LOW COST, HIGH EFFICIENT SPWM CONTROLLER FOR PHOTOVOLTAIC INVERTER

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Abstract. In recent trends, the development and implementation of photovoltaic (PV) power generation and its utility is gaining more attention due to energy crisis. In this paper, the development of single phase sinusoidal pulse width modulation (SPWM) controller based inverter control for PV application is presented. An algorithm is developed using a low cost dsPIC micro controller to control the inverter operation. A 500W prototype is developed in the laboratory and the experiments are conducted. The THD is measured for different operating conditions and the maximum THD obtained is 4%.

Keywords: Photovoltaic Power generation, SPWM control, dsPIC microcontroller.

1. Introduction

In the tropical regions such as India and Latin America, distributed generation of power using PV module is the future trend to solve energy crisis. This inverter should operate over a wide working range of various sunlight and environmental conditions. Also the output of inverter must obey the power standards like total harmonic distortion, power factor and electromagnetic interference (EMI). Main reason to deal with the energy crisis is to reduce the price per watt for the full system, where the inverter is integrated with the system to reduce the total power consumption. The SPWM is a major control scheme in inverter, due to its features like low THD in output voltage, low switching losses and higher output voltage for the same dc-bus voltage. In practice most of the single phase SPWM implementation is done with analog ICs. The drawback of the analog control is difficulty in circuit modification and its control. Therefore it is proposed to implement a digital SPWM control in this work. This paper presents the development of a low cost SPWM controller using dsPIC 33FJ16GS504 microcontroller.

2. System Overview

The system consist of a microcontroller circuit gate driver, full bridge inverter circuit, step up transformer, LC filter and a feedback network for output correction. The feedback is optically isolated to protect the low voltage components from the hazardous environment. Here the step up transformer is designed with respect to the carrier frequency of the SPWM signal. The SPWM is used instead of maintaining the width of all pulses the same as in the case of multiple-pulse modulation, the width of each pulse is varied in proportion to the amplitude of a sine wave evaluated at the center of the same pulse. This helps to reduce distortion factor and the lowest order harmonics significantly.

3. SPWM Topology

The heart of the system is a dsPIC 33FJ16GS504 Microcontroller. This microcontroller is specially developed for the generation of Sinusoidal PWM (SPWM) with dead time control. The dead time controller circuit is useful to make the design simpler, more reliable and the most important thing is to reduce the cost

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and components. dsPIC 33FJ16GS504 generates four Sinusoidal PWM signals. RB0 to RB3 pins are output for Sinusoidal PWM signals.

33FJ16GS504 is a 16-bit, low power, high performance microcontroller with DSP capability. This controller has programmable memory capacity of 16K and an inbuilt crystal of 32MHz speed. The controller has various peripheral interfaces like 4 PWM channels, 12 ADC inputs with 10bit resolution and 35 I/O Pins with individual control.
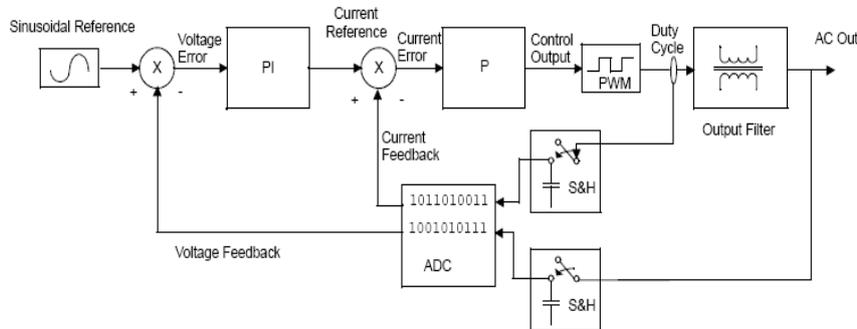

Fig. 1: Inverter Control Scheme

Table 1: dsPIC® DSC device resource allocation for full-bridge converter

Signal Name	Description	Type of Signal	dsPIC® DSC Resource Used	Sample Rate/ Frequency
S1	Inverter Drive Signal	PWM Output	PWM1L	6.25KHz
S2	Inverter Drive Signal	PWM Output	PWM1H	6.25KHz
S3	Inverter Drive Signal	PWM Output	PWM2L	6.25KHz
S4	Inverter Drive Signal	PWM Output	PWM2H	6.25KHz
I	Inverter Output current Feedback	Analog Input	AN1	25KHz
AC0	Inverter Output Voltage Feedback	Analog Input	AN2	25KHz
TMP	Bridge Stage Temperature	Analog Input	AN3	25KHz

4. Gate Driver

TLP250 is a Toshiba made photo coupler made of GaAiAs Ired LED and two photo transistors with a simple 8 pin DIP package is used as the gate driver. The supply amplitude of the SPWM pulse (V_a) should be in the range of -15V to +15V to ensure that the MOSFET work in enhanced mode. This method is employed to maintain simplicity by reducing the external components.

