An Efficient Method of Controlling AC Power Using DSP 2407-A Controller

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Abstract

This paper presents the design and hardware implementation of ac power controller card using TMX320LF DSP 2407A controller. Sinusoidal PWM technique is used to control the ac power. The on chip capture unit is made use of to sense the speed of the AC motor which reduces the hardware. The designed controller is tested by regulating speed of an AC motor in closed loop and the results show comprehensive efficiency in terms of set speed to speed achieved.

Keywords:

captureunit, DSP2407A controller, modulation index, SPWM signals, zero crossing.

1. Introduction

Single phase inverters are widely used in induction heating, standby power supplies and uninterrupted power supplies[1].To control voltage of single phase inverter, sinusoidal pulse width modulation technique[2][3], is used, which significantly reduces low order harmonics and distortion factor. The Sinusoidal pulse width modulation technique makes use of reference sine wave and carrier triangular wave to generate PWM signals. The root mean square (rms) output voltage value of a sinusoidal PWM inverter can be varied by varying the modulation index (width of the pulses changes), which is defined as

$$\delta = A_r / A_c \quad (1)$$

Where A_r and A_c are amplitude of reference and carrier signal. The rms output voltage is given by

$$V_s = \left(\sum_{m=1}^{2p} \frac{\delta_m}{\pi} \right)^{1/2} \quad (2)$$

Where delta is the modulation index and p is the number of pulses. The fundamental output voltage [7] depends on the number of pulses per half cycle, but at the same time more

number of pulses leads to over modulation, which inurn adds up more harmonics.

The disadvantages associated with microcontroller based single phase SPWM inverter [4] are its speed of operation, higher power consumption and additional hardware requirement.

The modern DSP'S [5] with higher speed of operations, large memory capacity, power control application related on-chip peripherals and power saving facilities, helps in reducing extra hardware and power consumption.

This paper presents the simple and low cost alternating voltage controller designed using DSP2407A based PWM inverter. The designed power card can be used to control ac loads which don't demand very high precisions.

2. Design Flow

The controller block diagram is as shown in Figure-1. The 4 digit required speed in RPM (rotation per minute) is entered through 4X4 keypad and at the same time they are displayed on LCD using DSP controller. The DSP controller generates reference sine wave as well carrier triangular wave and compares them in order to generate two SPWM signals.

The current running speed of the motor is read, using Capture unit of DSP controller and is compared with the set speed. Modulation index is varied, by varying the amplitude of the sine wave till the motor attains the set speed. The current speed of the motor is continuously displayed on LCD (liquid crystal display) using DSP controller.

The bridge inverter output is passed through step up transformer to boost the output signal level to 220 volts from 30volts, so that it can drive the 220 volts ac motor. The power circuitry is isolated from controller using ILQ74 optoisolator.

The main routine of the program generates sine wave, triangular wave and SPWM gate signals. The interrupt service routine program accepts the keys, displays the set and current running speed of the motor, reads the current running speed of the motor from the capture unit and compares that with set speed and varies the modulation index.

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3. Controller Implementation

The controller implementation flow is explained in the forgoing sections.

3.1 LCD and Keyboard Interface

A 4x4 keypad is interfaced with DSP controller, through which four keys are accepted. The columns of the keypad is connected to port B ,which is configured as input port ,through which column status is read and rows of the keypad is connected to port C, which is configured as output port, using which rows are activated one by one. After interrupting the DSP through X1INT interrupt, four keys are scanned and detected. Using software codes they are further processed to form 4 digit speed in RPM.

A 16x2, 14 pin LCD [8] is used to display four digit set speed and motor's current running speed. LCD accepts characters in ASCII format. Command signal to the LCD is sent through port F and data are sent through port E of the DSP controller. For sending any of the command to the LCD the RS Pin [8] is made low and for data the RS pin is made high. A falling edge pulse on the enable pin latches the information present on the data pins of LCD.

3.2 Generation of Spwm Gate Signal

The SPWM gate signals are obtained by generating two sinusoidal signals of opposite polarity, called reference signals(reference signal 1 and reference signal 2), and one triangular wave of higher frequency called carrier signal. The required two SPWM gate signals to drive inverter bridge circuit is generated as follows.

Sample value of reference signal 1 is compared with the sample value of carrier signal and a high is maintained if reference sample value is higher than carrier sample value else it is maintained low. Similar procedure is carried out to generate second SPWM gate signal by comparing reference signal 2 with the carrier signal.

i.e. $V_{reference} > V_{carrier}$ = High gate output (3)

$V_{reference} < V_{carrier}$ = low gate output (4)

The two SPWM gate signal sample thus generated are subtracted to get the required gate signal which will be fed to the diagonal switches of inverter bridge circuit. After every half cycle, i.e., at every zero crossing of reference signals, gate signal is altered so that same gate signal is applied alternatively to diagonal switches of the inverter bridge circuit.

The required dead band time of 60ns [8] for IRFZ48N MOSFET switch can be either generated through software delay or using inbuilt dead time generator. In this research we have used software delay (to minimize Hardware) to create required dead band time to avoid dead short circuits.

3.3 Capture Unit

To read the current running speed of the motor, Capture unit of DSP controller is used. For every rotation of the motor IR sensor produce one pulse. These pulses are applied as input to the capture unit(CAP1 Pin).The value of the general purpose timer(GP) timer is captured and stored in the corresponding 2-leveldeep FIFO(first in first out) stack when a specified transition is detected on a capture input pin(CAP1 Pin).

