GENERATE THREE PHASE SOURCE FROM SINGLE PHASE SUPPLY

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MAY 2009

"I hereby declare that I have read through this report entitle generate three phase source from single phase supply and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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Date	:	08 MAY 2009

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A report submitted in partial fulfillment of the requirements for the Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2009

I declare that this report entitle generate three phase source from single phase supply is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ZURAIDA HANIM BINTI ZAINI

Date : 08 MAY 2009

To my beloved family…

ACKNOWLEDGEMENT

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ABSTRACT

The main purpose of this project is to analyze the way to generate three phase source from single phase supply. In order to achieve the objective of this project, the analysis about phase converter was made. A Phase converter is a device that converts power provided as single or multiple phases to a different number of phases. The majority of phase converters are used to produce three phase electrical power from a single phase source, thus allowing the operation of three phase equipment at a site that only has single phase electrical service. Phase converters are used where three phase service is not available from the utility, or is too costly to install due to a remote location. This project will focus on application of Variable Frequency Drive (VFD) as a phase converter. VFD are designed primarily to control the speed of Alternating Current (AC) motor, but can be adapted to function as phase converters because VFD has the ability to create voltages that vary in frequency.

ABSTRAK

Tujuan projek ini utama itu adalah untuk analisa kaedah untuk menjana sumber tiga fasa daripada bekalan satu fasa. Untuk mencapai objektif projek ini, analisis tentang penukar fasa telah dibuat. Penukar fasa adalah sebuah alat yang menukar kuasa yang dibekalkan samada satu fasa atau berbagai fasa kepada fasa yang berlainan. Kebanyakan penukar fasa digunakan untuk menghasilkan kuasa elektrik tiga fasa daripada bekalan satu fasa yang membolehkan peralatan tiga fasa beroperasi dengan hanya bekalan satu fasa. Penukar fasa digunakan dikawasan yang tidak boleh dibekalkan dengan perkhidmatan tiga fasa, atau dikawasan pendalaman dimana pemasangan perkhidmatan tiga fasa akan menelan belanja yang besar. Fokus projek ini adalah terhadap penggunaan Pemacu Frekuensi Bolehubah (VFD) sebagai penukar fasa. Kegunaan utama Pemacu Frekuensi Bolehubah adalah untuk mengawal kelajuan motor arus ulang-alik (AC), tetapi fungsinya boleh diadaptasi sebagai penukar fasa kerana Pemacu Frekuensi Bolehubah mempunyai kebolehan untuk menghasilkan voltan semasa frekuensi berubah.

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LIST OF ABBREVIATION

AC	-	Alternating Current
DC	-	Direct Current
IGBT	-	Insulated Gate Bipolar Transistor
PWM	-	Pulse Width Modulation
VFD	-	Variable Frequency

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A wide variety of commercial and industrial electrical equipment requires three phase power. Electric utilities do not install three phase power as a matter of course because it costs significant more than single phase installation. As an alternative to utility installed three phase, rotary phase converter and rotary phase converter have been used for decades to generate three phase power from single phase source.

Construction of three phase power lines can cost expensively and can have an undesired environmental impact. Even when three phase lines are nearby, the cost installation is considerable. Based on anticipated electricity demand for three phase application, the utility may not charge the customer for the cost of an installation. Continuing monthly surcharges for the service are also common.

Phase converters have historically been employed where utility three phase was unavailable, or where the electricity demand did not justify the cost of utility three phase installation. Reduced motor life caused by voltage and current imbalance, harmonics that pollute the power grid and damage equipment, or the inability to operate sensitive equipment or multiple loads are just some of the problems that have limited the use of phase converter.

1.2 PROJECT OBJECTIVE

The Variable Frequency Drive (VFD) was not originally design to function as phase converter; in fact most VFD's are powered from a three phase source. The main target is to make the VFD able to transform the single phase power to three phase source and work properly. The project will use VFD because of the ability to create voltages that vary in frequency.

There are some objectives that need to be achieved to complete this project which are:

i) To study the basic of phase converter.
ii) To analyze the characteristics of VFD.
iii) To conduct the lab session.
iv) To analyze the result of experiment.

1.3 PROJECT SCOPE

There is little scope in doing this final year project. Firstly, study and analyze the characteristics of VFD and identify the component that will connect together with the VFD. Then, conduct the lab session and testing. Finally, the analysis from the lab session will be carried out.

