

Embedded control of a boost unity power factor supply with a DC motor load

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This paper presents a proposed setup utilizes a boost converter circuit driving a dc motor load. A pulse width modulation (PWM) technique is assessed to realize a sinusoidal supply line current, hence improving system power factor. Experimental hardware has been constructed and the software control algorithm has been implemented using an embedded C167 micro-controller. System response is demonstrated for two control modes: voltage control mode and speed control mode. Experimental results show simplicity and effectiveness of the proposed setup.

هذه الورقة البحثية تعرض نموذج عملي يستخدم دائرة تعويض تغذى محرك تيار مستمر كحمل. ويستخدم كذلك طريقة يطلق عليها التشكيل في عرض النبضة، وذلك لجعل تيار المصدر على شكل جيبي مما يحسن معامل القدرة للنظام. وقد تم تركيب الدائرة العملية وكذلك عمل برنامج التحكم الخاص بها وذلك باستخدام متحكم دقيق. وفي هذه الورقة البحثية تم عرض استجابة النظام في حالتين من التحكم الأولى عن طريق التحكم في جهد المحرك والثانية عن طريق التحكم في سرعة المحرك. ولقد أوضحت النتائج العملية سهولة وفاعلية النظام المقترح.

Keywords: Power factor preregulator, Boost converter, Embedded micro-controller

1. Introduction

Recently, variety of high power factor ac to dc converters has been studied to improve the harmonic pollution caused by these converters [1-9]. Construction and operation of the boost converter topology has been demonstrated in literature, showing the simplicity and the validity of using this topology in some domestic applications. Unity power factor converters perform active wave shaping of the ac input current to ensure a sinusoidal current shape, while delivering a constant output voltage [4]. Microcontroller applications are now feasible in the area of electrical machine drives as it provides a very high performance level with relatively low cost [2]. This paper concentrates on control of the boost ac to dc converter loaded by a dc motor using C167 embedded controller. The main objective of the proposed setup is to achieve high supply power factor together with appropriate system response in both voltage control mode and speed control mode.

2. Experimental setup

The hardware setup, shown in fig. 1, has been experimentally implemented to drive a 2-

hp dc motor from an ac supply source with high power factor during the steady state operation. A Siemens C167 16-bit micro-controller is used to perform all control tasks; such as reading all feedback signals and generating the appropriate PWM signal. The embedded C167 micro-controller executes a software algorithm, will be discussed in section 3, to control the IGBT switch in order to meet the required performance. A four-diode uncontrolled bridge rectifier converts the ac supply voltage into a dc voltage feeding the dc motor. A power diode, a controlled switch (IGBT), an inductor and a capacitor are used to construct the boost converter circuit. A gate drive circuit isolates the micro-controller from the power circuit and also supplies the IGBT switch with the appropriate switching voltage and current. A Hall-effect current transducer is used to measure the rectified supply current (inductor current). The rectified supply voltage and the boost circuit output voltage are measured using voltage transducers. A tacho generator is utilized to measure the actual motor speed. All the aforementioned measured signals are fed back to the microcontroller through different channels of the built-in A/D converter. The PC is only used to write the software program,

which is compiled and transferred, to the microcontroller through the serial port. Control parameters and reference values are initialized via the keyboard then the PC goes off-line during the execution of the microcontroller program.

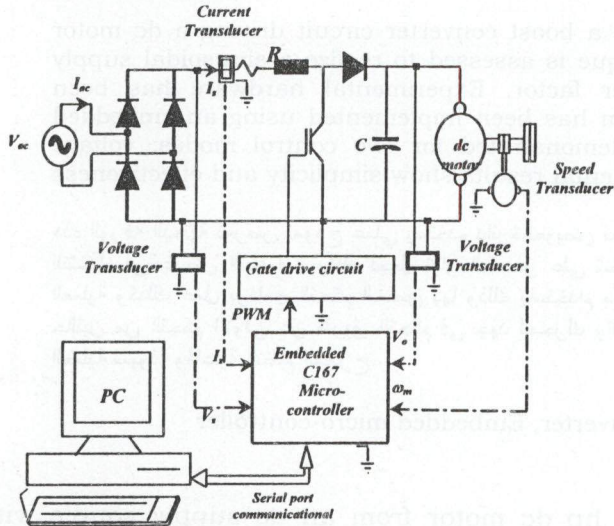


Fig. 1. Experimental setup.

