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새로운 단일전력단 및 단일스위치 방식의 자기결합형 역률개선 컨버터 그룹

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New Group of Magnetic Coupled Power Factor Correction Converter with Single-Stage and Single-Switch

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Abstract - A new group of magnetic coupled high power factor converter with a single-switch /single-stage is proposed. The proposed converter gives the good power factor correction, low current harmonic distortions, and tight output voltage regulation. The prototype shows the IEC555-2 requirements are met satisfactorily with nearly unity power factor.

1. Introduction

The widespread use of switched mode power supplies and other factors has contributed to unwanted harmonics placed on the power system to which such load are connected. Thus, there is a need to look for a converter which can do harmonics rectification, power factor correction, isolated dc-dc conversion, and tight output voltage regulation to meets the adoption of standards IEC 555-2 [1-3].

In this paper, a new converter group based on a forward dc-dc converter is introduced. Although this converter has a disadvantage such as high voltage stress, the proposed converter is capable of drawing high quality current waveforms from the ac power source by using a magnetic coupled technique. Furthermore, a regulated dc output with the fast transient response can be obtained in a single-stage/single-switch with the relatively reduced current stress suffered by a power switch. The experimental results show the feasibility of the magnetic coupled technique for the power factor correction in a low power level power supplies.

2. Proposed converter group

Fig. 1 shows the proposed high power factor converter group with a magnetic coupled stage. The proposed converters of Fig. 1 resembles the forward converter. The most obvious difference is the magnetic coupled stage in the input side section which is wound on the transformer core. This magnetic coupled winding generates a modulated voltage of switching frequency V_t which is the reflected voltage from the primary side of transformer during the turn off time. This high frequency content of V_t, is filtered by the inductor, L_f, to produce an output, V_x, which adds to V_i. The dc link capacitor, C_{DC}, is the high capacitance energy storage capacitor required to store the 120*Hz* ripple energy needed in a single-phase high power factor converter.

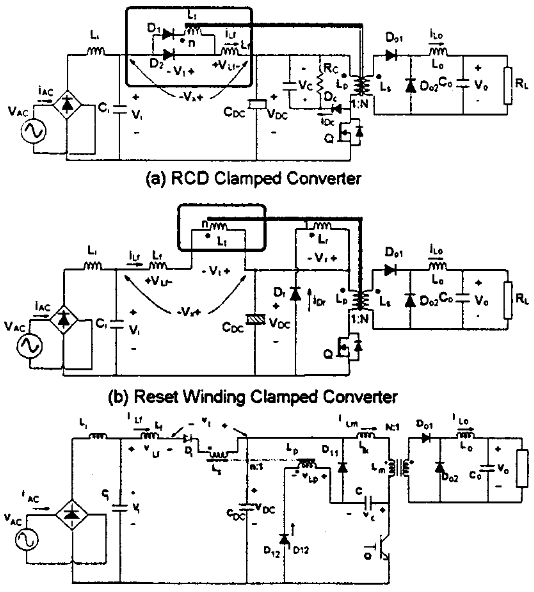

(a) RCD Clamped Converter
(b) Reset Winding Clamped Converter
(c) Lossless Snubber Clamped Converter

Fig. 1. Circuit diagram of proposed converter group

3. RCD Clamped Converter

Fig. 2 shows the steady-state waveforms, DC link waveforms, voltage conversion ratio, normalized line current amplitude, and experimental DC link waveforms and line current and voltage. The magnetic coupled inductor L_f generates the narrow pulses whose amplitude is nV_c. This voltage V_t makes the magnetic coupled stage operate in a

