

## Forward Single-Stage Power Factor Correction

Xiaoshuang Wang, Jing Zhao, Yani Zhan

Xi'an communication college, Xi'an 710106, China

**Abstract:** Power Factor Correction is the capacity of generating or absorbing the reactive power produced by a load. The major industrial loads have an inductive power factor. The current tends to go beyond the power is usually used for the power conversion. This paper introduces a forward Single-Stage Power Factor Correction AC/DC converter. The simulation results verified our design.

**Keywords:** PF; Converter; Correction

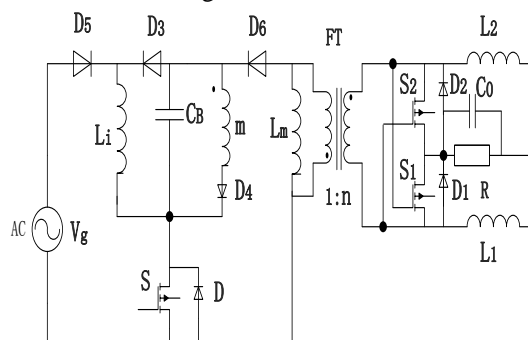
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\*Corresponding Author: Xiaoshuang Wang

### 1. Introduction

Power Factor Correction (PFC) is the capacity of generating or absorbing the reactive power to a load without the use of the supply. The major industrial loads have an inductive power factor, so that the current tends to go beyond the power is usually used for the power conversion. An excessive load current represents a loss for the consumer, who not only pays for the over-dimensioning of the cable, but also for the excess power loss in the cables. The generation stations do not want to transport the useless reactive power of the alternators toward the loads. The distribution network cannot be used at high efficiency, and the voltage regulation in the various points becomes complicated. The principle used by these generation stations almost always penalizes the low power factor of the clients.

We discuss a Single-Stage high PFC AC/DC converter as an example for digital control application in this section. The system consists of an AC/DC diode rectifier and a Double Current Synchronous Rectifier [1]. As shown in the Figure 1.



**Figure 1. Proposed Single-Stage PFC Double-Current Synchronous Rectifier.**

Suppose that the output inductors  $L1$  and  $L2$  are equal to each other  $L1=L2=L0$  which called output inductor. There are three switches: main switch  $S$ , two auxiliary synchronous switches  $S1$  and  $S2$ . It inherently exhibits high power factor because the PFC cell operates in continuous conduction mode (CCM). In addition, it is also free to suffer from high voltage stress across the bulk capacitor at light loads.

In power electronic equipment, the PFC circuits are

usually added between the bridge rectifier and the loads to eliminate high harmonics distortion of the line current. In general, they can be divided into two categories, the two-stage approach and the Single-Stage approach. In the two-stage approach, it includes a PFC stage and a DC/DC regulation stage. It has good power factor correction and fast output regulations, but the size and cost increase. Many Single-Stage approaches have been proposed in the literature [2-3]. It integrates a PFC cell and a DC/DC conversion cell to form a Single-Stage with a common switch. Therefore, the sinusoidal input current waveform and the output voltage regulation can be simultaneously achieved. It thereby meets the requirements of performances and costs.

However, there exists a high voltage stress across the bulk capacitor  $C_B$  at light loads if DC/DC cell operates in discontinuous current mode (DCM). To overcome this drawback, a negative magnetic feedback technique was proposed in literature. However, the dead band exists in the input current and the power factor is thereby degraded. To deal with this problem, the DC/DC cell will operate in DCM.

The voltage across the bulk capacitor is independent of loads and the voltage stress is reduced effectively.

### 2. Operating Principles

Figure 1. depicts the proposed forward Single-Stage high PFC converter topology. A physical three-winding transformer has turns ratio  $1:n:m$ . A tertiary transformer winding, in series with diode  $D4$ , is added to the converter for transformer flux resetting. The magnetizing inductance  $L_m$  is parallel with the ideal transformer. In the proposed converter, both PFC cell and DC/DC conversion cell are operating in CCM. To simplify the analysis of the circuit, the following assumptions are made:

(1) The large-valued bulk capacitor  $C_B$  and output capacitor  $C_o$  are sufficiently large so that the voltages across the bulk capacitor and output capacitor are approximately constant during one switching period  $T_s$ .

(2) All switch and diodes of the converter are ideal. The switching time of the switch and the reverse recovery time of the diodes are negligible.

(3) The inductors and the capacitors of the converter are considered to be ideal without parasitic

components.

Based on the switching of the switch and diodes, the proposed converter operating in one switching period  $T_s$  can be divided into five linear stages described as follows.

Stage 1 [0,  $t_1$ ](S:on,D1 on, D2:off, D3:off, D4: off, D5:on,D6:on):In the first stage, the switch S is turned on. The diodes (D1, D5, D6) are turned on and the diodes (D2, D3, D4) are turned off. Power is transferred from bulk capacitor CB to the output via the transformer.

