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Improved Power Quality Single Mode Power Supply using Buck-Boost Converter

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ABSTRACT: This paper deals with the design, analysis, simulation, and development of a power-factor-correction (PFC) multiple-output switched-mode power supply (SMPS) using a bridgeless buck-boost converter at the front end. Single-phase ac supply is fed to a pair of back-to-back-connected buck-boost converters to eliminate the diode bridge rectifier, which results in reduction of conduction losses and power quality improvement at the front end. The operation of the bridgeless buck-boost converter in discontinuous conduction mode ensures inherent PFC operation and reduces complexity in control. The performance of the proposed multiple-output SMPS is evaluated under varying input voltages and loads by simulating this circuit in MATLAB/Simulink environment, and the results obtained through simulation are validated experimentally on a developed prototype.

KEYWORDS: buck-boost converter, DC-DC converter, SMPS

I. INTRODUCTION

Due to advancement in power electronics techniques, the various types of renewable energy sources are solar energy and wind energy have become very popular and difficult. Photovoltaic (PV) sources are used in many applications. Grid-connected photovoltaic (PV) system is reducing investment outlay because it does not need battery to store energy. Additionally, the use of power electronic devices is increasing and nonlinear loads to cause serious problems in electric power systems. Hence, the technology that combines PV grid connected generation and active filtering is proposed. Both the PV grid-connected generation and active filtering need to keep DC bus stable and the key of unified control is generating the uniform current reference accurately. In buck-boost converter, the output voltage magnitude is either greater than or less than the input voltage magnitude. The buck–boost converter is called DC-to-DC converter. There are two different topologies in buck–boost converter. One is inverting topology and another one is non-inverting topology. Both of them can produce a range of output voltages. The output voltage is opposite polarity than the input. This is called a switched-mode power supply (SMPS) with same circuit topologies to the boost converter and the buck converter. Based on the duty cycle of the switching transistor, the output voltage is adjustable. The main problem of this converter is that the switch does not have a terminal at ground and this complicates the driving circuitry. If the power supply is isolated from the load circuit because the supply and diode polarity can be reversed. The switch can be on either the ground side or the supply side. The next topology is a step-down converter (buck) followed by a step up converter (boost). The output voltage is of the same polarity of the input, and can be lower or higher than the input. A non-inverting buck-boost converter may use a single inductor which is used for both the buck and the boost inductors.

During the time of transition, Soft-switching forces either the voltage or the current to be zero; therefore there is no overlap between voltages, current andno switching loss. There are two types of soft-switching one is zero-voltage switching (ZVS) and another one is zero-current switching (ZCS).The transistor turn-on transition occurs at zero voltage is called as Zero-voltage switching. Diodes may also operate with. Zero-voltage switching removes the switching loss induced by diode stored charge and devices output capacitances. The transistor turn-off transition occurs at zero current is known as the Zero-current switching. Zero-current switching eliminates the switching loss caused by IGBT current tailing and by stray inductances. The developed converter is applied to boost the output of a PV panel. In order to develop voltage less than or more than the input voltage, the buck-boost version is selected.

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Switched mode power supplies (SMPS) that make use of resonant circuits for their operation, have emerged as an alternative to the more conventional types employing pulse width modulation (PWM). Among the important advantages claimed for this class of SMPS over the PWM type are the following.

1. Circuit operation is possible at much higher frequencies, giving scope for reducing the size of reactive components.
2. Because of smooth voltage and current waveforms, noise and interference are reduced.
3. Stress on the switching devices is also reduced because of smooth voltage and current waveforms; zero voltage and zero current switching are possible.
4. Parasitic circuit elements, such as transformer leakage inductance, can be taken into account as part of the circuit itself and so need not affect the circuit performance adversely.

The distinguishing feature of soft switched converters is that they switch ON and OFF at zero current or zero voltage. In zero current switching, the switch turns ON from a finite blocking voltage to zero ON state current and turns OFF at zero ON state current to a finite blocking voltage. The zero voltage switching is the dual of the zero current switching process. In either case the switching loss is substantially reduced. The zero current or zero voltage switching is achieved by switching close to the resonant frequency of the load (resonant load converter), or by addition of resonant elements to the switch (resonant switch converters) or by forcing a resonant transition during the switching process (resonant transition). SMPS employing resonant converters are not without drawbacks. For example, the ratio of the total installed VA of the various components to the output power - i.e. utilisation of the components - is generally poorer than with PWM type of SMPS. However, because of their many attractive operational features, resonant mode SMPS have taken up an appreciable share of the SMPS market [1-4].

III. PRINCIPAL OPERATION

Consider the circuit shown in Fig. 1. This diagram pertains to the transfer of power from a sinusoidal source of voltage Vg at frequency f (f = ω/2π) to the load resistor R through a resonant circuit consisting of L and C. The output voltage Vo and the source current Ig of this circuit can be obtained from the following expressions.