3. Control algorithm

Fig. 2 shows the flowchart of the implemented software control algorithm. The C167 microcontroller utilizes its internal A/D converters to read the actual output voltage V_o , motor speed ω_m , rectified supply voltage V_s and current I_s . The program validates two modes of control operation while maintaining the supply power factor at unity; voltage control mode and speed control mode. Through the voltage control mode, the voltage error V_e between the reference voltage V_r and the actual output voltage V_o determines the voltage gain V_g to be multiplied by the actual sinusoidal supply voltage V_s in order to generate a sinusoidal supply current reference I_r . A proportional plus integral (PI) digital current control algorithm with current limiting action is performed to generate a PWM signal. This PWM signal controls the IGBT switch to get the required output voltage and sinusoidal supply current, hence improving system power factor. The speed control mode performs similar algorithm to control motor speed, instead of output voltage, with unity supply power factor.

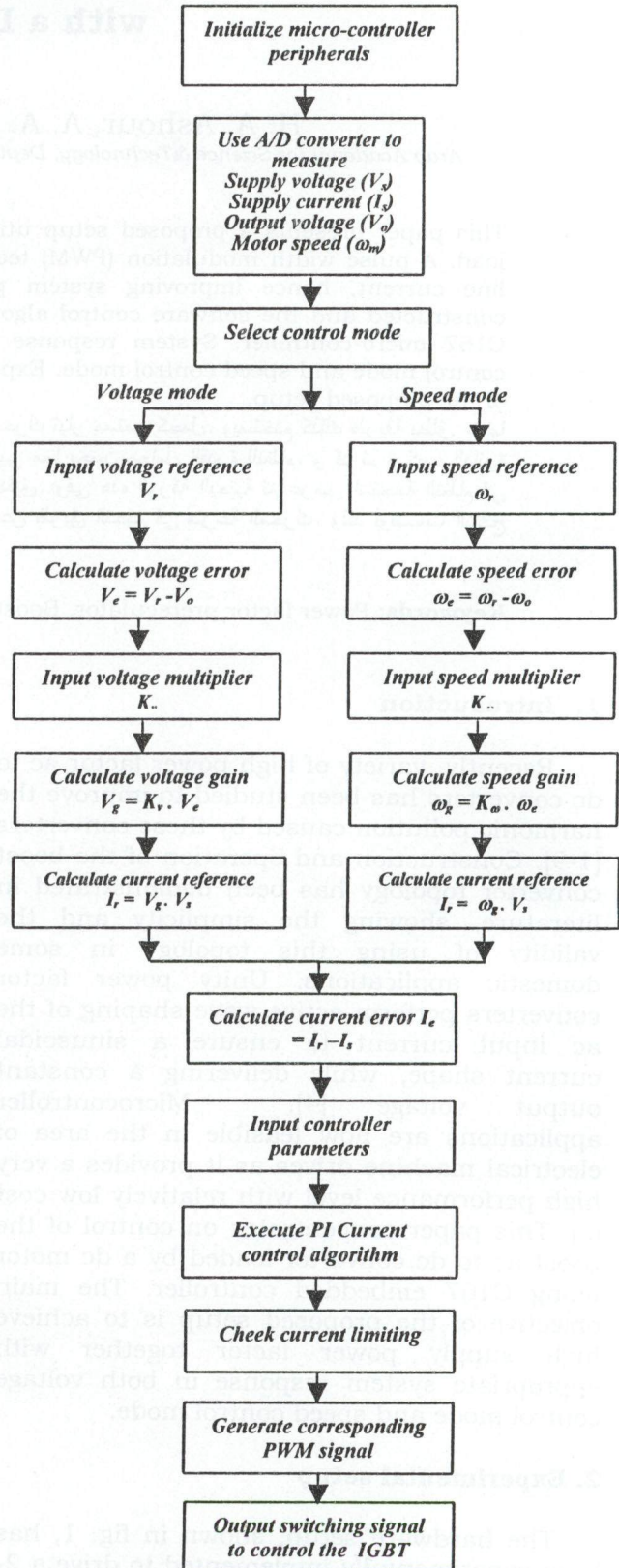


Fig. 2. Program flowchart.

4. Experimental results

The experimental hardware setup and the software control algorithm have been implemented. System performance for both voltage and speed control modes will be demonstrated through the following sections.

4.1. Voltage control mode

The program is running under voltage control mode. Different test results will be discussed in the following sections.

4.1.1. Power factor improving

Fig. 3-a depicts the rectified supply voltage V_s and current I_s waveforms without any switching action (the IGBT is completely off and $V_s = V_o = 50V$). From this figure it can be seen that although the supply voltage is sinusoidal, the corresponding supply current is not sinusoidal. These supply voltage and current are not in phase; hence system power factor is low. Figs. 3-b and 3-c illustrate supply voltage and current waveforms for required output voltage of 70V and 115V respectively from input supply voltage of 50V. These figures show that supply current is controlled by chopping of the IGBT switch and reshaped to be sinusoidal as the supply voltage (in phase). Hence supply power factor is improved and approaches unity for different required output voltages. It can be also seen that the controller increases the instantaneous value of the sinusoidal supply current to increase the output voltage.

4.1.2. Voltage step response

Controller parameters have been experimentally tuned, by try and error, to get minimum overshoot in voltage step response. Fig. 4 shows output voltage V_o and input supply current I_s when the voltage reference V_r is changed from 50V to 75V. It can be seen that the output voltage reached the steady state value after 0.3 sec without an overshoot. Different voltage responses could be achieved by changing controller parameters.

