to be heated. C is the resonant capacitor. S is the power switching device. The source is V_g .

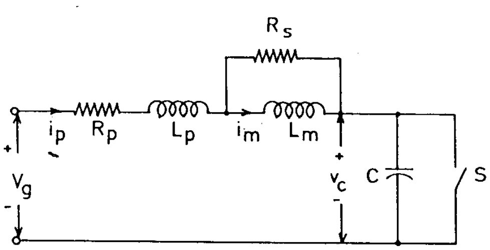

Fig.1. Single switch voltage fed resonant inverter

Circuit operation

The steady state waveforms of the circuit operating in the half wave mode are shown in Fig.2. It may be seen that the switch turns ON and OFF at zero voltage and so the switching losses are low. The output power is varied by controlling T_{on}.

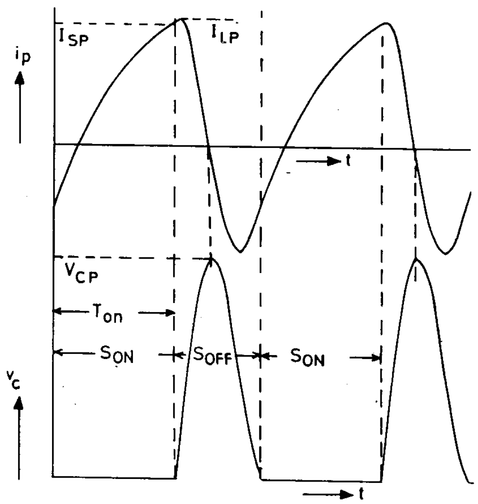

Fig.2. Steady state waveforms of single switch resonant inverter

Defining equations

The circuit defining equations are

$$L_p di_p/dt = V_g - v_c u - (R_p + R_s)i_p + R_s i_m \quad (1)$$

$$L_m di_m/dt = (i_p - i_m)R_s \quad (2)$$

$$C dv_c/dt = i_p u \quad (3)$$

Where u = 1 when S is ON, and 0 when S is OFF.

The coupling factor k $[L_m/(L_p + L_m)]$ and the coil time constant τ $[(L_p + L_m)/R_s]$ are defined for convenience.

Simulated results

The circuit equations may be simulated in per unit quantities with V_g , τ and (L_p+L_m) as the base quantities. The simulation is carried out to evaluate the output power, maximum switch voltage and maximum switch current, for different values of coupling factor and resonant capacitor. The switch utilization factor (output power / switch VA rating) UFS is defined.

For any given coupling factor k and capacitance C, there is a lower limit on the ON time ($T_{on(min)}$) below which the circuit can not operate. On account of this the range of control of output power is limited. This condition is shown in Fig.3. The circuit fails to sustain operation, because the capacitor voltage does not come down to zero following resonance.

For any given coupling factor k and capacitance C, switch utilization (UFS) either attains a peak value (for low C), or monotonically decreases (for high C), as ON time (T_{on}) increases from its minimum value. Control range (CRF) increases with the ON time (T_{on}). The operating point where switch utilization is the best is selected if the control range for that operating point satisfies the need. If not, the operating point satisfying the control range is selected. The switch utilization factor corresponding to the operating point is named as UFS_{max} (C,k). This operating point (Rated T_{on}) is the local best for a given capacitance C and a coupling factor k.

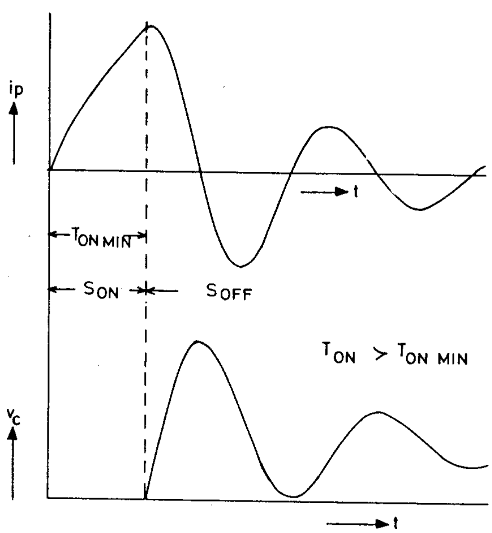

Fig.3. Failure of normal operation for less ON time.

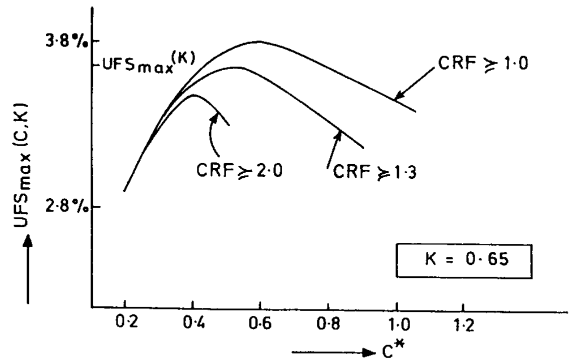

Fig.4. Switch utilization with resonating capacitance

The capacitance is totally under our control, making it possible to select the capacitance to get the best switch utilization. Figure 4 shows, for a given coupling factor k, the switch utilization (UFS_{max} (C ,k)) as a function of capacitance C, for different control range (CRF). It is seen that for any control range there is an optimum capacitance (C_{opt}) where the switch is best utilized (UFS_{max} (k)).

Conclusion

A single switch resonant inverter is presented. The defining equations are given. The simulated results indicate that the switch is best utilized for a particular value of capacitance in the circuit. When the design is made with this optimum value of C, the switch in the circuit is utilized best.

References

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