1.4 PROBLEM STATEMENT

The design of VFD phase converter is built to provide speed control for three phase motor. With today's technology, manufacturer have designed phase converter to transform three phase electrical power from a single phase source. Existing phase converter in the market is difficult to control the frequency and voltage to accommodate changing load. The VFD phase converter will be able to create voltages that vary in frequency.

In order to generate three phase source, the output will be approach solution to reduce the cost of phase service. This design will improve portable phase converter, VFD are design in light weight and easy to use.

Hitachi X200 Series Inverter is the new equipment that available in the Power Efficiency Lab at Faculty of Electrical Engineering. Since the equipment is new, the complete user manual and complete documented manual that describes the steps on handling the equipment needs to be provided. The manual and lab procedures will be discussed in this project considering to the safety precaution.

Even though the basic testing procedure manual has been provided by the manufacturer, the steps on handling the equipment is not elaborated in details. So, it is necessary to analyze the characteristic and specification in order to apply in the laboratory for earning process. The testing procedures and safety precaution should be prepared. It also necessary to ensure that all the equipment is follows the specification which has been given by supplier.

1.5 THESIS OUTLINE

Chapter 1 explains the background and problem statement of the project. The project objective and scope are also expressed in this chapter. In addition, the project methodology describes the important action to ensure the completeness of this project is discussed.

Chapter 2 discuss literature review of the project and the source achieved by gathering information through internet and references book to further study on theory related to this project.

Chapter 3 explains the methodology that use in this project. This chapter will show the project implementation schedule.

Chapter 4 discusses the overview of Hitachi X200 Series Inverter and ways to setup this equipment, application and safety precaution when conducting the experimental work.

Chapter 5 explains the result and analysis of this project. The experimental results are being analyzed in this chapter.

Chapter 6 discusses the conclusion and recommendation of these project activities. The recommendation given may be postulated as a contribution to future time to university and industry.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 INTRODUCTION

Electricity supply systems have to deliver power to many type of load. The greater power supplied, for given voltage, the greater the current. Three phase systems are well suited to electricity supply application because of their ability to transmit high powers efficiently and to provide powerful motor drive.

2.2 DISADVANTAGES OF THE SINGLE PHASE SYSTEM.

The earliest application of alternating current was for heating the filaments of electric lamps. For this purpose the single phase system was perfectly satisfactory. Some years later, a.c motors were developed, and it was found that for this application the single phase system was not very satisfactory. For instance, the single phase induction motor- the type most commonly employed- was not self starting unless it was fitted with an auxiliary winding. By using two separate winding with current differing in phase by a quarter of a cycle or three winding with currents differing in phase by a third of a cycle, it was found that the induction motor was self starting and had better efficiency and power factor than the corresponding single phase machine.

The system utilizing two windings is referred to as a two phase system and that utilizing three windings is referred to as three phase system.

2.3 THREE PHASE SYSTEM

One of the reasons for using three-phase systems instead of single phase is that by adding a third wire it is possible to distribute electric power more effectively. In a single phase AC circuit there is one "feeding" and one returning path. The two wires making the paths have the same loss of energy due to resistance because they carry exactly the same current. In a three phase AC-circuit the currents are out of phase, so when one wire is "feeding" current to a motor winding, the other two wires make the returning path at the same time as they are feeding current to the other two motor windings. The sum of the three currents is alway zero, and then actually one can say that three returning wires have been omitted.

Another reason for using three phase electrical power is that it makes a very simple and efficient connection between a generator and a motor, ie transmitting mechanical energy from one place to another at low cost without losing too much energy. The "rotating magnetic field" in the generator is converted to AC-current, and the exact opposite happens in the motor. The principle is simple, and it is possible to connect several motors as well as generators to the same power line. But the motors and generators must run at the same frequency, therefore AC-motors connected to mais run at constant speed.

