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Phase Conversion of VFD based Induction Motor

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Abstract - *In this Paper we are going to present speed control of three phase induction motor by Single Phase to Three Phase topology using Variable Frequency Drive (VFD).the main aim of the project is to control the speed of induction motor with the consideration of economic & energy saving. By using VFD we can control the speed in variation. We are using three phase power from single source to drive induction motor. The converter consist of DC power supply, an IGBT HEX-Bridge, integrated gate drive IC, & microcontroller to produce PWM signal.*

Key Words: Phase Converter, Variable Frequency Drive (VFD), IGBT/MOSFET, Pulse Width Modulation (PWM), Induction Motor

1. INTRODUCTION

In this paper we are going to Design how three phase induction motor can be controlled using VFD, as we know that induction motor can run only rated speed, the main aim of the project is to control the speed of three phase induction motor. However in many applications need variable speed operation. Reduction speed in 20% result gives approximately 50% energy saving. The project consists of in two main parts, a Power Circuit & Control Circuit. A power circuit consists of three phase bridge rectifier & three phase PWM inverter. On the other hand control circuit consists of Microcontroller, Driver IC & Opto couplers. A single phase power given to bridge rectifier circuit AC to DC converter & then output of rectifier circuit given to Hex- Bridge inverter circuit i.e. DC to AC converter now from driver circuit we will get PWM signal

2. BLOCK DIAGRAM OF PROPOSED SYSTEM

The main aim of the project dealt with the concept of speed control of a three-phase induction motor with energy saving. To do so, a VFD (Variable Frequency Drive) is used for controlling the speed of a three-phase induction motor with variable load attached to the motor. It certainly leads to the best performance and high efficiency of the induction motor. In recent years, a major issue that is threatening Tamil Nadu for the past two years is the shortage of electricity. In such case, the unwanted energy should be saved. As a result, the implementation of VFD helps in saving a large amount of energy by reducing the sudden jerks happening at the starting of the motor.

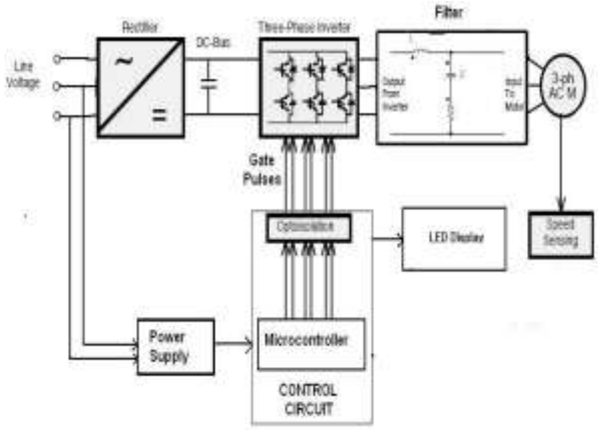

Fig -1: Block Diagram of Proposed System

Variable Frequency Drive (VFD) can be used to control the speed of three-phase induction motor. A variable frequency drive is a system equipped for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor.

3. PHASE CONVERTER TECHNOLOGIES

3.1 Static Phase Converter

The simplest type of phase converter is generically called a static phase converter and has been in use for nearly one hundred years. 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. They make use of the idea that a three-phase motor can be started using a capacitor in series with the third terminal of the motor. It then runs with essentially two of the three windings powered.

3.2 Rotary Phase Converter

Rotary phase converters produce three-phase power from a single-phase source. They are capable of powering resistive, capacitive and inductive loads and can power multiple loads. A rotary phase converter consists of a three-phase motor (usually without external shafts) and a bank of capacitors wired together to act as a single large capacitor.

A rotary phase converter consists of a three-phase motor (usually without external shafts) and a bank of capacitors wired together to act as a single large capacitor. Two of the leads to the motor 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 inputs. The output leads from the phase converter are connected across the three motor terminals. Typically the motor used in the phase converter is larger than the loads it is supplying.

3.3 VFD as Phase Converter

Variable frequency drives (VFDs) are designed primarily to control the speed of AC motors, but can be adapted to function as phase converters. 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 (either 4 or 6 semiconductor diodes) which charge up a DC link capacitor. Three pairs of semiconductor switches are also connected to the DC link capacitor. These switches generate a pulse-width-modulated (PWM) voltage for each of the three-phases on the output.

Harmonic	3^{rd}	5^{th}	7^{th}	9^{th}	11^{th}	13^{th}
Percent	73.2	36.6	8.1	5.7	4.1	2.9

Table -1: VFD Input Harmonic Content

A VFD cannot produce a sinusoidal output voltage. The inductance of a motor powered by a VFD responds to the area beneath the curve of a plot of the voltage as a function of time. So, even though the voltage isn't sinusoidal, if the on/off times of the switches are chosen correctly then the current in the leads to the motor *can* be sinusoidal as long as the *average* value of the voltage is sinusoidal. Since the torque generated by the motor is proportional to the currents and not the voltages, then to a first approximation the motor behaves as if it had sinusoidal voltages applied to it.

