DEVELOPMENT OF P-RESONANT CONTROLLER FOR Z-SOURCE THREE PHASE INVERTER

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Specially dedicated to…

My parents, and my instructors who have helped me in difficult times, and I do not forget my friends who support me and help me in the duration of the projects. And the nameless people who counseled me, directly or indirectly.

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ABSTRACT

This project presents a P-Resonant (PR) controller to control the output current and voltage for a Z-Source three phase inverter. The model scheme is developed and simulated in MATLAB/Simulink software environment. The Z-Source inverter is special type of inverter that provide the voltage boost capability in which it results with an output voltage greater than the input DC voltage and that cannot be obtained using the traditional inverter. Using the P-Resonant controller, the inverter reference tracking performance can be enhanced. Simulation study of P-Resonant controller is presented. The results show the P-Resonant controller achieves very good results with a good tracking capability for the reference values of both current and voltage. Besides, it maintains a small error signal which makes it a preference controller compared to the other traditional controllers.

CONTENTS

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

DC	direct current
AC	alternating current
VSI	voltage source inverter
CSI	Currentsource inverter
ZSI	Z-source inverter
PR	Proportional Resonant
PWM	Pulse Width Modulation
SPWM	sinusoidal pulse-width modulation
PI	Proportional integral
PID	Proportional Integral Derivative
PD	Proportional Derivative
SVM	Space Vector Modulation

CHAPTER 1

INTRODUCTION

This chapter discusses the background of the research, the objectives of project, problem statement and scopes of study.

1.1 Introduction

Recently, power electronics has evolved and becomes very important in our life. Power electronics is a technology that deals with the conversion and control of electrical power with high-efficiency switching mode electronic devices for a wide range of applications. This include a dc and ac power supplies, electrochemical processes, heating and lighting control, electronic welding, power line volt–ampere reactive (VAR) and harmonic compensators, high-voltage dc (HVdc) systems, Flexible AC Transmission Systems, photovoltaic and fuel cell power conversion, high-frequency (HF) heating and motor drives. Power electronics has found an important place in modern technology being a core of power and energy control. Almost all the new electrical and electromechanical equipment contain power circuits [1].

1.2 Background of Project

The power inverter is an electronic device that can transform a direct current (DC) into alternating current (AC) at a given voltage and frequency. The inverters are used in photovoltaic off-grid (stand alone) for powering electric remote houses, mountain chalets, mobile homes, boats and are also used in grid-connected photovoltaic systems to enter the current produced by the plant directly into the power grid distribution (solar inverters). The inverters are also used in many other applications, ranging from UPS to speed controllers for electric motors, from power supplies switching to lighting. By the term "inverter" is designed to include a group "rectifier-inverter", supplied with alternating current and used to vary the voltage and the frequency of the alternating current output as a function of the incoming (eg for the supply of particular machinery). The most common inverters used to power the AC loads are of three types: square wave inverter (suitable for resistive loads), modified sine wave inverter (suitable for resistive, capacitive, inductive loads can produce noise) and pure sine wave inverter (suitable for all types of loads because faithfully reproduce a sine wave equal to that of our domestic power supply).

Three-phase inverters are used for variable-frequency drive applications and for high power applications such as HVDC power transmission. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals. For the most basic control scheme, the operation of three switches is coordinated so that one switch operates at each 60^0 point of the fundamental output waveform. This creates a line-to-line output waveform that has six steps. The six steps waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated as described above. When carrier-based PWM techniques are applied to six step waveforms, the basic overall shapes, or envelope, of the waveform is retained so that third harmonic and its multiples are cancelled [2].

The Z-source inverter is an alternative power conversion topology that can both buck and boost the input voltage using passive components. With its unique structure, Z-source inverter can utilize the shoot through states to boost the output voltage, which improves the inverter reliability greatly, and provides an attractive single stage dc to ac conversion that is able to buck and boost the voltage. The shoot-through duty cycle is used for controlling the dc link voltage boost and hence the output voltage boost of the inverter [3].