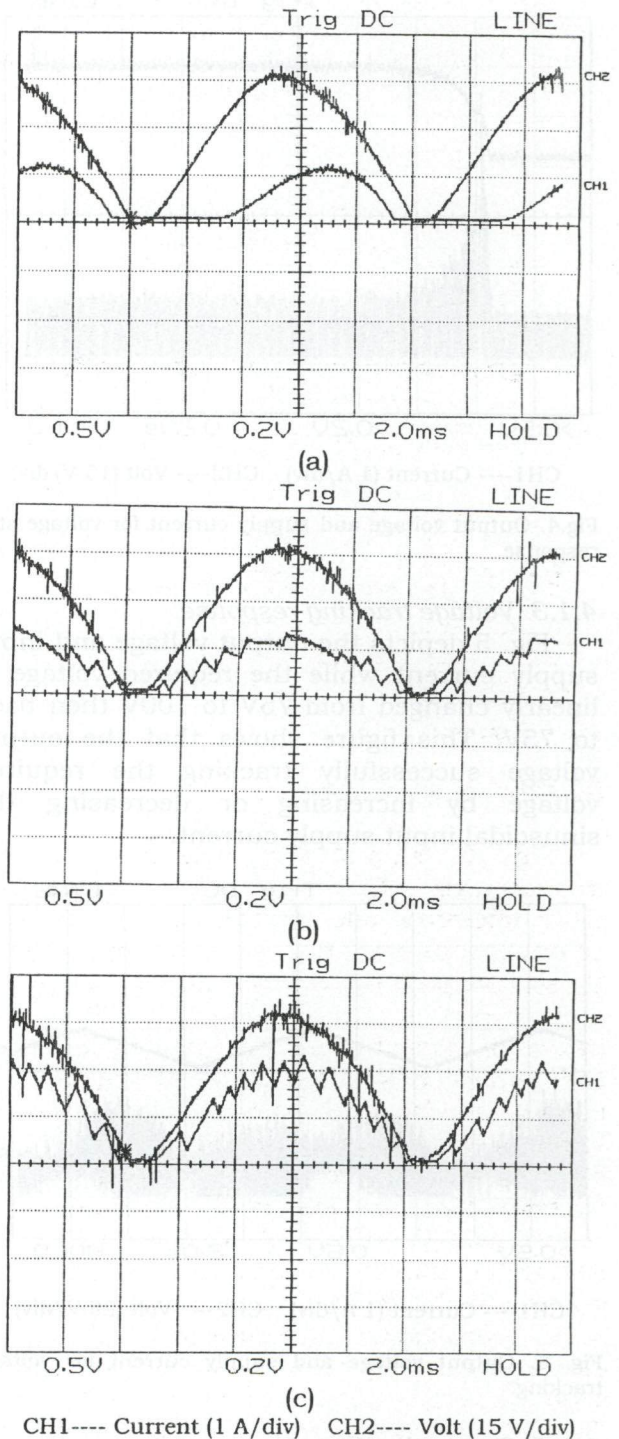


Fig.3. Supply voltage and current for unity power factor improving. (a) Without controller, (b) with controller for output voltage of 70 V, and (c) with controller for output voltage of 115 V.

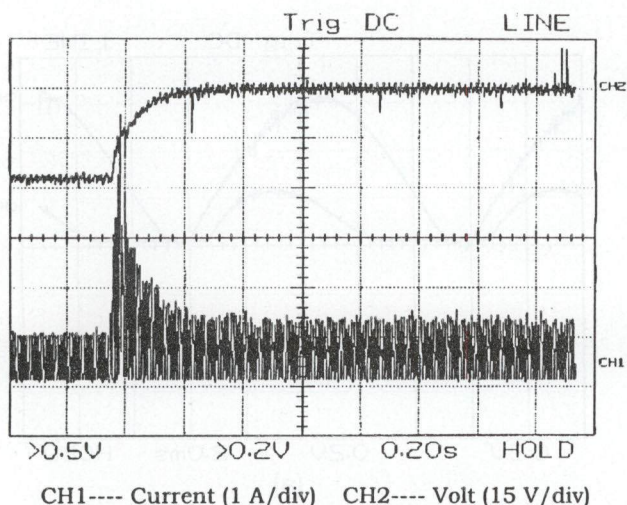


Fig.4. Output voltage and supply current for voltage step response.

4.1.3. Voltage tracking response

Fig. 5 depicts the output voltage and input supply current while the required voltage is linearly changed from 75V to 100V then back to 75V. This figure shows that the output voltage successfully tracking the required voltage by increasing or decreasing the sinusoidal input supply current.

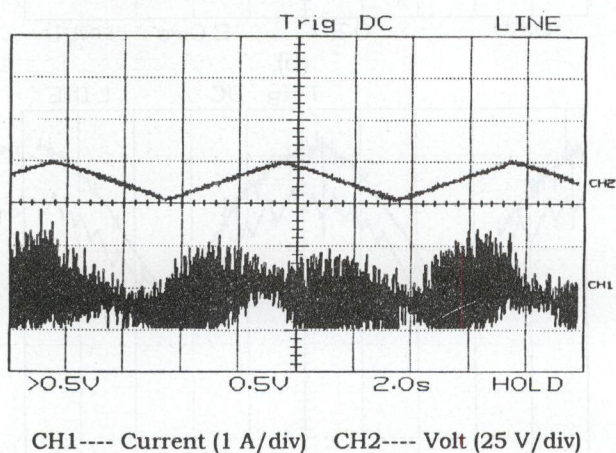


Fig. 5. Output voltage and supply current for voltage tracking.