Stage 2 [ $t_1, t_2$ ](S:off, D1:off, D2:on, D3:on, D4:on, D5:off, D6:off):The stage begins when the switch S is turned off. The diodes (D2, D3, D4) are turned on and the diodes(D1, D5, D6) are turned off. The current  $i_{Li}$  flows through the diode D3 and charges the bulk capacitor CB.The diode D4 is turned on for transformer flux resetting. In this stage, the output power is provided by the inductor  $L_o$ .

Stage 3 [ $t_2, t_3$ ](S:off, D1:off, D2:on, D3:off, D4:on, D5:off, D6:off):The stage begins at  $t_2$  when the input current  $i_{Li}$  falls to zero and thus diode D3 is turned off. The switch S is still off. All diodes, except D3, maintain their states as shown in the previous stage. During this stage, the voltages  $(-v_{CB}/m)$  and  $(-v_o)$  are applied across the inductors  $L_m$  and  $L_o$ , and thus the inductor currents continue to linearly decrease. The output power is also provided by the output inductor  $L_o$ .

Stage 4 [ $t_3, t_4$ ](S:off, D1:off, D2:off, D3:off, D4:on, D5:off, D6:off):The stage begins when the current decreases to zero and thus diode D2 is turned off. The switch S is still off. The diode D4 is still turned on and the diodes (D1, D3, D5, D6) are still turned off. During this stage, the voltage  $(-v_{CB}/m)$  is applied across inductor  $L_m$ . The inductor current continues to linearly decrease. The output power is provided by the output capacitor  $C_o$  in this stage.

Stage 5 [ $t_4, t_5$ ](S:off, D1:off, D2:off, D3:off, D4:off, D5:off, D6:off):The stage begins when the current  $i_{Lm}$  falls to zero and thus diode D4 become off. The switch S is still off and all diodes are off. The output power is also provided by the output capacitor  $C_o$ . The operation of the converter returns back to the first stage when the switch S is turned on again.

According to the analysis of the proposed converter, the key waveforms over one switching period  $T_s$  are schematically depicted in Figure.2.The slopes of the waveforms  $i_{Co}(t)$  and  $i_{CB}(t)$  are defined[4]:

$$m_{Co1} = \frac{nv_{CB} - v_{CO}}{L_o}, \quad m_{Co2} = -\frac{v_{CO}}{L_o},$$

$$m_{CB1} = -\left[\frac{v_{CB}}{L_m} + \frac{n(nv_{CB} - v_{CO})}{L_o}\right]$$

$$m_{CB2} = -\left(\frac{v_{CB}}{L_i} + \frac{v_{CB}}{m^2 L_m}\right),$$

$$m_{CB2} = \frac{v_{CB}}{m^2 L_m}$$

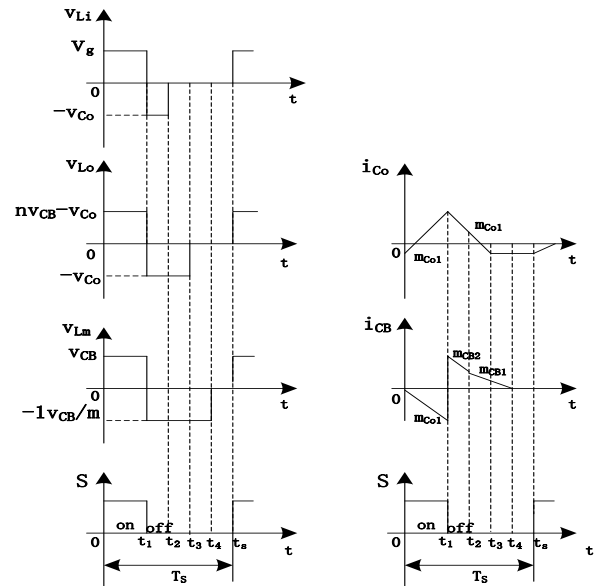


Figure 2. Typical waveforms of the proposed converter.

### 3. Simulation Results

The pspice simulation results presented in Figure.3 demonstrate that both PFC and DC/DC cells are operating in DCM. It reveals that the proposed converter has high power factor. According to the total harmonic distortion(THD) obtained in the simulation results, the power factor is calculated to be PF=0.999.

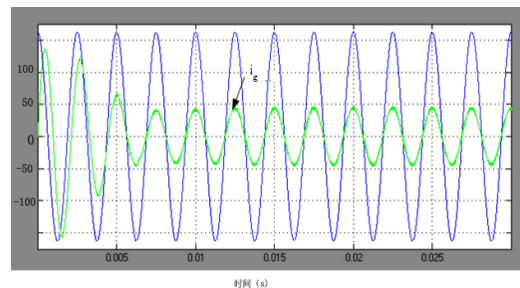


Figure 3. Input line voltage and current.

### 4. Conclusion

In this paper, the Single-Stage PFC Double-Current Synchronous Rectifier has been combined to create a Single -Stage high power factor correction converter. The proposed converter exhibits high power factor.

### References

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