

Performance Improvements in Manual Welding Power Supply Based on Resonant Mode

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ABSTRACT: This paper describes improvements developed in an arc welding power supply based on resonant inverters. A new stand-by operation sequence based on sliding phase is proposed in order to reduce the discharge capacitor size. This stand-by solution also relieves the voltage specification of the resonant inductor. The interleaving operation of paralleled stages and the output connection wires are used to minimize the output capacitor current ripple and so extend the power supply's lifetime. Moreover, synchronous rectification is proposed in order to increase the efficiency and reduce the operation temperature of the output power stage. Finally, sequences are described for establishing and extinguishing arcs. TIG welding is selected for testing operations.

KEYWORDS: FACTS, simulation, Modelling, STATCOM, Transient Stability, MATLAB.

I. INTRODUCTION

As opposed to linear power supplies, in switch-mode power supplies, the transformation of dc voltage from one level to another is accomplished by using dco-dc switch-mode power converters, in which power semiconductor devices are operated as a switch. In linear regulators, the regulation device - for instance, a transistor - is operated in active region (see Fig. 1.1). This mode of operation requires high voltage drop across its terminals, thereby resulting in high power dissipation. In the switch-mode operation, the transistor is operated saturation (switch on) and cut-off (switch off) regions. High voltage and current therefore do not co-exist in the device, except during switching transitions, the latter being a small fraction of a switching period. Therefore, the switch-mode operation results in lower power dissipation. Further, due to high-frequency operation, the size of isolation transformer and passive components in the filter are drastically reduced. Increased speeds, higher voltage and current rating and a relatively low cost of these devices are the other factors that have contributed to the emergence of switching power supplies. However, these benefits of switching power supplies come at the cost of higher complexity, more switching losses, higher switching stresses and electromagnetic interference (EMI).

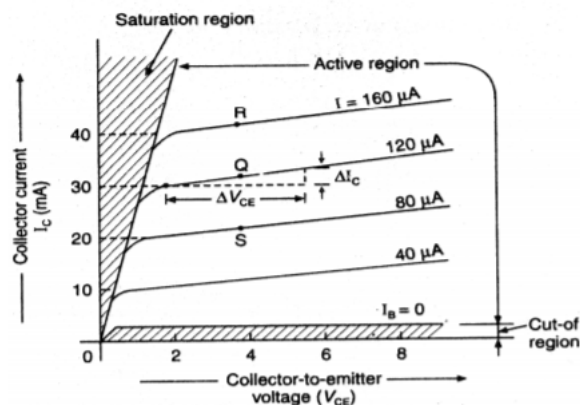


Fig. 1: Output characteristics of a common-emitter transistor

These problems are exacerbated with increasing switching frequency. Therefore, although the power devices are capable of being operated at higher frequency, these problems pose a practical upper limit on the switching frequency. Further miniaturization of power converter circuits is possible if they operate at still higher switching frequency, and to do this, a way to reduce or eliminate the switching losses and stresses must be conceived. Passive turn-on and turn-off snubbers are used to control the rate of rise of voltage and current, clamp overshoots during switching transitions, to reduce switching losses and to reduce EMI. However, snubbers only transfer the losses from switch to the snubber resistor, and therefore do not result in overall reduction in the losses [1]. Improvement in the efficiency is possible with loss-less or energy recovery snubbers, in which the energy stored in the snubber capacitor or inductor is transferred to the source or load, instead of being dissipated. [2].

II. RESONANT CONVERTERS

Figure 2(a) shows the block diagram of a dc-dc resonant converter (RC). The input can either be a dc voltage source or a dc current source. An inverter (full bridge, half-bridge or push-pull) excites the resonant network (RN) with high frequency square-wave waveform. A transformer at the output of RN is used to stepup or down the voltage according to the requirement and provides galvanic isolation. Rectifier and filter is used to get the dc output. The nature of the filter, inductive or capacitive, decides the nature of load to be current sink or voltage sink, respectively. Simplified block diagram of a RC is shown in Fig. 2(b), in which the dc source and square-wave inverter are shown as the voltage or current source to the RN whereas transformer, rectifier, filter and load resistance are shown as voltage or current load. Therefore, based on the type of source, type of load and the RN, it is possible to group RCs as follows [3]:

