INSTANTANEOUS POWER FACTOR CORRECTION IN THREE - PHASE USING POWER FACTOR PREREGULATOR IN CONVERTERS

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Abstract

In this paper a novel three - phase power -factor correction scheme is proposed using two single phase PFC modules. A Power Factor Preregulator (PFP) is used to provide soft switching . In this approach the three phase input is first transformed to two phase by means of bifilar winding transformer . Two standard single phase PFC modules are then employed to process the two phase power to dc output. The proposed approach has simplified control and high performance features.

Key- Words: Power factor correction , PFP, Soft - switching .

I. INTRODUCTION

Power supplies connected to ac mains introduce harmonic currents in the utility. It is very well known that these harmonic currents cause several problems such as voltage distortion, heating, noise and reduce the capability of the line to provide energy. In fact and the need to comply with “standards” or “recommendations” have forced to use power factor correction in power supplies.[2]

In this paper a new three-phase PFC scheme using two standard single-phase PFC modules. “Two” phase is produced by means of a bifilar winding transformer from a “three” phase input. Two standard single-phase PFC modules are employed, one on each phase to process the power. Split inductors and diodes are used to limit interaction between the two PFC stages. The outputs of the two PFC modules are connected to the common dc output. Due to cascade operation of the two PFC stages, low frequency (120 Hz) ripple components in the dc-link capacitor cancel each other. The advantages of the proposed scheme are as follows

- Input current waveforms are nearly sinusoidal at unity power factor.
- In this scheme, Power Factor Preregulator is used for soft switching. This reduces switching losses.
- The dc output is regulated and is immune to voltage sags and other power quality disturbances.
- High input current harmonics and low input power factor.

To combat these disadvantages, Designers are increasingly incorporating active input power factor correction methods.[11]

This paper proposes a simple controller for boost chopper to improve the power factor and ac side current distortion. The method is derived from analysis using the integral of the ac and dc side voltages and the ac side current over a carrier period. The proposed controller predicts the quasioptimal pulse width to be applied to the Boost Chopper at the beginning of every carrier period. This method is easily realized by Pulse Width Prediction(PWP) controller.

The PWP controller is implemented with a constant frequency carrier. The PWP controller composes IC 3855 is used as power factor preregulator which provides softswitching . Experimental results on performance characteristics of power factor preregulator with constant frequency carrier is presented.

II. PROPOSED METHOD

A. Principle of the Method

Fig. 1 shows a schematic diagram of a single phase front-end diode rectifier with a Boost Chopper for power factor preregulator application. Boost Chopper is realized using IGBT.

In Mode I, the ac-side is short-circuited by means of conduction of either the upper switching devices or the lower switching devices. In this case, the dc-side circuit becomes independent of the ac-side.

Mode II represents the duration (pulse width) when the switching devices, S1 and S3, conduct; the ac and dc-side circuits are connected by those devices. In Mode III, S2 and S3 conduct, and the bridge circuit behaves in a similar fashion as in Mode II.

Consider the kth period consisting of a combination of Mode I and either II or III, shown in Fig 2. Integrating both sides of (1) over $t_k <= t <= t_{k+1}$, gives

$$\int_{t_k}^{t_{k+1}} v_s \, dt - L\{i_s(t_k+1) - i_s(t_k)\} = \int_{t_k}^{t_{k+1}} v_B \, dt \qquad \text{(i)}$$

Where the current $I_s(t_k)$ is the initial current, and $I_s(t_{k+1})$ is the desired current at the end of the carrier period to keep the input power factor at unity. The source voltage and the dc-side voltage are assumed to remain constant during the period; the voltages, $v_s(t_k)$ are used. The first term on the left-hand side of (3) evaluates to

$$\int_{t_k}^{t_{k+1}} v_s \, dt = T_s \, v_s \, (t_k) \qquad \text{(ii)}$$

Where T_s is the carrier period, which is the reciprocal of the carrier frequency f_s. The right-hand side of (3) evaluates to

$$\int_{t_k}^{t_{k+1}} v_B \, dt = \int_{t_p}^{t_q} v_B \, dt$$

$$= \begin{cases} \int_{tp}^{t_q} v_o \, dt = \lambda'_k \, v_o(t_k) \\ \text{(Modes I \& II)} \\ \int_{t_p}^{t_q} (-v_o) \, dt = -\lambda'_k v_o(t_k) \\ \text{(Modes I \& II)} \end{cases} \qquad \text{(iii)}$$

Where the pulse is assumed to start at t_p and end at t_q. The time difference, i.e., pulse width, is

$$\lambda'_k = t_q - t_p \qquad \text{(iv)}$$

From (3)-(5), the desired pulse width is obtained by introducing a generalized pulse width λ_k that can either a positive, zero, or a negative. Then

$$\lambda_k = \frac{1}{v_o(t_k)}[T_s v_s(t_k) - Li_s(t_{k+1}) + Li_s(t_k)] \tag{v}$$