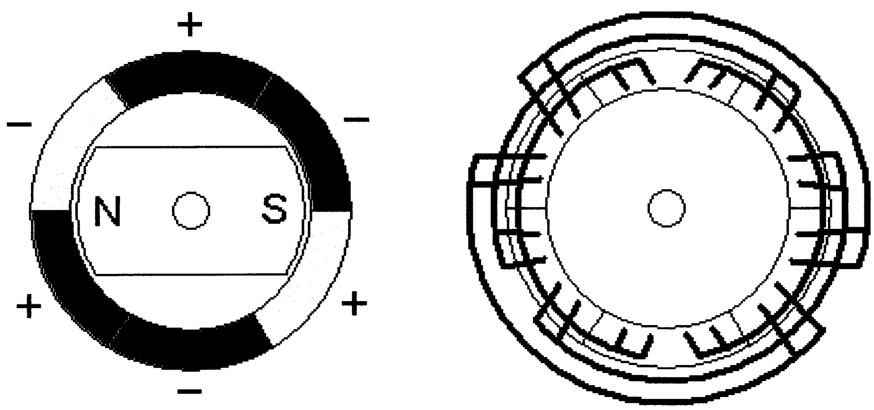

Figure 2.3.a: Three phase system

The poles in a three phase motor are located 1/3 turn or 120 degrees relative to each other. "Real" windings to the right.

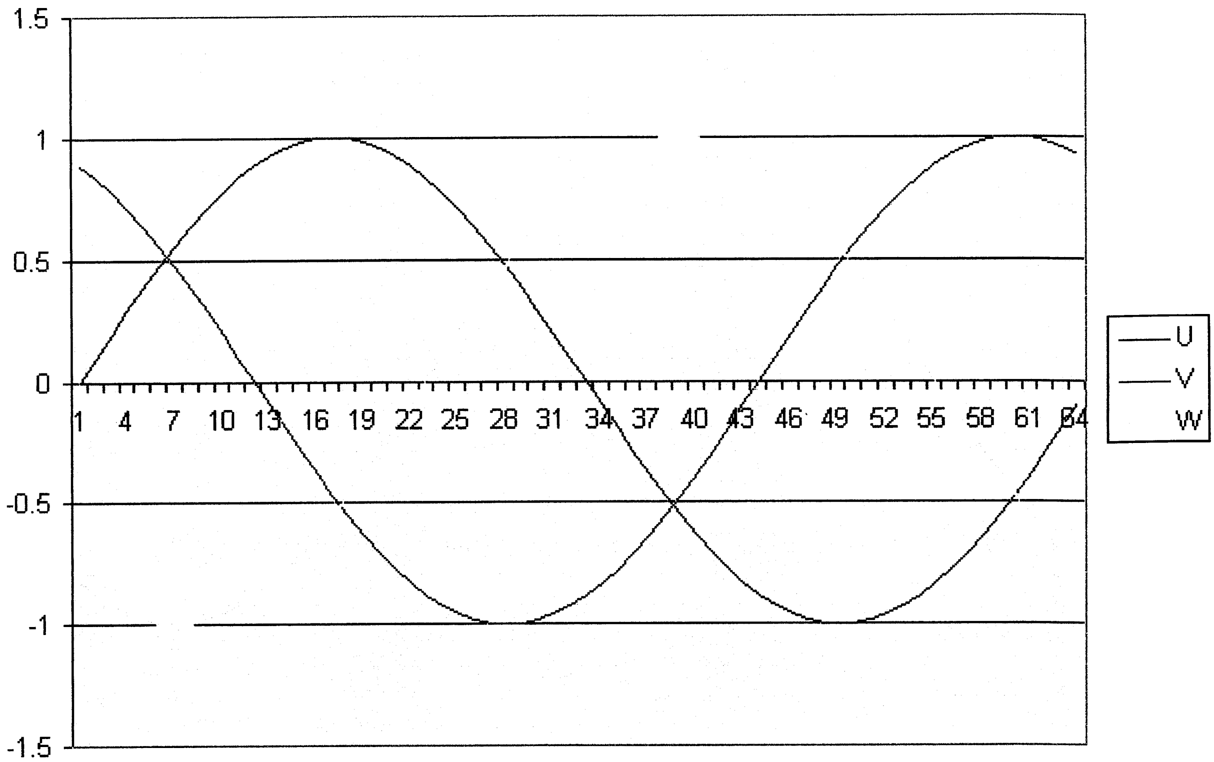

Figure 2.3.b: Three phase waveform

The electric current form three sine waves. The phases are 120 degrees apart. Rotor position can be found by adding the currents as vectors at any time instant.

