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Design of an improved PWM inverter using PI controller

[1] Bharati Mishra, [2] Swati Sucharita Kar

[1] Department of Energy System, Electrical Engg College of Engineering and Technology, Bhubaneswar India

[2] Department of Energy System, Electrical Engg College of Engineering and Technology, Bhubaneswar India

Abstract

Inverters are used in a large number of power applications. The function of an inverter is to convert DC power to AC, these are referred to as Voltage Source Inverters (VSI). VSI are divided up into three categories: Pulse-width Modulated Inverters, Square-wave Inverters, and Single-phase Inverters with Voltage Cancellation. This paper will talk about the different types of Inverters and how they work. It will continue on with examples of some types of inverters and what types of factors affect their efficiencies. Our project is based on the design of PWM Inverter and PI Controlled PWM Inverter for the performance analysis and comparison of the techniques for best DC-ac conversion scheme evaluation. Our proposed scheme has been designed in MATLAB/SIMULINK environment showing performance measures.

Keywords: Pwm, Pi Controller, Inverter, Photo Voltaic, Matlab/Simulink.

Introduction

Within the last decade, there have been major advancements in power electronics. Power electronics have moved along with these developments with such things as digital signal processors being used to control power systems. An Inverter is basically a converter that converts DC-AC power. Inverter circuits can be very complex so the objective of this paper is to present some of the inner workings of inverters without getting lost in some of the fine details. A voltage source inverter (VSI) is one that takes in a fixed voltage from a device, such as a DC power supply, and converts it to a variable-frequency AC supply.

Voltage-source inverters are divided into three general categories: Pulse-width Modulated (PWM) Inverters, Square-wave Inverters, Single-phase Inverters with Voltage Cancellation. Pulse-width modulation inverters take in a constant DC voltage. Diode-rectifiers are used to rectify the line voltage, and the inverter must control the magnitude and the frequency of the ac output voltages. To do this the inverter uses pulse-width modulation using it's switches. There are different methods for doing the pulse-width modulation in an inverter in order to shape the output ac voltages to be very close to a sine wave. These different methods will be discussed further with a focus on sinusoidal-PWM. Squire-wave inverters have their input connected to a controlled DC voltage in order to control the magnitude of the output ac voltage. The inverter only controls the frequency of the output where the input voltage is controlled the magnitude. The output ac voltage has a waveform similar to a square wave which is where the inverter got it's name. Lastly, Single-phase inverters with voltage cancellation, take in a constant DC source and output a square-wave like ac voltage. They can control both the frequency and the magnitude of the output but do not use PWM and therefore have a square-wave like output. These inverters have combined characteristics of the previous two inverters. The voltage cancellation only works with single phase inverters, not three phase, this will be explained more further later on in the paper.

Switch-mode DC-to-ac inverters are used in ac-motor drives and uninterruptible ac power supplies where the main objective is to provide a sinusoidal ac output where magnitude and frequency can both be controlled.

Byoung-kuk Lee et.al (2002) proposed a functional simulation model for the voltage-source inverter (VSI) using the switching function concept is studied and the actual implementation of the model is proposed with the help of Matlab Simulink. Also, this concept is extended to the voltage-doubler-type pulse width-modulated (PWM) AC-DC rectifier and the PWM AC-DC-AC converter. With the developed functional model, the simplification of the static power circuits can be achieved so that the convergence and long run-time problems can be solved. Also, in the functional model, the design parameters, such as voltage and current ratings of the power semiconductor switches and load current, can be easily calculated. The general switching function concept is reviewed in brief and the proposed functional models for the VSI, voltage-doubler rectifier, and PWM AC-DC-AC converter and their implementations using Matlab Simulink are explained in detail. Also, several informative simulation results verify the validity of the proposed models

Boost Converter

Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. The main components of a boost converter are an inductor, a diode and a high frequency switch. These in a coordinated manner supply power to the load at a voltage greater than the input voltage magnitude. The control strategy lies in the manipulation of the duty cycle of the switch which causes the voltage change [11] and [12].