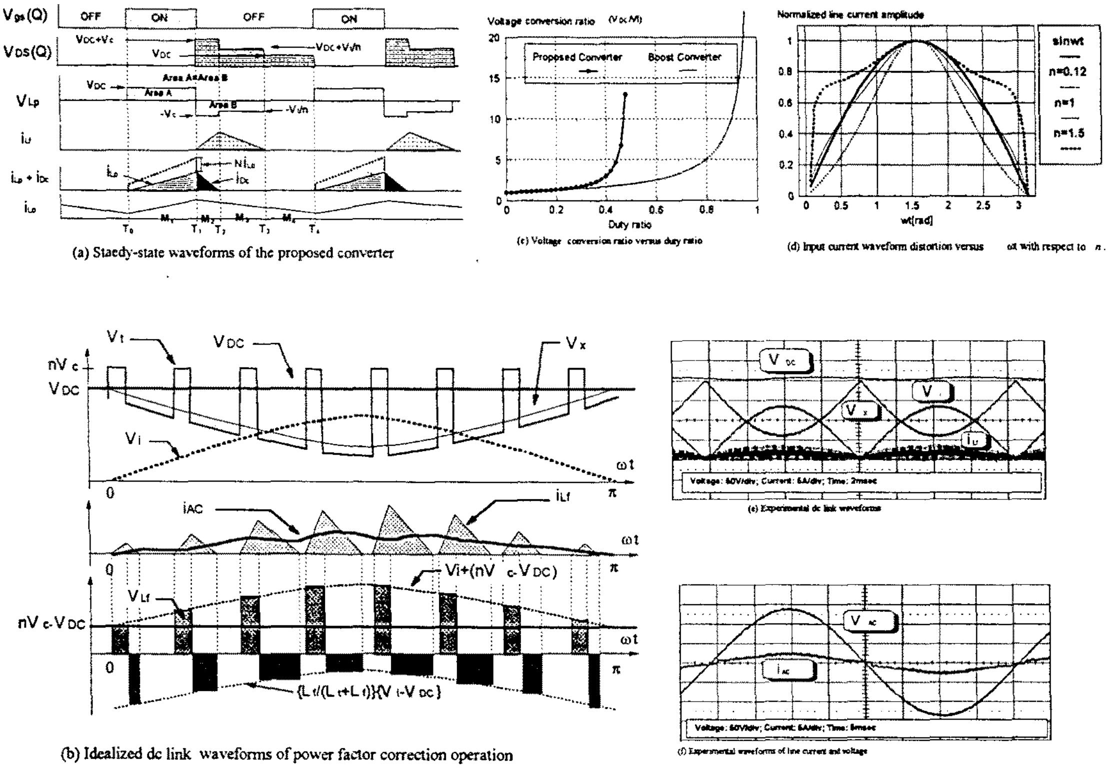


Fig. 2 RCD Clamped Magnetic Coupled Converter

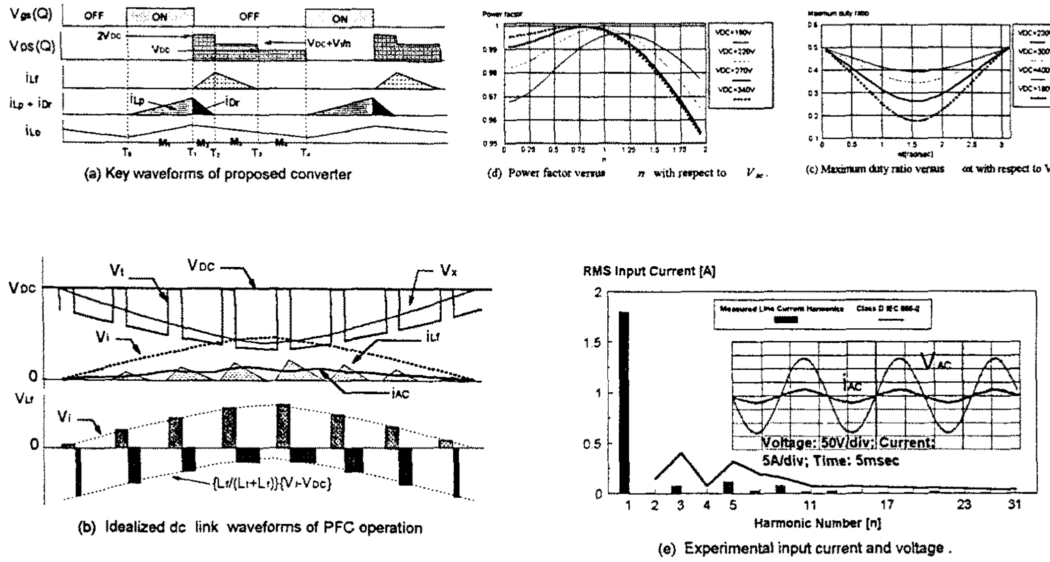
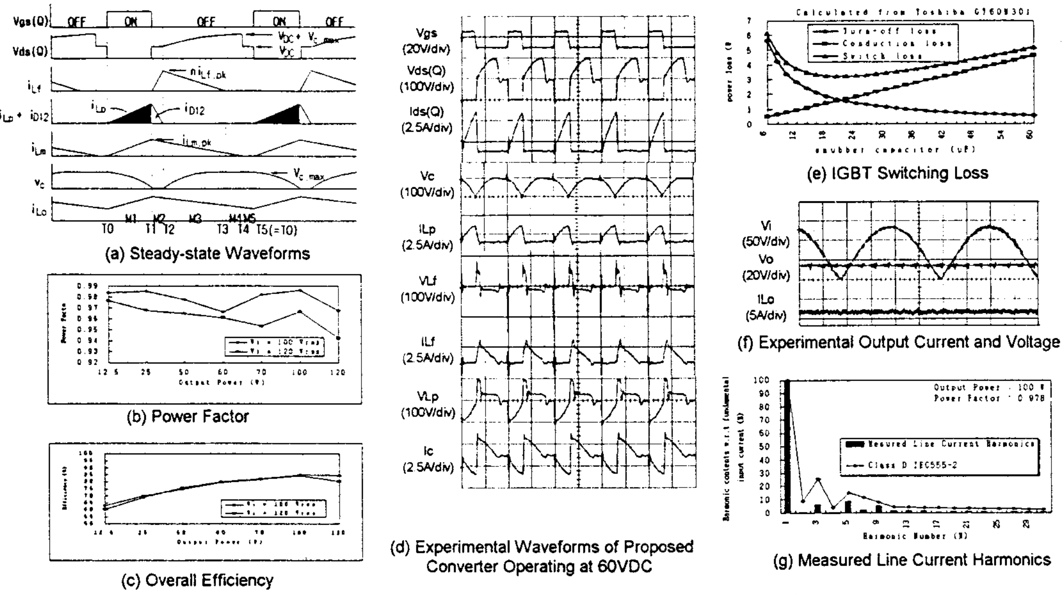


