

Current-fed high-frequency link inverter with active input filter

S.-K. Chung, Y.-J. Song and P.N. Enjeti

A current-fed high frequency link inverter, with an active input filter for the AC power supply using the battery or fuel cell, is presented. The circuit topology and operation are investigated, and experimental results are provided to show the validity of the proposed scheme.

Introduction: A single-phase inverter can be used to generate low rating AC power from a DC source such as a battery or fuel cell. A high-frequency (HF) link inverter is attractive for this application because of its compact structure without the bulky DC link [1]. Current- and voltage-fed types are considered for the HF link topology. The current-fed type is effective for the power converter with the low input and high output voltages because it can operate in the boost mode [2, 3]. The current-fed HF link inverter can, therefore, be considered as a low-cost and compact solution for a single-phase AC power supply.

However, a single-phase inverter generating a 60 Hz output from a DC input has an input current ripple of 120 Hz that is inevitable and degrades the durability of the battery or fuel cell. To overcome this problem, a current-fed HF link inverter with an active input filter is proposed. The proposed inverter generates a single-phase sinusoidal output in a single stage and has the capability of eliminating the input current ripple. The circuit topology and operation are presented, and experimental results are provided to show the validity of the proposed scheme.

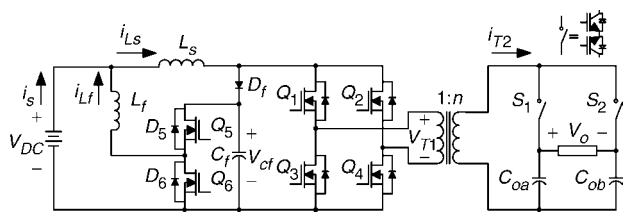


Fig. 1 Proposed current-fed HF link inverter

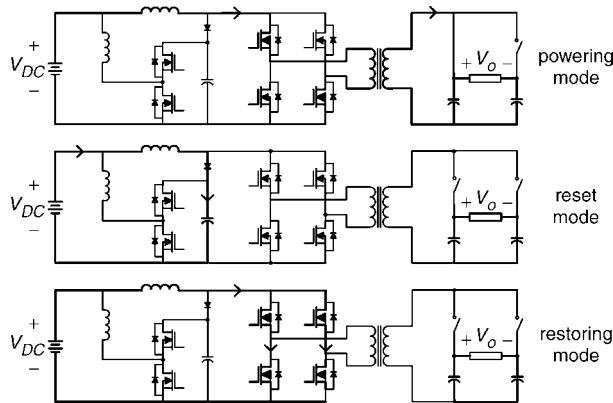


Fig. 2 Three operating modes of current-fed HF link inverter

Inverter topology and operation: Fig. 1 shows the proposed inverter with the active input filter. The main inverter has a single stage without the buck regulation stage, which consists of the primary inductor (L_s), full-bridge inverter (Q_1 – Q_4), HF transformer, two bidirectional switches (S_1 , S_2) and output capacitors (C_{oa} , C_{ob}). The diode D_f and capacitor C_f are used for voltage clamping as well as active filtering. The full-bridge and push–pull inverter can be considered in the primary side. The full-bridge inverter provides a simple structure and easy construction of the HF transformer. Fig. 2 shows three operating modes of the main inverter explained as follows:

- **Powering mode:** Two diagonal switches (Q_1 and Q_4 , or Q_2 and Q_3) are closed in this mode. The primary inductor current (i_{L_s}) is sinusoidally modulated by the full-bridge inverter, and transferred to the secondary side through the HF transformer. One of two bidirectional switches is turned on according to the polarities of the link current and

desired output voltage. The bidirectional switches are turned on/off at the zero link current to minimise the switching loss.

- **Reset mode:** All primary switches are opened in this mode. The primary inductor is reset using C_f and D_f . There is not an additional flyback winding for the inductor reset. The capacitor voltage v_{C_f} is controlled by Q_5 and Q_6 during the active filter operation and maintained to be higher than V_{dc} and v_{T1} . The primary inductor current decreases at a rate of $(V_{dc} - v_{C_f})/L_s$.

- **Restoring mode:** Both switches of one inverter leg (Q_1 and Q_3 , or Q_2 and Q_4) or all four switches are closed in this mode. The primary inductor current is boosted at a rate of V_{dc}/L_s and therefore can be controlled using the reset and restoring modes during the non-energy transferring interval [2, 3].