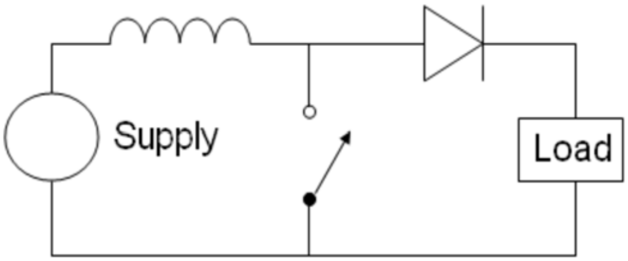

Fig 1: A boost converter

Modes of Operation

There are two modes of operation of a boost converter. Those are based on the closing and opening of the switch. The first mode is when the switch is closed; this is known as the charging mode of operation. The second mode is when the switch is open; this is known as the discharging mode of operation [12].

A. **Charging Mode**
In this mode of operation; the switch is closed and the inductor is charged by the source through the switch. The charging current is exponential in nature but for simplicity is assumed to be linearly varying [11]. The diode restricts the flow of current from the source to the load and the demand of the load is met by the discharging of the capacitor.

B. **Discharging Mode**
In this mode of operation; the switch is open and the diode is forward biased. The inductor now discharges and together with the source charges the capacitor and meets the load demands. The load current variation is very small and in many cases is assumed constant throughout the operation.

Waveforms

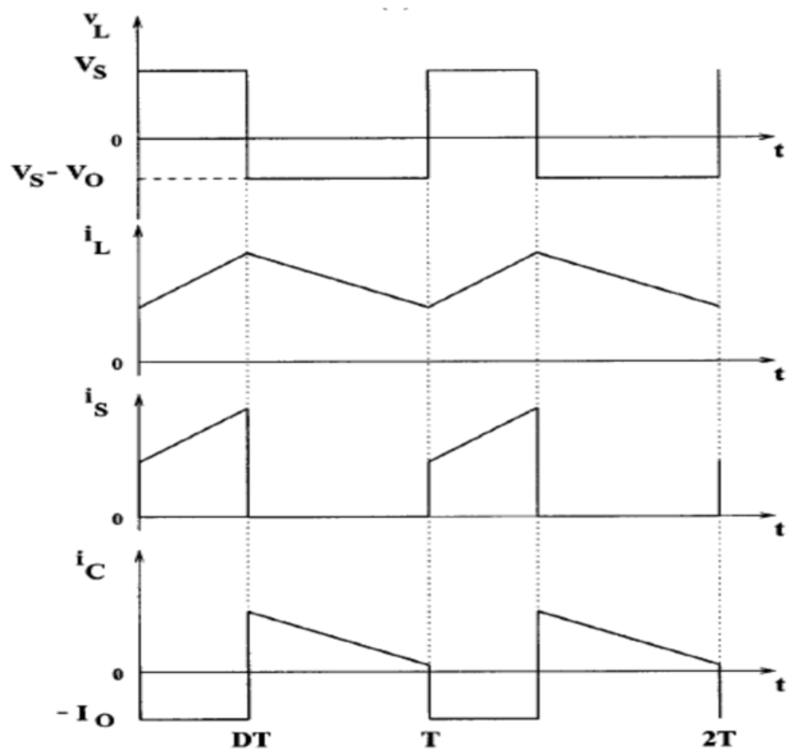

Fig 2: Modes of Operation

Pulse-Width Modulated (PWM)

Inverters that use PWM switching techniques have a DC input voltage that is usually constant in magnitude. The inverters job is to take this input voltage and output ac where the magnitude and frequency can be controlled. There are many different ways that pulse-width modulation can be implemented to shape the output to be AC power. A common technique called sinusoidal-PWM will be explained. In order to output a sinusoidal waveform at a specific frequency a sinusoidal control signal at the specific frequency is compared with a triangular waveform (See Figure 7a). The inverter then uses the frequency of the triangle wave as the switching frequency. This is usually kept constant.