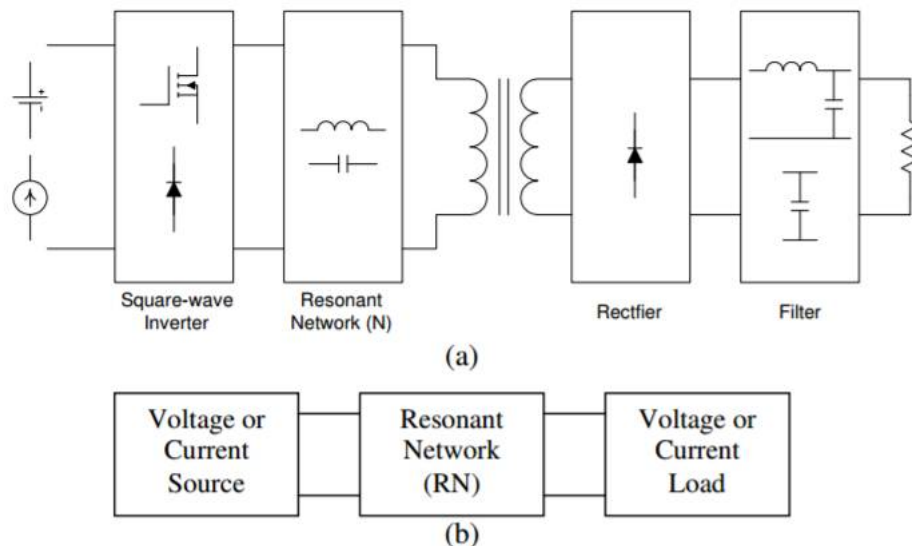


Fig. 2: (a) Block diagram of a dc-dc RC. (b) Simplified block diagram

- Voltage source-RN-voltage sink, or VNV topologies,
- Voltage source-RN-current sink, or VNI topologies
- Current source-RN-voltage sink, or INV topologies
- Current source-RN-current sink, or INI topologies.

The RN has two or more reactive components. Not all network combinations of reactive components are useful for RCs. The RCs are defined [5] as the ones in which, • the power transfer from input to output is primarily via the fundamental component of switching frequency. The harmonics of source and load contribute little to the power transfer. What this implies is that the RN acts either as a low pass or a band pass filter, isolating the input and output at harmonics of

switching frequency. • The waveforms of the voltage or current response of RN to the excitation of source and load is piecewise sinusoidal. This definition decides which topologies are resonant. It is not implied that the topologies that do not meet this criteria are not usable. They are only not classified as RCs. Further, for practical usability of RCs, some restrictions are placed [6] on the input and output impedances of a RN for different types of sources and loads. They are as follows: • for voltage source or loads, impedance seen by the source or load must be high at the harmonics of switching frequency. • For current sources or loads, impedance seen by the source or load must be low at the harmonics of switching frequency. • Only those networks, for which the transfer function is either low pass or band pass type, are considered as resonant.

III. SIMULINK MODEL

Load current is sensed at the transformer output by a current transformer or a Hall Effect sensor. Note that, although more convenient for the control, sensing the primary current is not possible, since this would affect load current accuracy. The current signal is then rectified, filtered and compared to current reference I^* . Error signal ϵ_I is fed to a PI amplifier, whose output controls the inverter frequency by a VCO (voltage controlled oscillator). Simulation of the circuit is done in MATLAB with a small resistance as load (Fig 3)