2.4 PHASE CONVERTER

A phase converter is a device that converts power provided as single phase or multiphase to a different number of phases. The majority of phase converters are used to produce three phase electrical power from a single phase source, thus allowing the operation of three phase equipment at a site that only has single phase electrical service. Phase converters are use where three phase service is not available from the utility, or is too costly to install due to a remote location. A utility will generally charge a higher fee for a three phase service because of extra equipment for transformer and metering and the extra transmission wire.

Figure 2.4.a: Static phase converter

The simplest type of old technology phase converter is generally called a **static phase converter**. This device typically consists of one or more capacitors and a relay to switch between the two capacitors once the motor has come up to speed. These units are comparatively inexpensive. These phase converter use of the idea that a three phase can be started using a capacitor in series with the third terminal of the motor. It is almost guaranteed hat a static converter will do a poor job of balancing the voltage on the motor. Unless motor operated on static converters run only for short periods or deliver significantly less than half of their rated output, they will damaged from overheating.

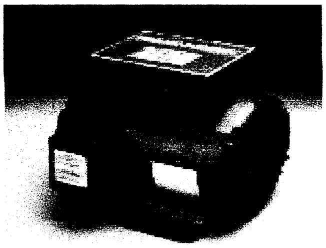

Figure 2.4.b: Rotary phase converter

The second type of old technology phase converter is generally called a **rotary phase converter.** This device consists of a three phase motor (usually without external shaft) and a bank capacitors wired together to act as a single large capacitor. Two of the leads to the motors are connected to the single phase power source and the third lead to the motor is connected in series with the capacitor bank to either one of the single phase input. The output leads from the phase converter are connected across the three motor terminals. Typically, the motor used in the phase converters is large than the loads it is supplying. The electrical interaction between the capacitor bank and the free running phase converter motor generated a voltage on the third motor terminal which approximates the voltage needed for a balanced three phase system. However, it usually isn't a very good approximation.

2.5 AC-MOTOR SPEED CONTROL

Different kind of machines, ie conveyors, pumps and fans are usually designed to run at constant speed provided by AC induction motors. Some machines like grinders and saws work best by maintaining a steady constant speed, but in many applications it is desirable to adjust the speed to different processing or energy needs. One typical application is saving energy on fans and pumps by adapting to the required flow. There is a quadratic relation between flow and speed, and if the flow requirement is not contant there can be a lot of energy savings by controlling the motor speed. Also the excess water or air flow usually means loss of energy in other parts of a system like when heating a house (the balance point between heating and ventilating). Another example is controlling the throughput in production lines by removing "bottlenecks" and adapting to the pace of the production. Also it is useful to vary the speed in stand alone machines such as lathes, drills and milling tools, however the electronic drive cannot increase the torque like gearboxes and belt transmissions.

Earlier, the electronics necessary to build a variable frequency drive was expensive and unreliable because of the high currents invoved with electric motors and the relatively complex signal generation. Today, as faster and cheaper integrated circuits as well as more efficient power transistors has emerged, VFD's are more often preferred compared to other speed control methods. Especially, replacing a DC-motor in some applications may lower the overall cost, increase reliability and lifetime of the system.

There is an important difference between synchronous and asynchronous AC-motors although they seem very similar. The synchronous AC-motor has permanent magnets or DC-windings in the rotor (the rotating part) in addition to the AC-windings in the stator (the fixed part). The speed of such motors is exactly proportional to the electrical frequency. Actually also the rotor position is proportional to the phase, so synchronous AC-motors are widely used as precision servo motors. Stepper motors are small synchronous four phase AC-motors. Also power generators usually are synchronous because by using DC-windings in the rotor, the output voltage can be controlled by changing a small current in the rotor-windings. Also the frequency is proportional to the rotational speed, making it easier to maintain the right output frequency.

The more common "squirrel cage" induction motor has a rotor with no magnetic field. In order for the motor to work, the magnetic field is "transmitted" from the stator AC-windings. One consequence of this transmission is that she speeds of the motor will lag some percent compared to the electrical frequency. This lag is bigger the smaller the motor is, and as load increase. The positive side of this design is that there is no need for electrical connection to the moving parts, and the "squirrel cage" rotor is less expensive to manufacture than permanent magnet or wire wound rotors. Actually the only "mechanical interface" between the fixed and moving parts in asynchronous induction motors are the two ball bearings. As long as the bearings sound OK, there is most certainly no need for maintenance.