4.1.4. Current limiting

Fig. 6 illustrates the output voltage and input supply current for inappropriate choice of controller parameters. It can be seen that although a high voltage overshoot is caused, the input current is limited to a predefined limit value (6A) until the voltage reaches the

required value. This limiting action protects circuit components from over current due to some possible faulty operations.

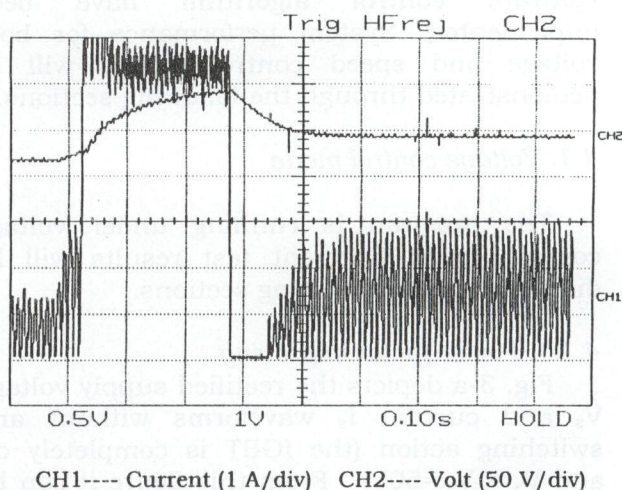


Fig. 6. Output voltage and supply current during current limiting.

4.2. Speed control mode

Following sections represent some experimental waveforms when the setup is tested under speed control mode.

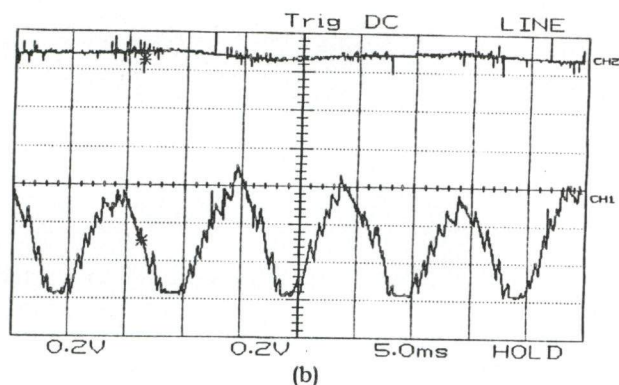
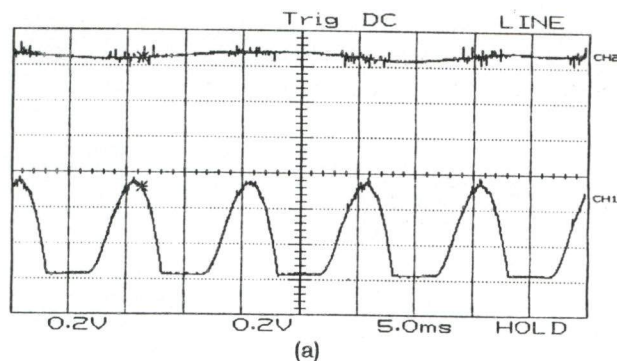
4.2.1. Motor speed and supply current

Waveforms of motor speed ω_m and input supply current I_s are shown in fig. 7-a while the IGBT switch is completely off. The input supply voltage is 75V and motor speed is 800 rpm.

Fig. 7-b shows same waveforms while the IGBT is controlled to get a motor speed of 800 rpm from 50V supply input voltage. Comparing figs. 7-a and 7-b it can be seen that the controller reshaped the supply current to be sinusoidal (in phase with the supply voltage), while keeping motor speed at the required value. Hence improving the supply power factor.