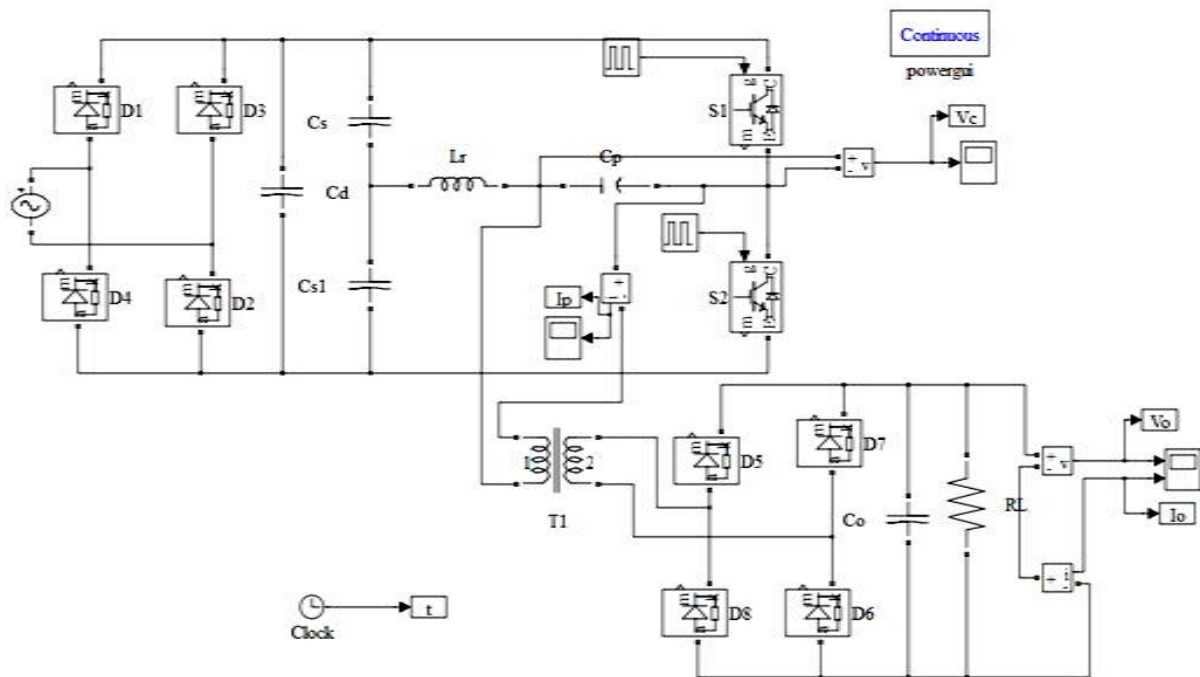


Fig.3: Simulation in open loop

The voltage across the parallel capacitor C_P (across primary winding) is shown in Fig. 4. Fig.5 shows the rectified dc output voltage and current of the circuit which can be used as the source for welding. The resonant frequency of circuit was decided to be 80kHz. The corresponding values of resonant components are $C_S = 235\text{nF}$, $C_P = 0.47\mu\text{F}$, $L_R = 11\mu\text{H}$, $N=3$, $C_O = 10\mu\text{F}$.

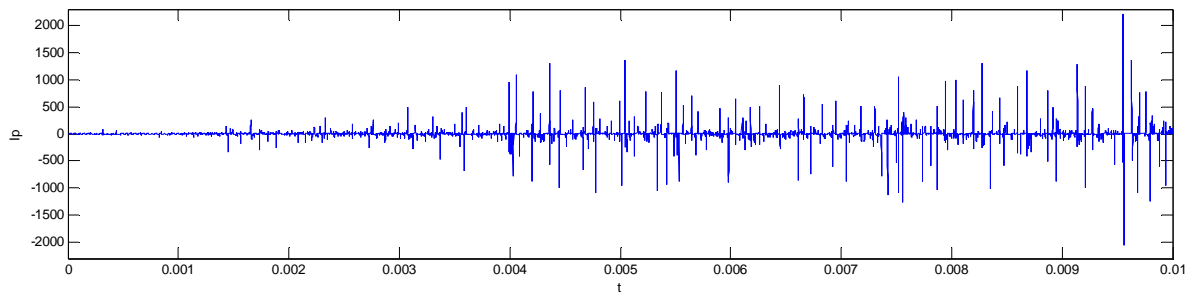
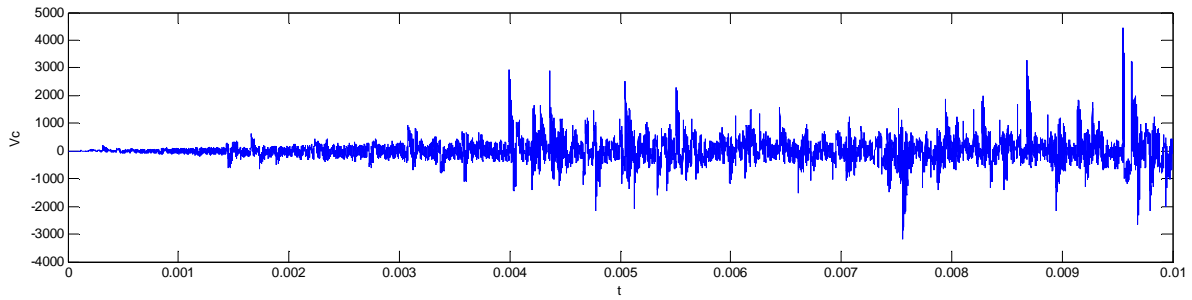