Capture FIFO status register is checked for the valid two FIFO entries (either by polling or interrupt method) and the time difference between these two entries will give the time taken for one rotation. The reciprocal of the time difference gives the number of rotation per minute. Therefore current speed in RPM is given by:

RPM = 1/ (difference between two FIFO stack reading * time for one cycle) (5)

After calculating the current running speed, Sine wave amplitude is adjusted to get the reference speed or set speed.

4. Results and Conclusion

The designed hardware is tested by running AC motor at different speeds as shown in Figure-3. The results obtained indicate an accuracy of 97% at lower speeds and efficiency improves at higher speeds. Figure-4 illustrates the variation in modulation index with respect to the reference or set speed.Figure-5 shows the output of the inverter at 800 RPM.Figure-6 explains the error in percentage in achieving the set speed. Further improvement in the performance can be achieved by using LC filters, which will reduce higher order harmonics. Since we have used step-up transformers to boost the signal level, primary of the transformer will add to the inductance effect at the load, this slightly distorts the waveform at inverter output. This can be avoided by using higher rating MOSFETS and thereby avoiding usage of transformers.

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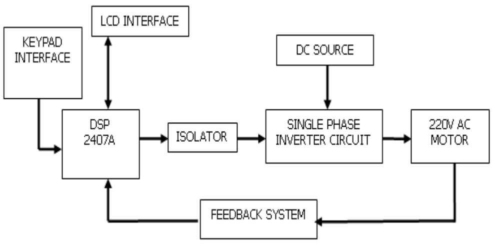

Fig-1 Controller Block Diagram

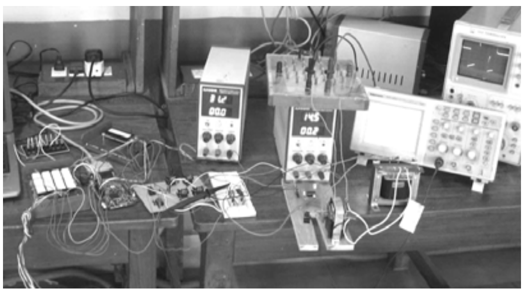

Fig-2 Experimental set up

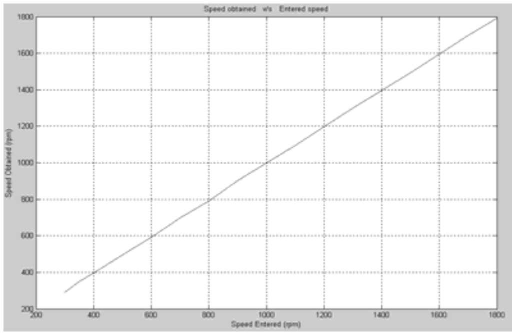

Fig-3 Reference v/s Motor current speed

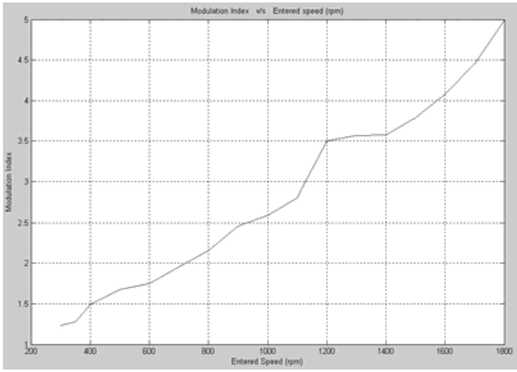

Fig-4 Modulation index v/s speed

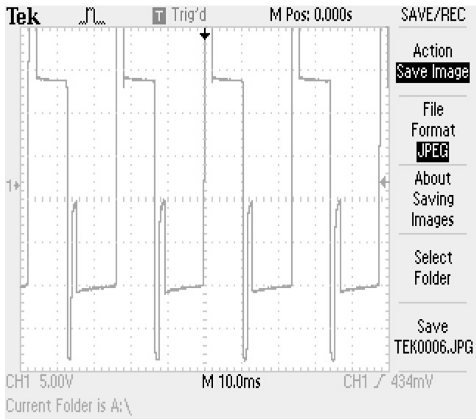

Fig-5 Square wave output at 800 RPM (distortion due to inductance effect)

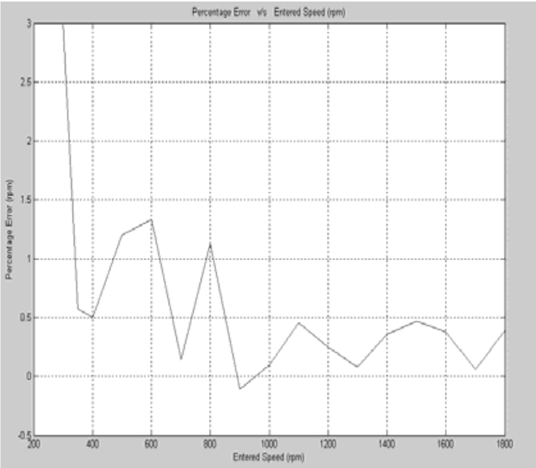

Fig -6 Percentage error v/s Entered Speed

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