The triangle waveform, inverter, is at a switching frequency fs, this frequency controls the speed at which the inverter switches are turned off and on. The control signal, voltage control, is used to modulate the switch duty ratio and has a frequency f1. This is the fundamental frequency of the inverter voltage output. Since the output of the inverter is affected by the switching frequency it will contain harmonics at the switching frequency. The duty cycle of the one of the inverter switches is called the amplitude modulation ratio, ma [3].

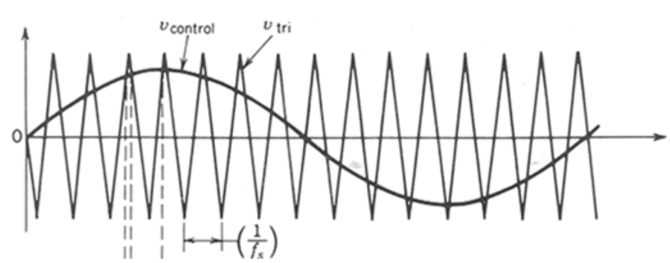

Fig 3: Desired frequency is compared with a triangular waveform

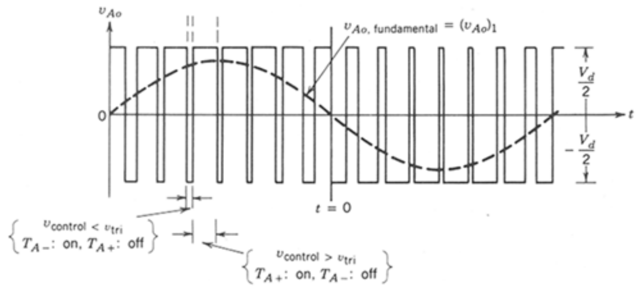

Fig 4: Pulse-width Modulation (PWM)

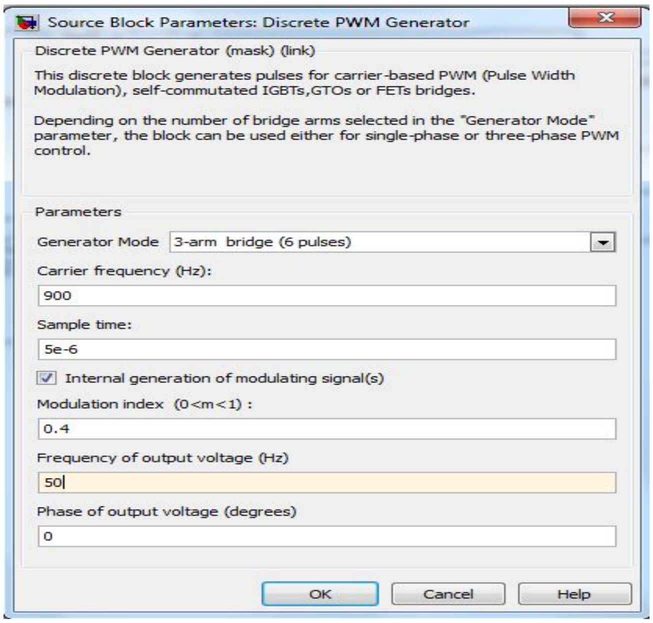

Fig 5: Matlab/Simulink Based Input for Pwm

Proposed Method

This paper proposes a three-phase inverter for with a novel pulse width-modulated (PWM) control scheme. The behavior of the proposed inverter was analyzed in detail. By controlling the pulse width or duty cycle, the desired inverter's output voltage can be achieved.

The inverter is capable of producing more than 300V output-voltage levels from the 200 DC supply voltage. A digital proportional–integral current-control algorithm was implemented to keep the current injected into the grid sinusoidal.

DC Voltage Source were connected to the inverter via a DC–DC boost converter. The power generated by the inverter is to be delivered to the power network. The DC–DC boost converter was required because the DC Voltage arrays had a voltage that was lower than the required voltage. High DC bus voltages are necessary to ensure that power flows from the DC Source to the system for DC-ac conversion. A filtering circuit C was used to filter the current injected into the Load.

This paper has presented a novel PWM switching scheme for the proposed multilevel inverter. It utilizes three reference signals and a triangular carrier signal to generate PWM switching signals.