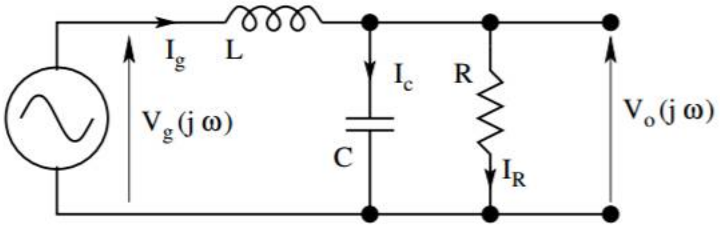

Figure 1: Resonant Power Processor

$$V_o = V_g \frac{1}{1 - \left(\frac{\omega}{\omega_o}\right)^2 + j\frac{\omega L}{R}}$$

$$I_g = V_g \frac{1 + j\omega CR}{R\left(1 - \left(\frac{\omega}{\omega_o}\right)^2 + j\frac{\omega L}{R}\right)}$$

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Where ωo = 1/ √ LC is the resonant frequency of L and C. The magnitude response of the circuit at various frequencies can be plotted using Eq. [1]. Some typical characteristics are shown in Fig. 2. The curves have been drawn for different amplitudes of the source voltage Vg and different values of load resistance R. Superimposed on the frequency response curves is a dotted horizontal line called the "constant Vo line". From Fig. 2, it becomes clear that it is possible to maintain constant amplitude of the output voltage Vo in the face of variation in the source voltage Vg and the load resistance R - in other words regulate the output voltage Vo - provided the frequency of the source is changed correspondingly.

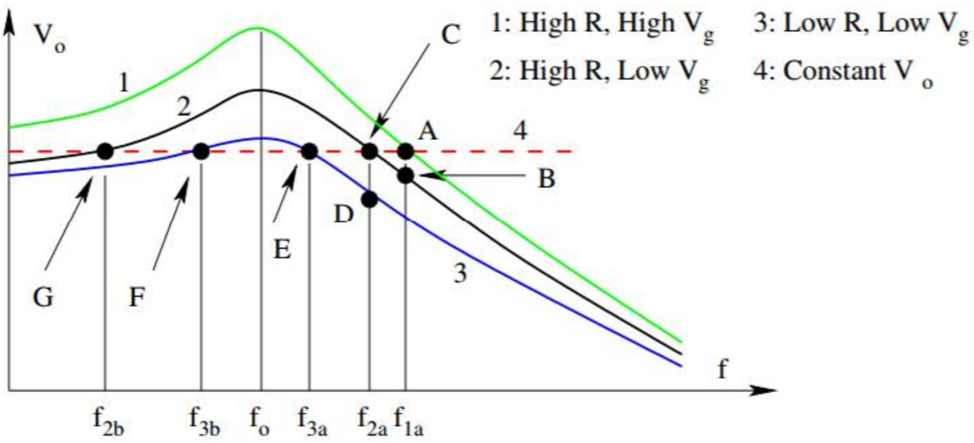

Figure 2: Gain Characteristics of the Resonant Circuit

III. SMPS USING RESONANT CIRCUIT

The relevance of Fig. 1 to switched mode power conversion can be readily appreciated by considering the block diagram of a general SMPS shown in Fig. 3. In conventional SMPS, the high frequency switching converter isusually of the PWM type. Well known configurations are forward, flyback, and push-pull converters.

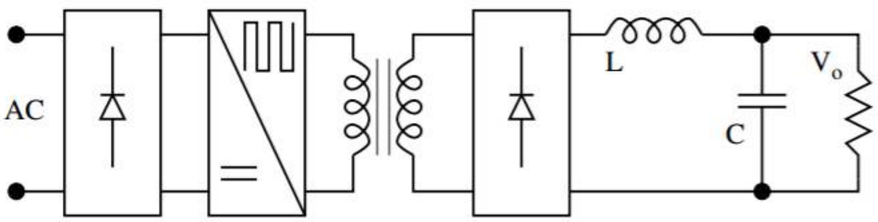

Figure 3: A Hard Switching SMPS

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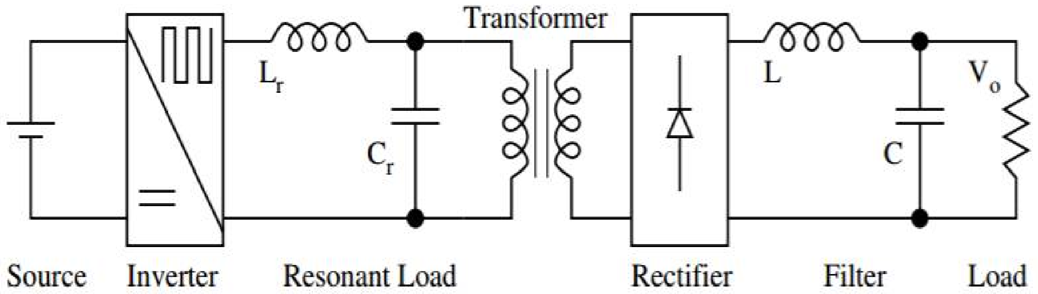

Figure 4: An SMPS Based on Resonant Circuit

Output voltage regulation is achieved by control of pulse-width, while the frequency is usually fixed. However in the light of the previous discussion, it can be realised that in place of the PWM converter, the configuration shown in Fig. 4 can be used. Voltage regulation can be achieved by frequency control of the sine wave.