Electric motors work with magnetic fields, and the magnetic field must move in a rotating pattern in order for the motor shaft to follow. Because of this, the electric power also must change according to that pattern; it cannot be DC-currents inside the motor windings. AC-motors are running on three phase "rotating" current. Single phase motors use a capacitor to generate a second phase pointing out the rotation direction. The DC-motors create AC-currents in the rotor windings when the copper commutator rotates relative to the brushes carrying direct current. So actually DC-motors are AC-motors with a built-in mechanical inverter. It may be three or more phase windings.

2.6 VARIABLE FREQUENCY DRIVE

Variable Frequency Drive (VFD) is designed primarily to control the speed of AC motors. While a phase converter will supply a three phase output at the same frequency as the input voltage from the power line, a VFD has the ability to create voltages that vary in frequency.

A VFD has an input rectifier which charge up a DC link capacitor. Three part of semiconductor switches are also connected to the DC link capacitor. The center connection of each switch pair is connected to one of the output terminals. If the top switch is on, the output terminal will be connected to the top or positive terminal of the link capacitor. If the bottom switch is on, then the output terminal will be connected to the bottom or negative terminal of the DC link capacitor. Each of the three output terminals is connected to one of the leads of a three phase induction motor. A VFD cannot produce a sinusoidal output voltage. It can only terminal of the output terminal to either positive or negative terminal of the DC link capacitor.

Among the electrical quantities, the sine wave frequency is probably the most complicated to change. Today there are two usual ways to do this, either by rotary motor-generators or by electronics. Rotary converters can convert between fixed frequencies like 50 to 60 Hz, or DC (0Hz) to AC and the opposite, but if the frequency need to change often/dynamically like in servo motors, it can only be done by electronics.

Electronic VFD's rectifies the 50Hz current and make a smooth DC-voltage in capacitors (working like small batteries). In other words the frequency is "eliminated" from the system, or changed to zero. Then the VFD must create its own frequency by alternating the DC-voltage through transistors at the desired frequency. Also (very important) the voltage must be proportional to the frequency. The output cannot be all 230 volts when the motor is near zero speed. The voltage is usually controlled by the amplitude of the sine output. Another way is to control the voltage at the input (rectifier) side.

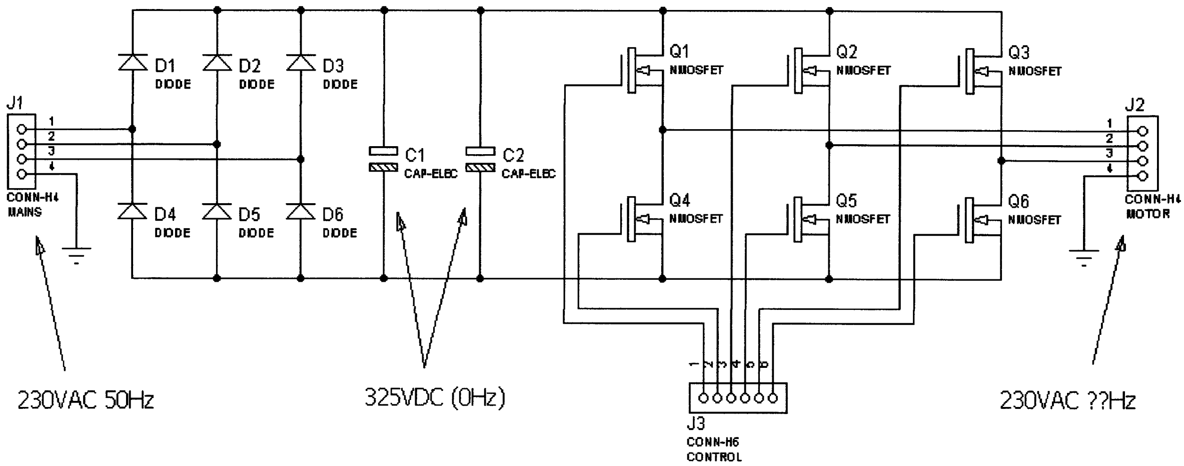

Figure 2.6.a: Power circuit of VFD

The figure shows the power parts af an VFD. There are two "bridges" in the circuit, one three phase rectifier and one three phase inverter bridge. The rectifier (left) is working without any additional electronics. All electrical current is simply conducted in the same direction as the arrows in the diode symbols. When the rectified current is stored in the capacitors, the value of the voltage reach the peak value of $230V_{RMS}$ (Root Mean Square)