P-Resonant (PR) controller gained a large popularity in recent years in current regulation of grid-tied systems. It introduces an infinite gain at a selected resonant frequency for eliminating steady-state error or current harmonics at the frequency. However the harmonic compensators of the P-Resonant controllers are limited to several low-order current harmonics, due to the system instability when the compensated frequency is out of the bandwidth of the systems [4].

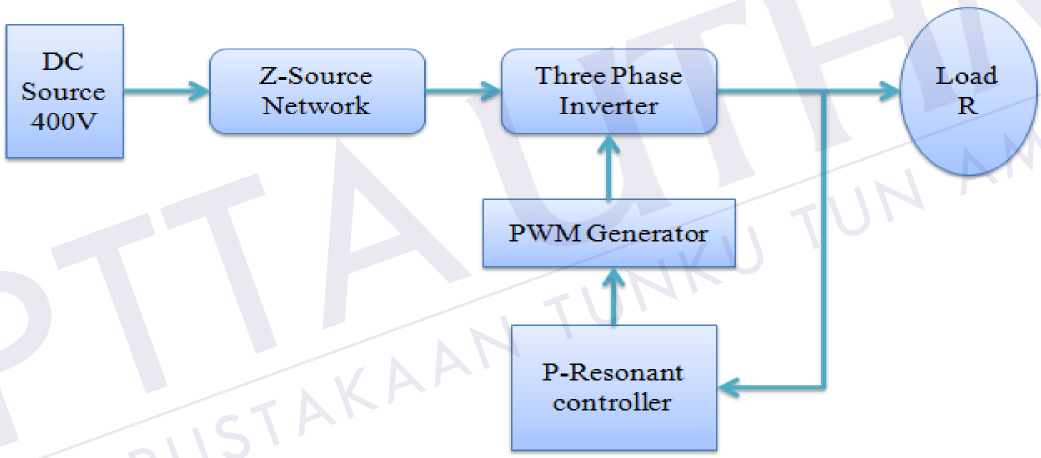

Figure 1.1: Project block diagram.

1.3 Problem Statement

Z-Source inverter widely used in many applications that required high controlled. In controlling Z-source inverter current/voltage, there are several ways can be used as conventional PI or PD become a suitable solution. However, the capabilities of these controllers are limited and the performance is not the best possible.

The inverter needs to be controlled. There are many types of controllers. These controllers have solution. However, have the main problem is that large steady state error.

Z-source inverter (ZSI), which is based on Z-source network, can buck and boost the output AC voltage, which is not possible using traditional voltage source or current source inverters. Z-source can have greater output AC voltage than the input, wish is not possible using traditional voltage source or current source inverters.

1.4 Project objectives

The objectives of this project are:

1. to develop and simulate the three-phase Z-Source inverter.
2. to boost the output voltage of the three-phase Z-Source inverter.
3. to develop P-Resonant controller that suitable for three Z-Source inverter.
4. to control the output current and voltage of Z-Source three phase inverter and reduce the steady state error.

1.5 Project scopes

This project is concerned with the scopes as follows:

1. Presenting and modeling of the three-phase Z-Source inverter that will be modeled using MATLAB Simulink software.
2. P-Resonant control with Sinusoidal Pulse width Modulation (SPWM) technique will be used to control the switching signals.

1.6 Project Structure Outlines

This project consists of five chapters.

Chapter 1 discusses the background of the research. In addition, the problem statement, objectives of project, scopes of study and project structure outline are presented.

Chapter 2 summarized the information of the related previous studies on the Z-Source inverter. In addition, the chapter covers the block diagrams and implementation model of the inverters and the controllers. It is covers also the comprehensive of the controller problems.

Chapter 3 discusses the methodology of implementation the three phase Z-Source inverter with P-Resonant controller and design it using MATLAB simulink.