4. BASIC COMPONENETS OF VFD

There are three basic components of VFD are

- Rectifier
- DC Bus
- Inverter

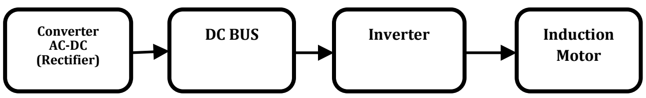

Fig -2: VFD Basic Block Diagram

4.1 Rectifier

A bridge rectifier circuit is a common part of the electronic power supplies. Many electronic circuits require rectified DC power supply for powering the various electronic basic components from available AC mains supply. We can find this rectifier in a wide variety of electronic AC power devices like home appliances, motor controllers, and modulation process

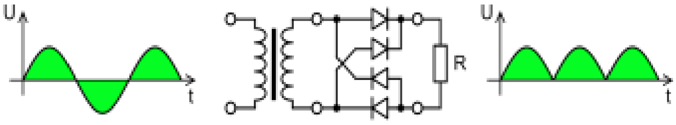

Fig -3: Rectifier

4.2 DC Bus

The DC bus in a VFD has found its usage as the technology has evolved. Some of the applications of DC bus, Common DC applications where a single rectifier unit acts a source of power to many inverter units through common DC bus. These inverters units can be connected to many motors. Using the DC bus as a discharge medium in the case of faster braking of load. A resister connected to DC bus can act as a brake resister which dissipates surge power generated by fast decelerating load.

4.3 Inverter

In this process a three phase AC voltage is converted into DC voltage. In order to obtain the essential DC voltage for the inverter, a three phase diode bridge rectifier has been Used. The bridge rectifier consists of six set of power diodes. They are connected in three legs and each leg consists of two sets of diodes. Each set of diode consists of two diodes connected in parallel combination to enhance the rating of the each set of diode. To reduce ripples and to have a smooth DC at the input of IGBT inverter, the DC link capacitor filter has been used at the output of rectifier.
+DC

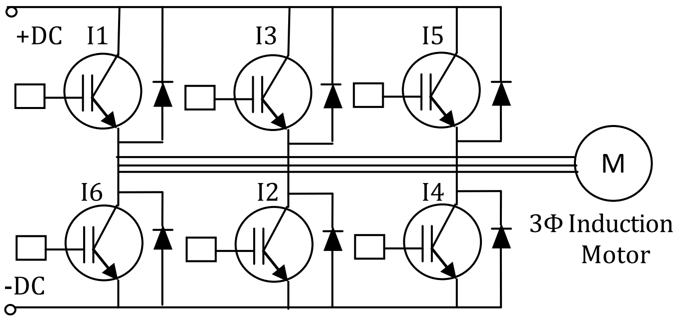

Fig -4: Three Phase Full Bridge Inverter

The 3-phase induction motor is connected to a 3-phase inverter bridge as shown in Fig. 4.The power inverter has six switches that are controlled in order to generate 3-phase AC output from the DC bus. The full bridge inverter is designed by using six IGBT's I1, I2, I3, I4, I5 and I6 with anti-parallel diodes across each IGBT. IGBT's pairs I1- I6, I3- I2 and I5 – I4 Comprise the first, second and third leg respectively. After every 60º one IGBT is fired in the sequence of 1, 2, 3, 4, 5, 6 and 1. At any instant of time two IGBT switches will be conducting, that is one from upper group and one from lower group. During the commutation Period three IGBT switches will be conducting, one from upper and two from lower switches Or one from lower and two from upper group. PWM signals generated from the digital signal Controller, controls these six switches. Switches I1, I3 and I5 which were connected to positive DC, are called upper switches. Switches I2, I4 and I6, connected to negative DC, are called lower switches. The amplitude of phase voltage is determined by the duty cycle of the PWM signals. The switching pattern produces a rectangular shaped output waveform that has harmonics. The inductive nature of the motor's stator windings filters the non sinusoidal waveform to produce a three phase sine wave with negligible harmonics

When switches are turned off, the inductive nature of the windings opposes any sudden change in direction off low of the current until all of the energy stored in the windings is dissipated. To facilitate this, fast recovery diodes are provided across each switch. These diodes are known as freewheeling diodes.

If both outgoing and incoming IGBTs remained ON simultaneously during turn-on and turn-off switching, there would be a short circuiting. To avoid this dead-time is given between switch-on and switch-off of IGBTs of the same leg. During dead time no IGBT of the same leg is conducting. The dead time for this inverter is 2µ Sec.