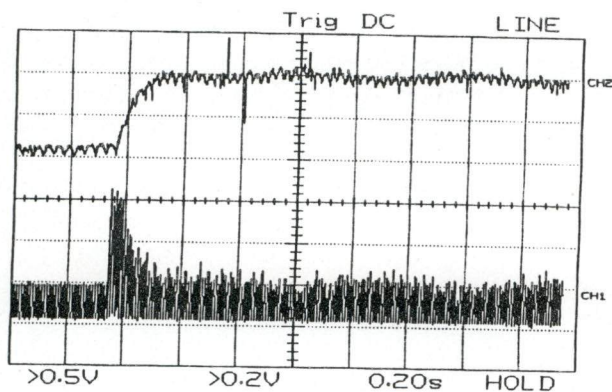
4.2.2. Speed step response

Motor speed and supply current waveforms are shown in fig. 8, while motor reference speed (ω_r) is changed from 500 rpm to 750 rpm. It can be seen that the supply current is controlled and motor speed reaches the required value while maintaining the supply power factor near unity.



CH1---- Current (0.4 A/div) CH2---- speed (125 rpm/div)

Fig.7. Motor speed and supply current for unity power factor improving. (a) Without controller, and (b) with controller for motor speed of 800 rpm.



CH1---- Current (1 A/div) CH2---- speed (125 rpm/div)

Fig.8. Motor speed and supply current for speed step response.

5. Conclusions

An embedded C167 micro-controller has been utilized to implement an algorithm that controls a boost converter topology driving a

dc motor load while maintaining the supply power factor at unity. Experimental results show the validity of using the proposed setup to control the output voltage or motor speed while providing high power factor in all test cases.

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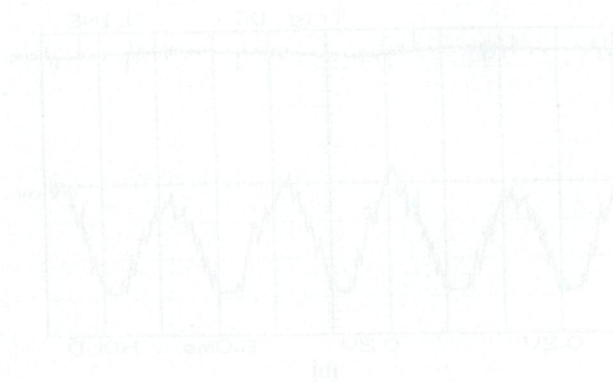
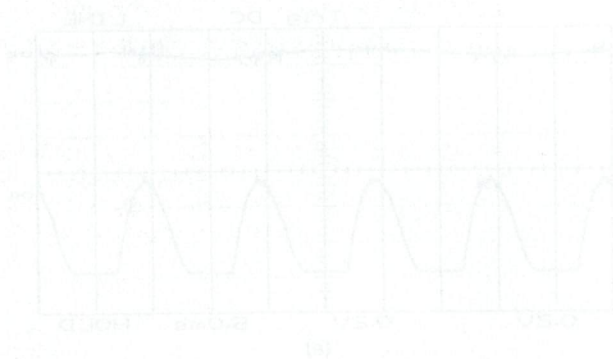


Fig. 7. Motor speed and supply current for unity power factor operation: (a) without controller and (b) with controller for motor speed of 800 rpm.

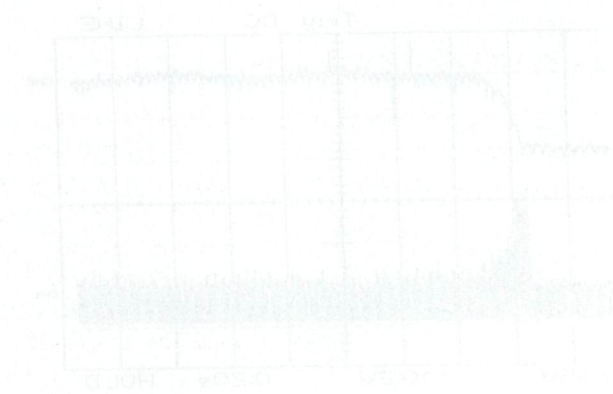


Fig. 8. Motor speed and supply current for speed step operation.

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