Chapter 4 presents the results and analysis of Z-Source three phase inverter and introduces the results with analysis of P-Resonant controller with different situations of reference current and reference voltage.

Chapter 5 the conclusion of this project for Z-Source three phase inverter with P-Resonant controller are presented and recommendations for future works

CHAPTER 2

LITERATURE REVIEW

This chapter summarizes the information of the related previous studies on inverters on general and Z-Source Inverter. In addition, the chapter covers types of most inverters, the related topologies, the effective control technique methods. The base comments and their detailed functions will be introduced and discussed. These reviews are done based on materials from journals, conference proceeding and books.

2.1 Overview of Inverters

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC) [5]. The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry.

2.1.1 Applications of Inverter

The inverter does not produce any power; the power is provided by the DC source. A power inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. Static inverters do not use moving parts in the conversion process [6]. The inverters have been used in many applications, such as DC power source utilization, an inverter converts the DC electricity from sources such as batteries or fuel cells to AC electricity. The electricity can be at any required voltage; in particular it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage [5].

In addition, they are used in Uninterruptible power supplies. An uninterruptible power supply (UPS) uses batteries and an inverter to supply AC power when main power is not available. When main power is restored, a rectifier supplies DC power to recharge the batteries. Moreover, the inverters are used in Electric motor speed control. Inverter circuits designed to produce a variable output voltage range are often used within motor speed controllers. The DC power for the inverter section can be derived from a normal AC wall outlet or some other source. Control and feedback circuitry is used to adjust the final output of the inverter section which will ultimately determine the speed of the motor operating under its mechanical load. Motor speed control needs are numerous and include things like: industrial motor driven equipment, electric vehicles, rail transport systems, and power tools. Switching states are developed for positive, negative and zero voltages. The generated gate pulses are given to each switch in accordance with the developed pattern and thus the output is obtained [1]. Furthermore, they are utilized in Power grid. Grid-tied inverters are designed to feed into the electric power distribution system. They transfer synchronously with the line and have as little harmonic content as possible. They also need a means of detecting the presence of utility power for safety reasons, so as not to continue to dangerously feed power to the grid during a power outage.

Energy Solar is another application of the inverters. A solar inverter is a balance of system (BOS) component of a photovoltaic system and can be used for both, grid-connected and off-grid systems. Solar inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection. Solar micro-inverters differ from conventional converters, as an individual micro-converter is attached to each solar panel. This can improve the overall efficiency of the system. The output from several micro inverters is then combined and often fed to the electrical grid [7]. Rather than energy solar the HVDC is used. With HVDC power transmission, AC power is rectified and high voltage DC power is transmitted to another location. At the receiving location, an inverter in a static inverter plant converts the power back to AC. The inverter must be synchronized with grid frequency and phase and minimize harmonic generation [8].

2.2 Inverter

The inverters have different topologies and the most known topologies are three phase current source inverter (abbreviated as I-source converter) and three phase voltage source inverter (abbreviated as V-source converter). In the I-source converter we deal with the current in the analysis of the performance. However, the performance analysis of the V-source converter is depended on the voltage. These two types will be explained in the next subsection.

2.2.1 Three Phase Current Source Inverter

Figure 2.1 shows the current-source converter (abbreviated as I-source converter) structure. A dc current source feeds the main converter circuit, a three-phase bridge. The dc current source can be a relatively large dc inductor fed by a voltage source such as a battery, fuel-cell stack, diode rectifier, or thyristor converter. Six switches are used in the main circuit, each is traditionally composed of a semiconductor switching device with reverse block capability such as a gate-turn-off thyristor (GTO) and SCR or a power [9].

Transistor with a series diode to provide unidirectional current flow and bidirectional voltage blocking. However, the Current-source converter has the following conceptual and theoretical barriers and limitations.

