Matlab Simulink Modelling of the DC-AC Inverter

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Abstract: Modeling and simulation are very useful for the development and implementation in both hardware and software design.   It can lead to improve the performance, reduced development and production cost and time.   This paper presents a Matlab Simulink model of the DC/AC inverter which is used in inverter power supply systems.   PI controller used to control the PWM pulses which control the switching operations of the transistors is also modeled. The principle of operations and the key features of the PWM of the DC/AC inverter are also presented.   The performance of the DC/AC inverter is investigated in both open loop control and closed loop control.

Keywords: DC/AC power conversion, pulse width modulation, microcontroller, embedded system

1. Introduction

A power inverter is a device that converts DC (Direct current) from sources such as batteries, solar panels, fuel cell, or wind to an AC (Alternative current) so that the output can be used in a wide range of AC applications including uninterruptible power supplies, motor controllers ,kitchen applications, house hold applications and Electric vehicles.

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Power inverters were first invented using a square wave output form, which led to many different problems involving the functionality of the devices that were being powered because they were designed to work with a sine wave instead of a square wave.   As the next step the researchers added some modification in to the hardware circuit to eliminate the harsh corners from the square wave and the device named modified sine wave power inverter.   The power inverter which used the modified sine wave minimizes the problem which occurred due to the square wave but it does not eliminate it.   A quantum leap occurred in the inverter power supplies when it became possible to use the Pulse Width Modulation Technique (PWM) to get the pure sine wave output.   Nowadays, Due to widespread use of the microcomputer based system in several applications and due to the fast development of the low cost microcontroller, engineers and researchers have been using digital control technique to improve the performance of the inverter power supply [6].   This paper deals with the inverter power supply which uses the SH2 microcontroller to generate the PWM patterns to produce the sinusoidal output.   This paper is organized as follows.   Section 2 describes the inverter power supply topology.   A single phase pulse width modulation is presented in section 3. Section 4 presents the PID controller which is used to adjust the modulation ratio.   Matlab model of the DC/AC inverter and the simulation results are presented in section 5 and 6, respectively.

2. Inverter Power Supply

As mentioned before, the inverter power supply is a device which can convert the DC to an AC voltage that can be used in different AC applications.   There are many different topologies which are used to determine the parts of the inverter power supply [1-5].   The choice of such topology depends on many factors such as size, cost, efficiency and capability.   In this paper, the inverter power supply has been broken into two stages.   The first stage is to step up the DC voltage level by using DC/DC converter and the second stage is

to convert the DC level to AC through the DC/AC inverter.   The system block diagram of the inverter power supply is shown in Figure 1.
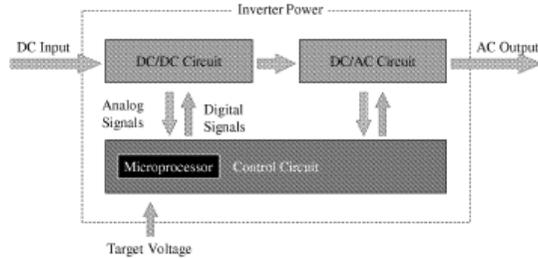

Fig.1 Block diagram of inverter power supply

In Japan the standard AC output wave consists of 100 V and 60Hz.   This paper focuses on second part which is the DC/AC inverter.

2.1. DC/AC Inverter

There are many different topologies for the DC/AC inverter. The most common topology is the full bridge configuration because of easy filtering [4,10].   The single phase full bridge inverter is shown in Figure 2, the gates of the transistors are controlled by the PWM generator output which is controlled by the PI (Proportional and Integral) controller algorithm.
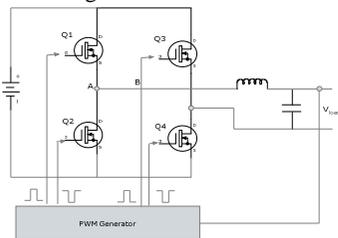

Fig. 2 Equivalent DC/AC inverter circuit

3. Pulse Width Modulation

Nowadays, pulse width modulation (PWM) is playing a major role in the generation of the pure sine [8-9]. Pulse width modulation can be defined as a switching method used for the conversion of the DC to AC, where the pulse width (duty cycle) at the switching gates of the transistors is varied according to a sinusoidal reference (control signal).   Generation of the pulse width modulation (PWM) pattern can either be done by using two different techniques which are analog and digital techniques[8].   For understanding the methodology of the PWM, a common analog PWM is described below.