Fig. 3 Reset Windin Clamped Magnetic Coupled Converter



(a) Steady-state Waveforms
(b) Power Factor
(c) Overall Efficiency
(d) Experimental Waveforms of Proposed Converter Operating at 60VDC
(e) IGBT Switching Loss
(f) Experimental Output Current and Voltage
(g) Measured Line Current Harmonics

Fig. 4. Lossless Snubber Clamped Magnetic Coupled Converter

discontinuous conduction mode. The peak values of i_{Lf} will follow the high frequency voltage pulses V_{Lf} (= $V_i + nV_c - V_{DC}$) whose amplitude is modulated by a line voltage with dc offset ($nV_c - V_{DC}$). The average current $I_{Lf,av}$ over a line half-cycle can be expressed as

$$I_{Lf,av} = \frac{1}{\pi}\int_0^{\pi} \langle I_{Lf}(\omega t)\rangle \, d\omega t \qquad (1)$$

It is noted that the average current $I_{Lf,av}$ depends on the turns ratio of the magnetic coupled power stage, n, R_c. In case of $n=1$ and $Rc=2k\Omega$, the power factor stays relatively high for the entire load range. Thus, the turns ratio of 1 for a magnetic coupled stage and the clamped resistor of $Rc=2k\Omega$ have been selected for the near optimum performance. The proposed converter meets the regulations with a considerable margin, and the measured power factor is 0.99.

4. Reset Winding Clamped Converter

Fig. 3 shows the steady-state waveforms, DC link waveforms, maximum duty ratio, calculated power factor, and experimental line current and voltage. Since there is no need to design procedure of clamp resistor, this converter shows low harmonic distortions in input line current and relatively simple design. The proposed converter meets the regulations with a considerable margin, and the measured power factor is 0.985.

5. Lossless Snubber Clamped Converter

Fig. 4 shows the steady-state waveforms, IGBT switching loss, experimental waveforms of the converter operating at 60Vdc input, power factor, overall effiency, experimental line current and voltage and its measured harmonics. As can be seen in Fig. 4, the proposed converter successfully meets the IEC-555-2 requirements with a efficiency of above 84%.

5. Conclusions

This paper presents the analysis and experimental results for a group of high power factor converters incorporating the magnetic coupled technique. The proposed new magnetic coupled power factor correction technique gives the good power factor correction and low line current harmonic distortions. Furthermore, the proposed new group of converter is capable of producing an isolated output voltage regulation in a single stage and single switch without the significant output voltage ripple at twice the line frequency.

For the lossless snubber clamped converter, the higher converter efficiency can be obtained. The prototype successfully meets the IEC555-2 requirements with a high power factor. Thus, the proposed group of converter is suitable for low power level power supplies.

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