The ac output voltage has to be greater than the original dc voltage that feeds the dc inductor or the dc voltage produced is always smaller than the ac input voltage. Therefore, the I-source inverter is a boost inverter for dc-to-ac power conversion and the I-source converter is a buck rectifier (or buck converter) for ac-to-dc power conversion. For applications where a wide voltage range is desirable, an additional dc–dc buck (or boost) converter is needed. The additional power conversion stage increases system cost and lowers efficiency [9].

At least one of the upper devices and one of the lower devices have to be gated on and maintained on at any time. Otherwise, an open circuit of the dc inductor would occur and destroy the devices. The open-circuit problem by EMI noise's misgating-off is a major concern of the converter's reliability. Overlap time for safe current commutation is needed in the Current-source converter, which also causes waveform distortion, etc [10].

The main switches of the Current-source converter have to block reverse voltage that requires a series diode to be used in combination with high-speed and high-performance transistors such as insulated gate bipolar transistors (IGBTs). This prevents the direct use of low-cost and high-performance IGBT modules and intelligent power modules (IPMs) [11].

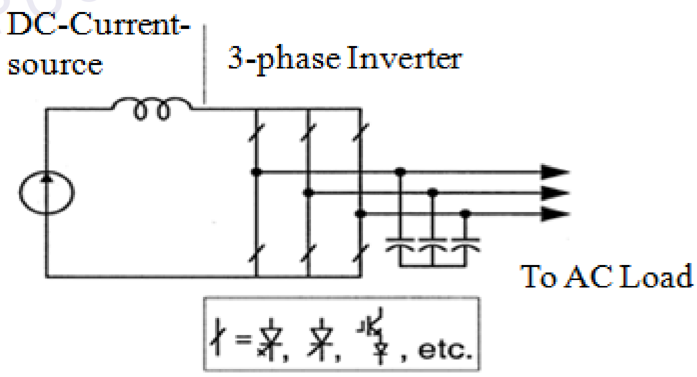

Figure 2.1: Traditional Current-source inverter.

2.2.2 Three Phase Voltage Source Inverter

Figure 2.2 shows the Voltage-source converter (abbreviated as V-source converter) structure. A dc voltage source supported by a relatively large capacitor feeds the main converter circuit, a three-phase bridge.

The dc voltage source can be a battery, fuel-cell stack, diode rectifier, and/or capacitor. Six switches are used in the main circuit; each is traditionally composed of a power transistor and an antiparallel (or freewheeling) diode to provide bidirectional current flow and unidirectional voltage blocking capability. The V-source converter is widely used. It, however, has the following conceptual and theoretical barriers and limitations [12].

The ac output voltage is limited below and cannot exceed the dc-rail voltage or the dc-rail voltage has to be greater than the ac input voltage. Therefore, the V-source inverter is a buck (step-down) inverter for dc-to-ac power conversion and the V-source converter is a boost (step-up) rectifier (or boost converter) for ac-to-dc power conversion. For applications where over drive is desirable and the available dc voltage is limited, an additional dc-dc boost converter is needed to obtain a desired ac output. The additional power converter stage increases system cost and lowers efficiency [10].

The upper and lower devices of each phase leg cannot be gated on simultaneously either by purpose or by EMI noise. Otherwise, a shoot-through would occur and destroy the devices. The shoot-through problem by electromagnetic interference (EMI) noise's misgating-on is a major killer to the converter's reliability. Dead time to block both upper and lower devices has to be provided in the V-source converter, which causes waveform distortion.

An output *LC* filter is needed for providing a sinusoidal voltage compared with the Current-source inverter, which causes additional power loss and control complexity [13].