5. Power Circuit

A full bridge inverter topology is chosen and used as the power circuit to handle high current at low voltage. This power circuit module consists of four power MOSFETs, a step up transformer and a LC filter circuit. IR3205 HEXFETs are used to deliver high current at low voltage to the step up transformer. An LC filter is implemented to suppress the harmonic content. The pulsating signal in the output is converted into a sinusoidal output.

6. Feedback and Control Circuit

A feedback network is constructed to take the necessary corrective action at the output stage with respect to the dynamic load. The feedback circuit consists of an optoisolator to isolate the low voltage components from hazardous voltage level. 4N35 is a 6 pin DIP opt isolator with transistor output. It is made up of gallium arsenide IR LED optically coupled with a silicon photo transistor. The transistor output of the optoisolator is coupled with signal conditioning circuit. The signal from the feedback network is acquired by the controller and the necessary control action is performed.

7. Fault State Criteria and Its Protection

There are many fault sources and disturbances which can influence the output of the system. These faults will make the system to enter the ERROR MODE. These include the following

- Battery Under voltage
- Battery Over voltage
- Output over current
- Over temperature

The error mode will trigger a single or a combination of faults depending on the operating condition. For example, a battery under voltage will not cause the system to enter the error mode if the soft start routine is active. Similarly transient load may cause the output current to exceed the limit for a short duration. Therefore, an output over current condition persists for an extended duration. All faults that are destructive to the system or to the load acting through the inverter are handled in high priority control loops. The over temperature fault is an example. Some other signals do not require high speed response and these faults are handled in normal priority during runtime.

8. Conclusion

In this paper the development of single phase SPWM controller based inverter for PV application is presented. The main aim for the development of such an inverter with a controller is to reduce the price per watt of the full system upon integration of the inverter with the system. SPWM control is implemented in dsPIC 33FJ16GS504 microcontroller using MicroC for dsPIC. The experiment is carried out using a 500W inverter. The results are obtained for different input voltages to the inverter and different load ratings. The maximum THD is measured as 5%. It is found that the SPWM inverter is working satisfactorily in different load conditions. Efficiency chart has been prepared using the recorded readings have been presented in the figure.6. This inverter can be a solution to the current energy crisis by reducing the price per watt and also conservation of total energy consumed by the system considerably. This can be implemented in very large geographies that are a part of the tropical countries that include India, Latin America apart of African continent.
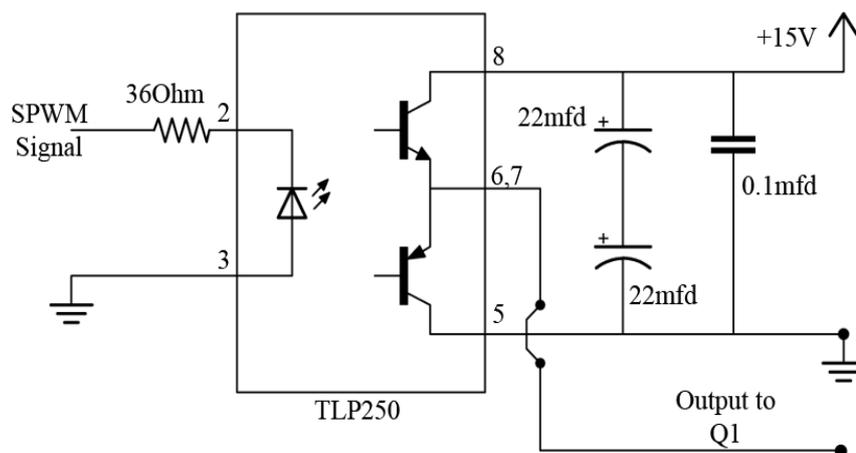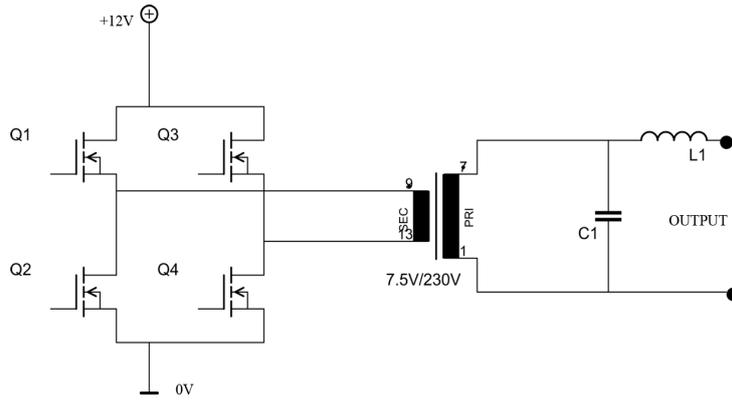
Fig. 2: MOSFET driver circuit
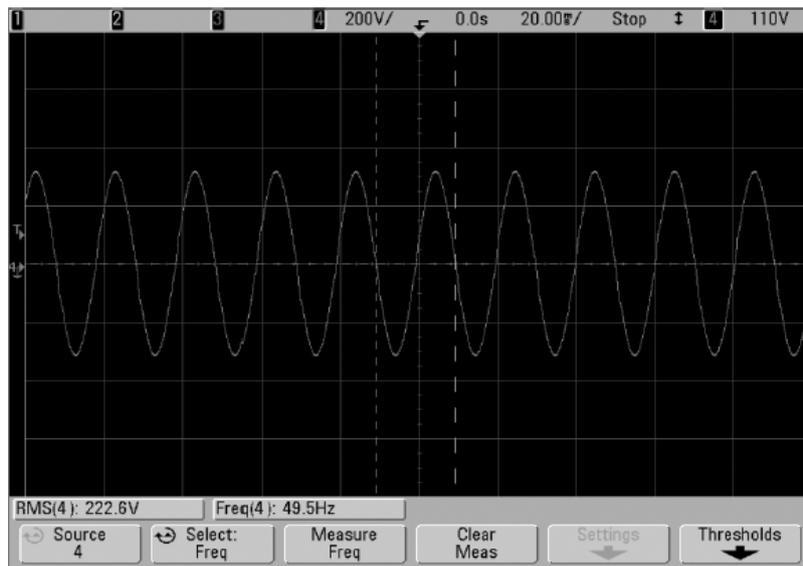
Fig. 3: Power Circuit