Active input filter: The input and output powers of the inverter should be balanced in both average and instantaneous senses. The output voltage and current of the inverter can be assumed as $v_o = \sqrt{2}V_{rms} \sin \omega t$ and $i_o = \sqrt{2}I_{rms} \sin(\omega t - \phi)$ for the linear load, where ϕ is the displacement factor. The instantaneous power is derived as:

$$P_o = v_o i_o = V_{rms} I_{rms} \cos \phi - V_{rms} I_{rms} \cos(2\omega t - \phi) \quad (1)$$

If it is assumed that $P_o = V_{dc} i_s$, the input current for a constant V_{dc} can be represented as:

$$i_s(t) = \frac{V_{rms} I_{rms}}{V_{dc}} \cos \phi - \frac{V_{rms} I_{rms}}{V_{dc}} \cos(2\omega t - \phi) = I_{av} + i_p \quad (2)$$

The second term of the right-hand side (i_p) in (2) means the input ripple current with 2ω frequency. The concept of the proposed filtering technique is that the filter capacitor (C_f) stores the excessive charge during the negative half cycle of the ripple current and supplies the stored charge to the output during the positive half. Fig. 3 shows the input current, net capacitor current and capacitor voltage. The charge ΔQ is equal to the area of the current half cycle and derived as $\Delta Q = \sqrt{2} I_{rms} / 60\pi$. The voltage ripple of the filter capacitor can be calculated as $\Delta v_{C_f} = \Delta Q / C_f$. Fig. 4 shows the operation of the active input filter, where it is assumed that the capacitor voltage v_{C_f} is controlled to be higher than V_{dc} and v_{T1} . There are two modes of the active filter operation. In mode 1, the filter capacitor supplies the stored charge to the output through the filter inductor L_f . In mode 2, the excessive charge is stored to the filter capacitor by the boost action of L_f , Q_6 and D_5 . Consequently, the filter inductor current is controlled to be the same as the ripple component of the primary inductor current.

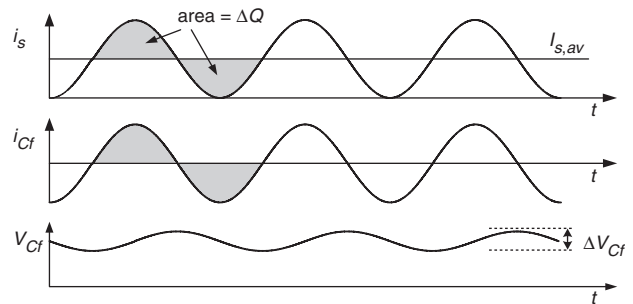


Fig. 3 Input current, net capacitor current and capacitor voltage waveforms

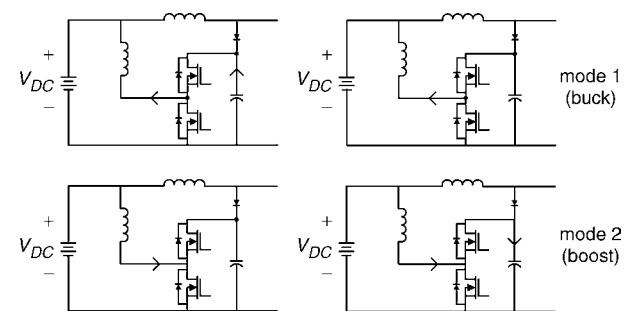


Fig. 4 Operating modes of active input filter

Experimental results: To show the validity of the proposed scheme, an experiment was carried out for the prototype inverter with the parameters as: $V_{dc} = 48$ V, $f_s = 20$ kHz, $L_s = 500$ μ H, $L_f = 500$ μ H, $C_{oa} = C_{ob} = 47$ μ F, $C_f = 5600$ μ F and $n = 4$, where f_s and n denote the switching frequency and transformer turns ratio, respectively. The DSP TMS320F2407 was used to control the inverter and active filter. Fig. 5 shows the input current and output voltage of the proposed inverter for the resistive load of 12 Ω . Note in this Figure that the input current has no ripple component for the sinusoidal output voltage.

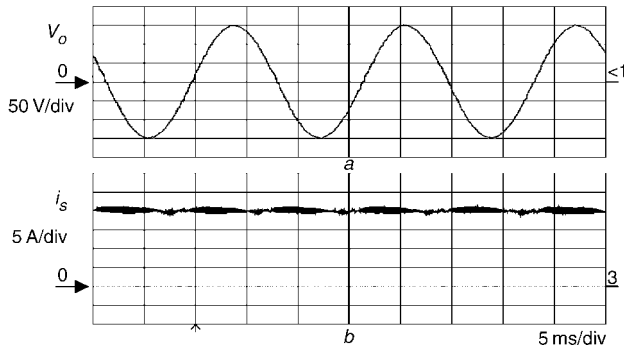


Fig. 5 Experimental waveforms

a output voltage
b input current

Conclusions: A new current-fed HF link inverter with the capability of eliminating the input current ripple is proposed. The proposed inverter scheme is a single-stage approach and has a simple transformer structure. The active input filter effectively eliminates the input ripple current. The size of the filter inductor is much smaller than that

of the passive LC filter with comparable performance. It is expected from the results that the proposed scheme will be used as a low-cost and compact solution for AC power supply using a battery or fuel cell.

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