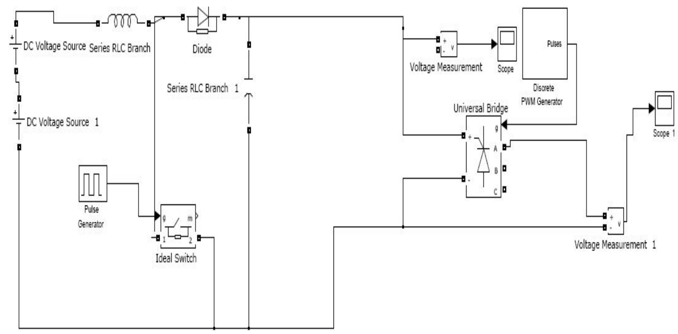

Fig 6: Simple Three Phase PWM Inverter Model:

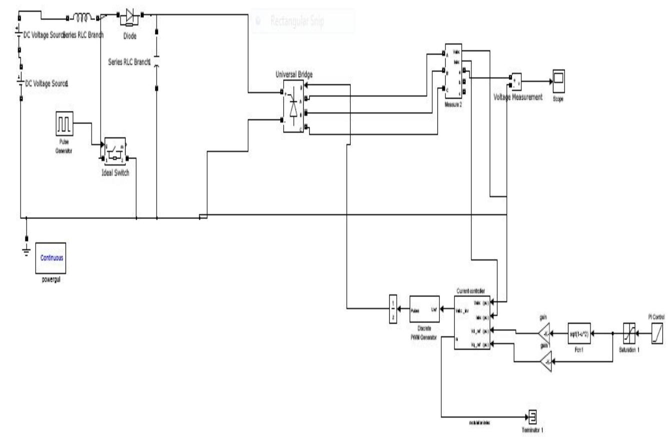

Fig 7: PI controller based Three Phase PWM inverter

Table 1: Comparison for the techniques

Proposed Scheme	DC Voltage Input	AC Voltage Output
Conventional PWM Inverter	200	380
Modified PI based PWM Inverter	200	390

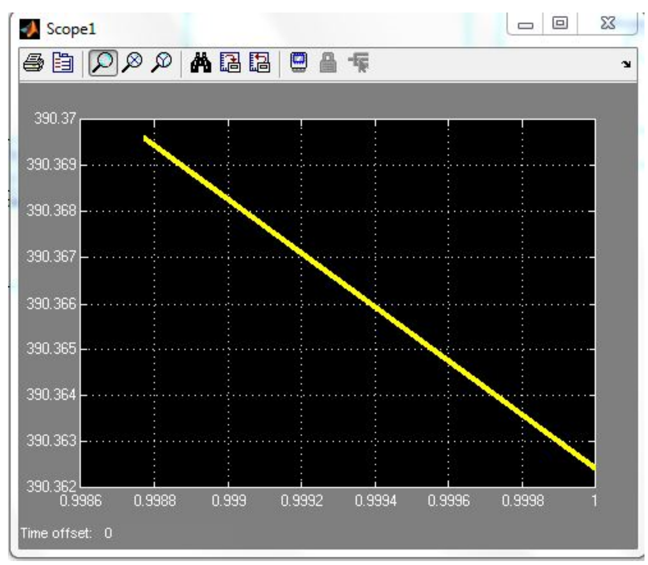

Fig 8: Results for the proposed scheme

Conclusion

The proposed system was verified through simulation and implemented in a prototype.

In the Present Work, the three phase inverter design using simple discrete PWM and PI controller based PWM techniques are successfully carried out by this research. The PI based scheme for the PWM Inverter actually improves the system efficiency. Compared to the conventional methods of VSI (Voltage Source Inverter), this method seems to be easy and effective giving better performance. By varying the duty cycle of the Inverter, the source impedance can be matched to adjust the load impedance which improves the efficiency of the system in real time implementations.

In the future works, we may work an analytical solutions of pulse width-modulation (PWM) strategies for multilevel inverters which may be used to identify that alternative phase opposition disposition PWM for diode-clamped inverters producing the same harmonic performance as phase-shifted carrier PWM for cascaded inverters and hybrid PWM for hybrid inverters.

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