The reference current value, $i_s(t_{k+1})$, at the end of the period must be proportional to the source voltage at $t=t_{k+1}$ to keep the power factor at unity. However, the voltage at $t=t_{k+1}$ is unknown unless the source voltage is a sine wave or other periodic wave. If the carrier frequency is chosen to be a high frequency compared with the source frequency, or T_s is very small, an approximated replacement of $\{Li_s(t_{k+1})\}$ with $\{\alpha v_s(t_k)\}$ gives

$$\lambda_k = \frac{1}{v_o(t_k)}[T_s v_s(t_k) - \alpha v_s(t) + Li_s(t)] \tag{vi}$$

Where α is the coefficient of a unit of time. Equation (8) implies that the pule width to be applied in the kth period can be predicted at the beginning of the carrier period and that the pulse point can be chosen so long as the pulsewidth is maintained.

In addition, the pulse width can be calculated by means of an analog operating circuit at every moment. The pulse width as a function of time can be written

$$\lambda(t) = \frac{1}{v_o(t)}[T_s v_s(t) - \alpha v_s(t) + Li_s(t)] \tag{vii}$$

This equation is simple enough to be represented by a simple analog circuit, and therefore a digital controller that is adequate for complex operation schemes, e.g., DSP, is not necessary. The pulse width calculating analog circuitry is called an analog PWP controller, in this paper. In practical control circuitry, the coefficient α is a variable gain to control an ac-current reference.

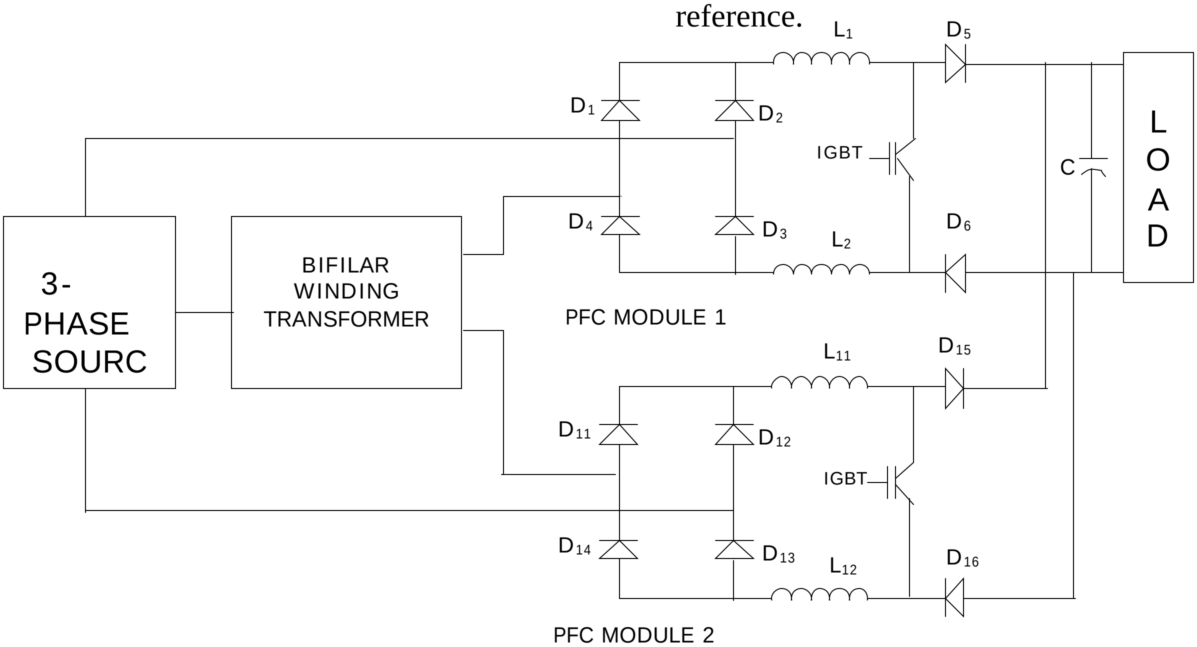
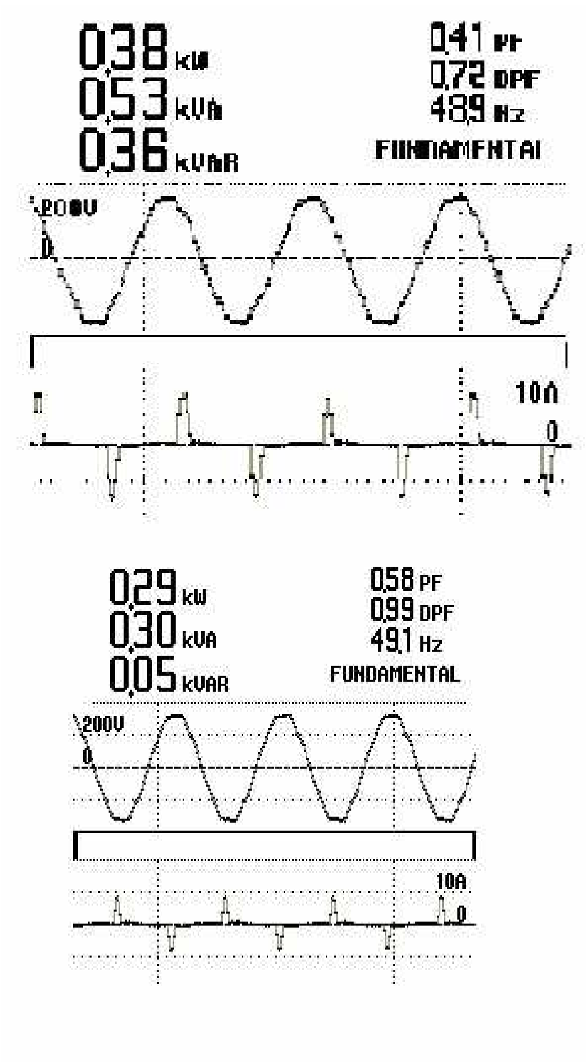