Fig. 4 The voltage across Capacitor C_p and Transformer Primary current I_p (Open Loop)

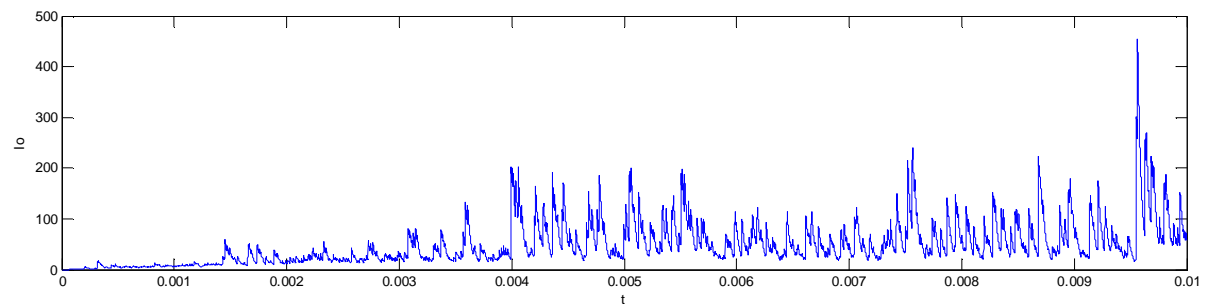
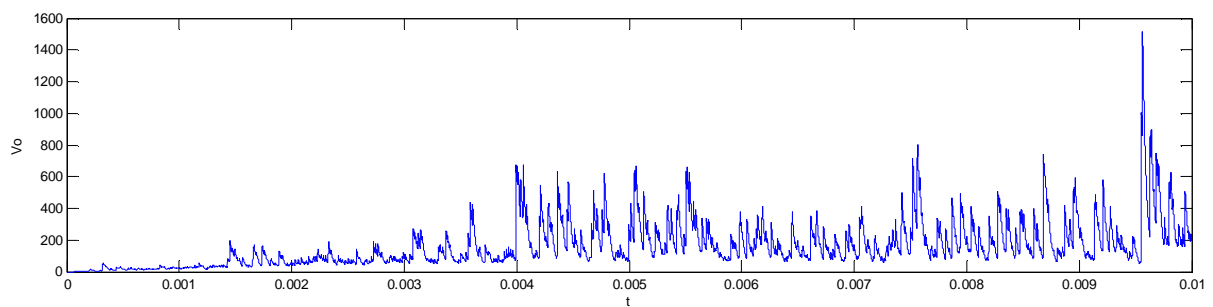


Fig.5.8 Output DC Voltage and Current (Open Loop)

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IV. CONCLUSION

The conventional transformer saturates when the applied winding volt-seconds are too large. Addition of an air gap has no effect on saturation. Saturation can be prevented by increasing the core cross-sectional area, or by increasing the number of primary turns.

8. Magnetic materials exhibit core loss, due to hysteresis of the B-H loop and to induced eddy currents flowing in the core material. In available core materials, there is a tradeoff between high saturation flux density B_{sat} and high core loss P_{fe} . Laminated iron alloy cores exhibit the highest B_{sat} but also the highest P_{fe} , while ferrite cores exhibit the lowest P_{fe} but also the lowest B_{sat} . Between these two extremes are powdered iron alloy and amorphous alloy materials.

9. The skin and proximity effects lead to eddy currents in winding conductors, which increase the copper loss P_{cu} in high-current high-frequency magnetic devices. When a conductor has thickness approaching or larger than the penetration depth δ , magnetic fields in the vicinity of the conductor induce eddy currents in the conductor. According to Lenz's law, these eddy currents flow in paths that tend to oppose the applied magnetic fields.

10. The magnetic field strengths in the vicinity of the winding conductors can be determined by use of MMF diagrams. These diagrams are constructed by application of Ampere's law, following the closed paths of the magnetic field lines which pass near the winding conductors. Multiple-layer non-interleaved windings can exhibit high maximum MMFs, with resulting high eddy currents and high copper loss.

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