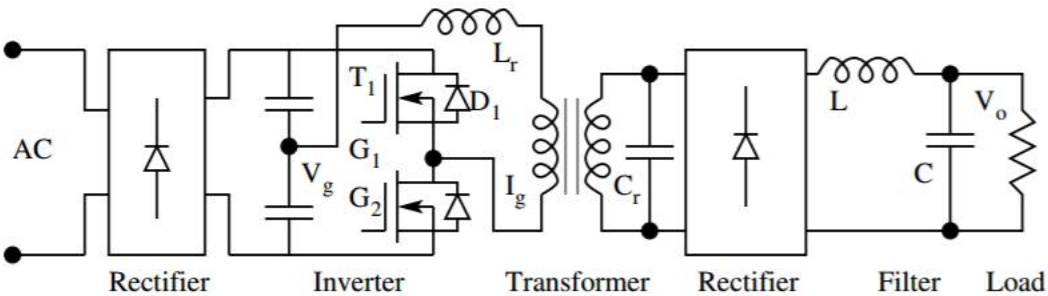

Figure 5: A Resonant Inverter Based SMPS

From the point of view of the inverter too, operation of the resonant circuit above and below the resonant frequency gives rise to important differences. As deduced earlier, operation of the circuit above resonance results in a lagging phase angle of current with respect to inverter voltage, whereas operation below resonance is more likely to result in a leading phase angle. Of course these deductions were based on the source voltage being purely sinusoidal, whereas the voltage produced by the inverter consists of harmonics, besides the fundamental. However, conclusions regarding the relative positions of the zero crossings of the inverter voltage and current are still valid. Therefore the waveforms of voltage across and current through the inverter switches can be drawn as shown in Fig. 5.

IV. SIMULATION MODEL

Input Stage: It includes uncontrolled rectifier and dc filter capacitorC_d. This Capacitor is normally designed for considerable dc voltage ripple (25-30% of rated dc voltage at full load) in order to enlarge the conduction interval of the rectifier diodes. This increases the power factor, but calls for a lower transformer turn-ratio N_1/N_2 which, in turn, results in higher current stresses in the primary winding and switches. Of course, a power factor controller can also be used in place of the uncontrolled rectifier. This improves the input behavior, but can involve unacceptable cost penalty.

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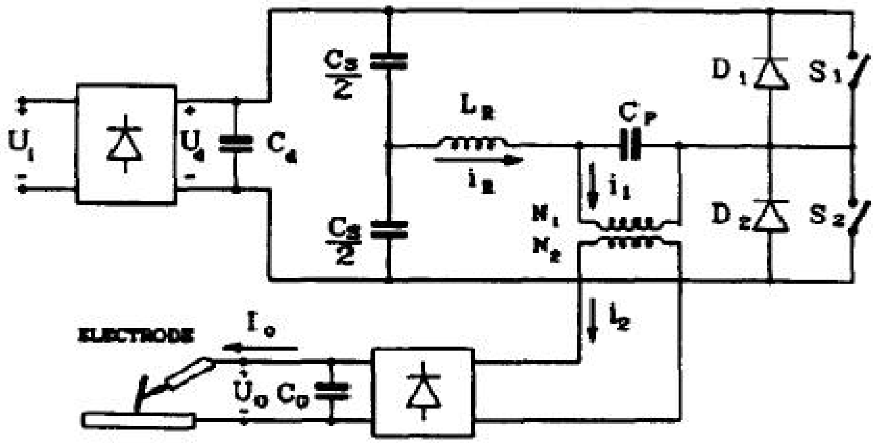

Fig. 6: Resonant Mode Converter Scheme

Inverter stage: In normal operation, the half-bridge inverter provides a square-wave voltage at a frequency above resonance, so that the resonant circuit becomes inductive, with the resonant current lagging the inverter voltage. This ensures a soft current transfer from the diodes to the MOSFETs, causing low reverse recovery currents and losses. MOSFET body diodes can therefore be used as inverter diodes D_1 and D_2, even for high operating frequencies. While turn-on loss of the MOSFETs is very small (commutation performed at zero voltage), turn-off loss is non-negligible, in principle, due to the inductive commutation (dc voltage U_d, stresses the MOSFET during the whole commutation). However, also these losses can be reduced by suitable Snubbed across the switches.

V. CONCLUSION AND FUTURE WORK

A BL boost converter based AWPS has been designed and implemented to demonstrate its improved performance with regard to PQ at input AC mains. Considering wide range of load and supply voltage variations as it is seen realistically in a welding power supply, the complete analysis has been carried out and it is seen that the power supply performs exceedingly well in the entire operational range. The supply current THD is found to be well within the acceptable limits, with a PF close to unity which meets the stringent requirements of IEC 61000-3-2 standard. Moreover, the DC-link voltage is regulated to a constant value throughout the operating range.

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