Fig.1 A Three-Phase Power Factor Correction Circuit



I. RESULTS FROM FLUKE METER
Uncompensated Waveforms

B. Implementation

Fig 2 shows the control block diagram of the proposed PWP method. The PWP controller detects the source voltage and current and the dc side voltage and calculates the pulse width (λ). The PWP controller is implemented using a IC3855. The PWP controller outputs as pulse that is arranged in the center of the carrier period. Arrangement of the pulse can be varied in the period as long as pulse width is kept constant. α is the signal to control the amplitude of the ac side current. To adjust the dc output voltage, it is necessary to control α. A conventional PI controller may be used to control the dc output voltage.

The rectifier in figure 1 draws the ac side current of which the shape is similar in fashion to the source voltage. That is, it behaves as a purely resistive load when viewed from a ac source terminals.

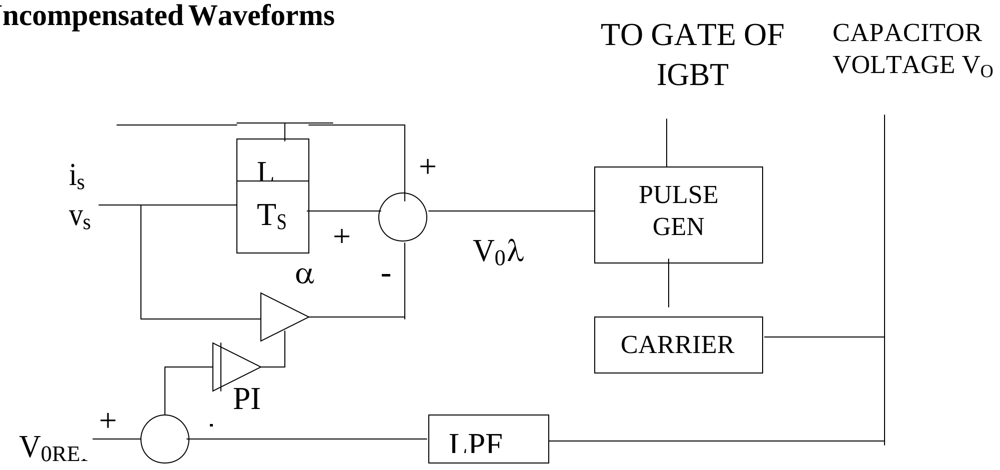


Fig.2 Control Circuit implementing IC3855.

II. RESULTS

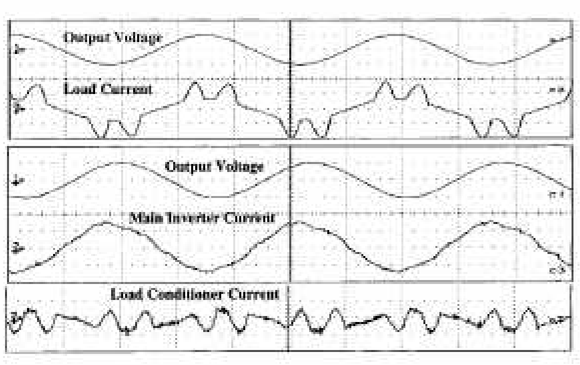


Fig.3 Output wave forms

III. CONCLUSION

In this paper a novel instantaneous power factor correction in power supplies with single-phase front-end diode rectifiers is proposed and analyzed. The proposed method rectifier draws sinusoidal ac current from the source with unity power factor. Experimental results are obtained and verified.

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