The PWM can be done simply by comparing a sinusoidal control signal at the desired frequency with a triangular wave form (carrier signal).   At each point where the control signal and the carrier signal are intersect the output of the PWM is toggled from high state to low state as shown in Figure 3.
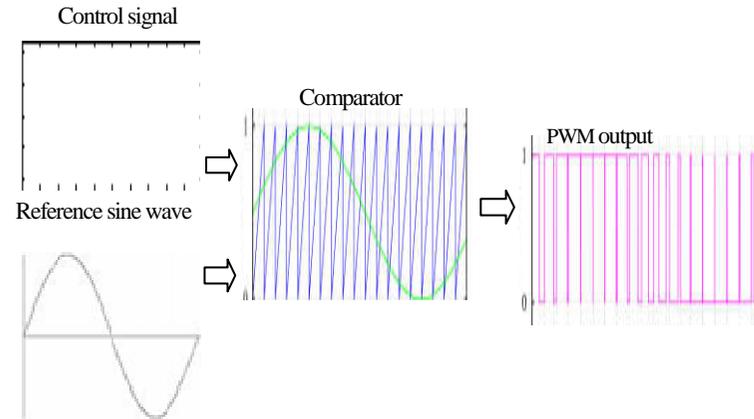

Fig.3 PWM pulse generator

The frequency of the carrier signal is generally kept constant along with its value. The control signal is used to control the switching duty by changing its value as a factor called modulation ratio m as described in equation (1),

$$m = V_{controller} / V_{carrier} \qquad (1)$$

As a second technique for the PWM, the micro controller, DSP and FPGA can be used to generate the PWM [3] , it is called a digital technique .

4. PID Controller

The proportional –integral –differential (PID) control is a popular feedback control method. It has been used in many industrial control systems. The main reasons for its popularity are its simple structure, which can be easily understood and implemented in practice, and its excellent flexibility [6]. Figure 4 describes the classic PID controller block diagram.
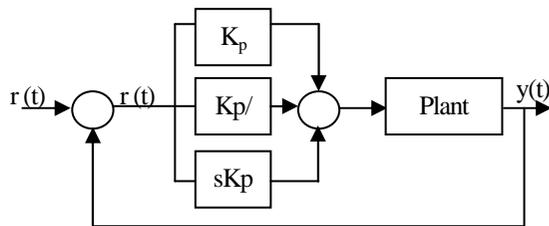

Fig.4 Classic PID controller

5. Simulation Results

Modeling and simulation is very useful for the development and implementation in both hardware and software. It can lead to improve the performance, reduced development and production cost and time.

There are a variety of software that are used for that purpose including Matlab and Simulink. Matlab and Simulink is software designed for modeling, simulating and analyzing, it supports linear and nonlinear system models in continuous time, sampled time or combination of both [7]. It consists of a rang of blocks such as communications, control, power system, and neural networks, etc. For the inverter power supply modeling the power system block set is convenient.

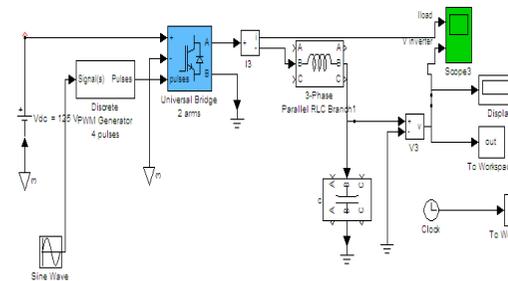The matlab Simulink model of DC/ AC inverter circuit of Figure 2 is shown in Figure 5.

Fig.5 Open loop Matlab model of DC/AC system

The full bridge block is used to model the actual full bridge which consists of the four MOFFET transistors Q1, Q2, Q3, and Q4. The pulse pin describes the PWM output. The PWM block can be used to generate pulses which are used to control the switching operations of the transistors.

The next sections deal with the two different cases of the DC/AC inverter which are the open loop control and the closed loop control

5.1 Open Loop Control

As the first step the modulation index was set to obtain 200 V RMS at no load then a linear load is connected to the open loop inverter. The simulation results for both cases are represented in Figure 7 and