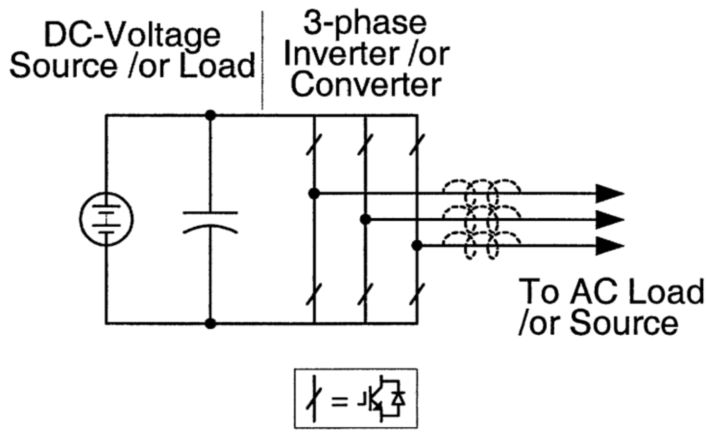

Figure 2.2: Traditional V-source inverter.

2.2.3 Disadvantages of Current Source Inverter (VSI) and Voltage Source Inverter (CSI)

Typical inverters (VSI and CSI) have few disadvantages as Behave in a boost or buck operation only. Thus the obtainable output voltage range is limited, either smaller or greater than the input voltage. Vulnerable to EMI noise and the devices gets damaged in either open or short circuit conditions. The combined system of DC-DC boost converter and the inverter has lower reliability. The main switching device of VSI and CSI are not interchangeable [14].

2.3 Z-Source Inverter

The Z-source inverter is an alternative power conversion topology that can both buck and boost the input voltage using passive components. With its unique structure, Z-source inverter can utilize the shoot through states to boost the output voltage, which improves the inverter reliability greatly, and provides an attractive single stage dc to ac conversion that is able to buck and boost the voltage [15].

2.3.1 Single Phase Z-Source Inverter

The Z-Source inverter [16] provides a single-stage topology for both voltage boosting and inversion. The topology of single-phase full bridge Z-Source inverter is shown in Figure 2.3.

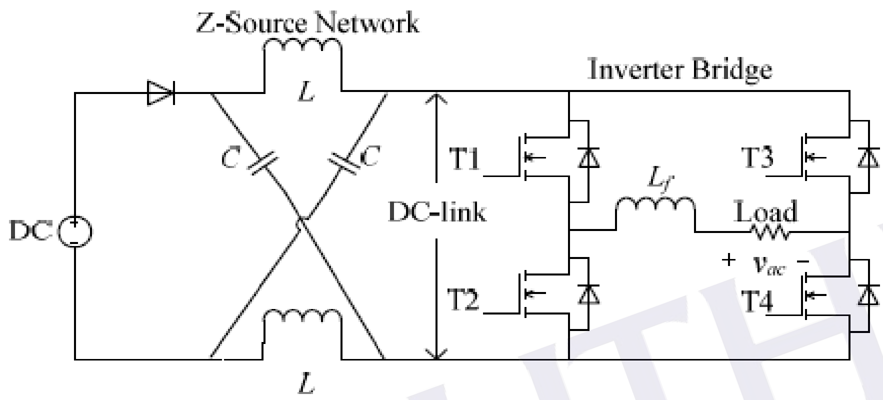

Figure 2.3: Single-phase full bridge Z-Source inverter.

The DC-side of a conventional single-phase full bridge voltage source inverter is modified with a unique X-shape impedance network, which is known as the Z-Source network. Therefore, shoot-through state, which is strictly forbidden in conventional voltage source inverters, is allowed and implemented here for voltage boosting purposes. Since the capacitor in the Z-Source network may be charged to a higher voltage than the DC source, a diode is connected to prevent possible discharging. To realize the bidirectional power flow characteristic, the diode can be replaced with an IGBT with anti-paralleled diode to form a bidirectional Z-Source converter [17].

2.3.2 Three Phase Z-Source Inverter

The unique feature of the Z-source inverter is that the output ac voltage can be any value between zero and infinity regardless of the fuel-cell voltage. That is, the Z-source inverter is a buck–boost inverter that has a wide range of obtainable voltage. The traditional V- and I-source inverters cannot provide such feature. To describe the

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