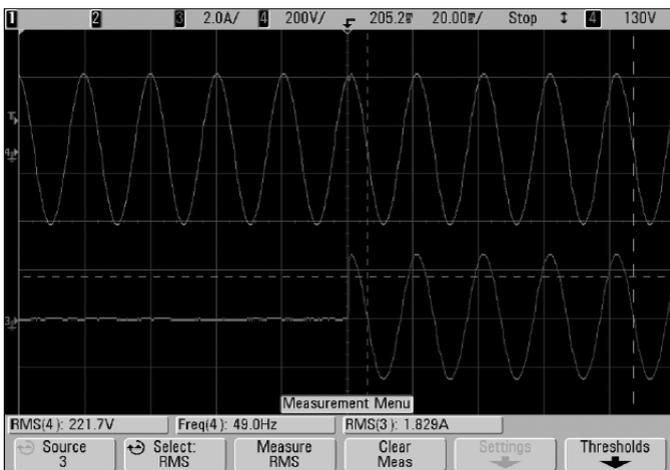Fig. 4: SPWM Signals viewed in a DSO with Computer Interface at No load
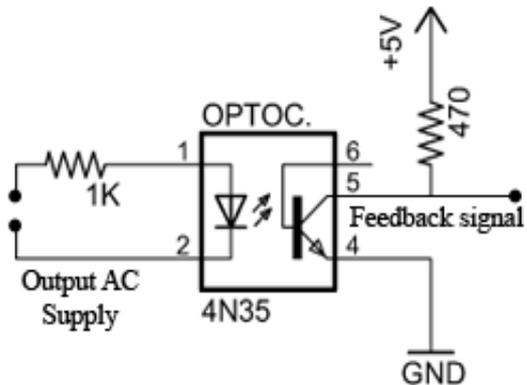

Fig. 5: Dynamic load responses – 450W load step
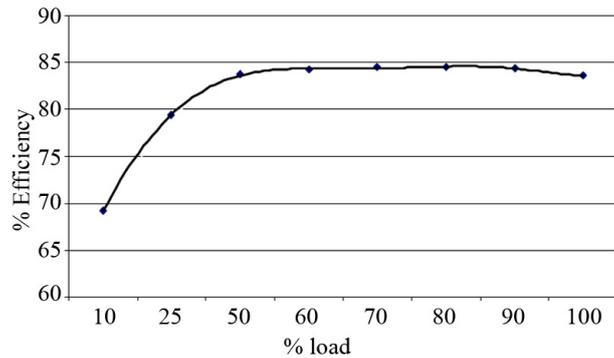

Fig. 5: Feedback isolation circuit

Fig. 6: Efficiency Chart

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