Figure 8, respectively. It can be seen that the load voltage has been reduced from 200 V to 169.7 V (84%) which will result in reducing the load power
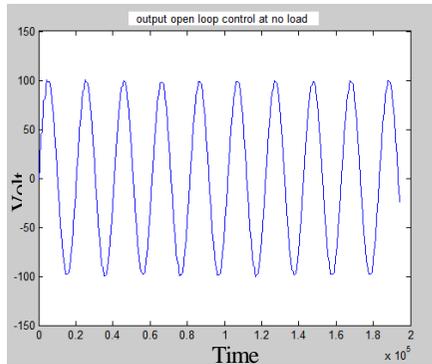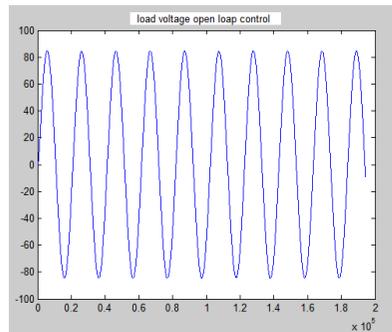

Fig. 7 Simulated output with no load

Fig. 8 Simulated output with linear load

5.2 Closed loop controlled

As the second step, we check the performances of the model after applying the PI controller. The main purpose for applying the PI controller is to control the value of the modulation ratio which adjusts the

PWM pulses which is used to the switching operations of the transistors. And also keep the voltage constant with different loads. Figures 9a and 9b present the DC/AC inverter models with the PI controller.
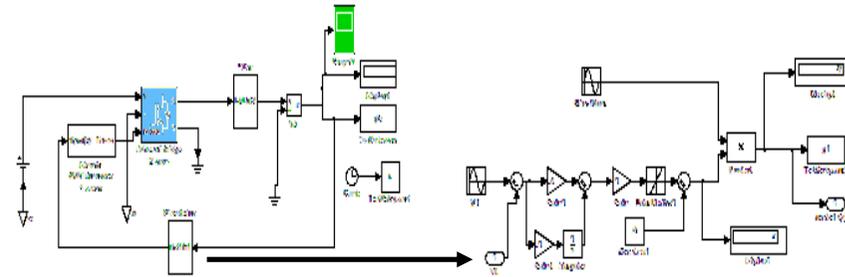

Fig.9a Closed loop Matlab model of DC/AC system   Fig. 9b Maltlab model of the PI controller

As shown in Figures 9a and 9b, the error signal is generated by comparing the load voltage V_L with the target output V_T. Subsequently, the error signal has been applied to the PI controller. Adjusting the PI coefficients is selected based on the trial and error technique. We can see the effect of applying the PI controller to the inverter, the performances are shown in Figures 10 and 11.
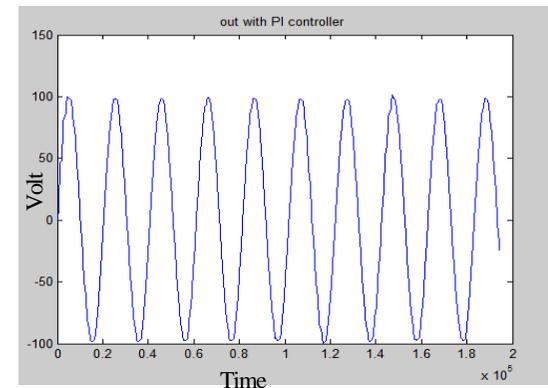

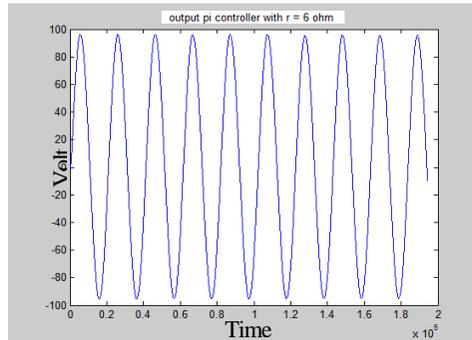Fig.10 Simulated output with PI controller in case of no load

Fig. 11 simulated output with linear load

It can be seen that the load voltage has been reduced from 200 V to 196 V (98%).

From sections 5.1 and 5.2, it can be seen using the PI controller improves the DC/AC inverter performance.

6. Conclusion and Future Work

This paper presented Matlab and Simulink model of the DC/AC inverter. The model is developed using the power system block set and it is shown that Matlab and Simulink software is a good tool to describe the DC/AC inverter as well as to improve the system performances by using the PI controller.

In this paper Matlab and Simulink is used as a tool for modeling. For the extension of the current work a new method for hardware modeling called the virtual device generation approach will be researched in the future work. A virtual device is defined as an instruction set simulator for the hardware of the embedded system, that is, the entire hardware model of the system in the virtual world. In this approach, we generate a virtual device based on the objected oriented programming method. The suggested method is aimed to minimize the suspension time of the embedded software development, due to that the simulator will be available in an early stage. This leads to improving the embedded software quality and reducing the total development time needed to complete the system.

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