5. CONTROL CIRCUIT

The control circuit of the proposed scheme consists of a Digital signal Controller (DSC). DSC controls power switches in the inverter circuit. The module has six pulse width modulation (PWM) output channels numbered PWM1H/PWM1L through PWM3H/PWM3L. The six output channels are grouped into high/low numbered pairs, denoted by the suffix H or L, respectively. This module contains 3 duty cycle generators, numbered 1 through 3. The duty cycle of each PWM can be varied individually to generate a 3-phase AC waveform. To derive a varying 3-phase AC voltage from the DC bus, the PWM Outputs are required to control the six switches of the power inverter. This has been done by connecting the PWM outputs to three IGBT drivers (TLP-250). Each driver takes one PWM signal as input and produces one PWM output. These signals are used to drive one half bridge of the inverter: one to the upper switch, the other to the lower switch. The driver also adds a fixed dead time between the two PWM signals.

According to the requirement, a software program is developed and is embedded in to the digital signal controller for the necessary action. The controller circuit essentially takes the reference speed and actual speed of the motor into account. Depending upon the difference between the reference speed and actual speed, the DSC decides the frequency of gate pulse of IGBT's in the inverter in order to bring the motor speed to the desired or set speed. The controller also decides the instant timing of the gate signal to be given to the IGBT's, in order to avoid the overlapping in conduction of incoming and outgoing IGBT's. Because the overlapping in conduction leads to the short circuiting of dc supply causing a dangerous current flow through the IGBT's. To avoid this dead time is added.

6. VF CONTROL

We will mention here only the salient points of VF control. The base speed of the induction motor is directly proportional to the supply frequency and the number of poles of the motor. Since the number of poles is fixed by design, the best way to vary the speed of the induction motor is by varying the supply frequency. The torque developed by the induction motor is directly proportional to the ratio of the applied voltage and the frequency of supply. By varying the voltage and the frequency, but keeping their ratio constant, the torque developed can be kept constant throughout the speed range. This is exactly what VF control tries to achieve. Figure 1 shows the typical torque-speed characteristics of the induction motor, supplied directly from the main supply. Figure 2 shows the torque-speed characteristics of the induction motor with VF control.

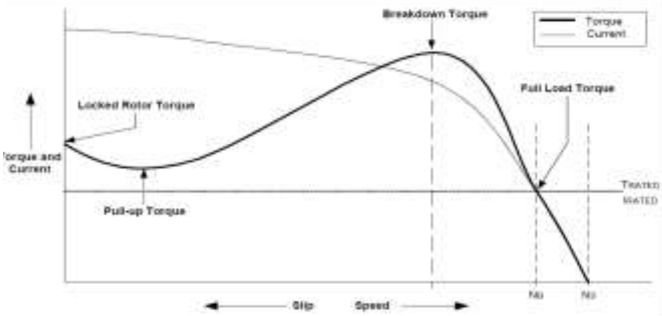

Fig -5: Torque-Speed Characteristics of Induction Motor

The starting current requirement is lower. The stable operating region of the motor is increased. Instead of simply running at its base rated speed (NB), the motor can be run typically from 5% of the synchronous speed (NS) up to the base speed. The torque generated by the motor can be kept constant throughout this region. At base speed, the voltage and frequency reach the rated values. We can drive the motor beyond the base speed by increasing the frequency further. However, the applied voltage cannot be increased beyond the rated voltage. Therefore, only the frequency can be increased, which results in the reduction of torque. The acceleration and deceleration of the motor can be controlled by controlling the change of the supply frequency to the motor with respect to time.

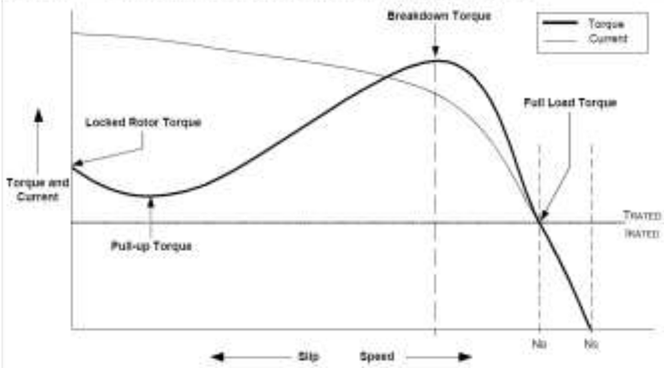

Fig -6: Torque-Speed Characteristics of Induction Motor with VF Control

7. CONCUSION

Hence the modern world which seeks a renewable energy source for the electricity requires the concept of power which can be achieved using the concept of VFD control for the speed control of 3-phase induction motors. A VF solution can be implemented using Variable Frequency Drive with PWM technique is suitable for crisp control of motors. In industries where motors and pumps used to satisfy all basic necessities can used the VFD controlled motors lead to higher energy saving. Also the additional resources used along with VFD like timers and run lamps provide greater safety and security measures against sudden jerk in current and voltage

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