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Novel three Phase Variable Frequency Drive

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Abstract- **This paper is intended to provide a novel and simpler way of speed control three phase induction motor using simultaneous The wide range control technique of three speed of induction motor has presented. With this technique the speed control is obtained by changing speed using simultaneous control of frequency and the three voltages which are spaced by 120o with respect to each other at all frequency. The variable frequency drive works principle, it's the electronic controller specifically designed to change the frequency and control signal voltage supplied to the controller and thereby the stator of three phase induction motor.**

Index terms- **Variable Frequency Drive (VFD), Inverter, Induction Motor, Rectifier**

I.INTRODUCTION

Variable frequency drives (VFD) can control the speed of an induction motor by converting fixed frequency and fixed voltage magnitude to variable frequency and variable voltage magnitude at motor terminals, and thus, provide significantly improved process control, energy saving, and soft motor starting. The common VFD structure comprises of an AC/DC rectifier, a dc link, inverter, additional control and protection circuits. The dominant type of VFDs is the pulse-width-modulation (PWM)-controlled voltage source inverter type [1]. t. As complex non-linear power electronics equipment, VFDs are more sensitive to voltage sags than older mechanical systems. The control and protection circuits in VFDs could disconnect the drives to protect their components during large voltage sags [1]. The sensitivity of VFDs to voltage sags are affected by many factors such as voltage sag types, loading and operating condition of the drives, threshold settings in the protection of the drives, and the control method etc [2]. Most drives will trip when voltage sags are below certain values. However, when the drives are able to ride-through voltage sags and remain in service .industrial facilities is required for power systems dynamic studies. In this paper, a generic dynamic modeling technique for VFD-motor systems able to ride through power system disturbances is proposed.

The wide variety of settings, operating modes, and operating conditions of a VFD compound the challenges involved in characterizing motor-VFD systems. One area of interest in terms of application is operation of VFDs under voltage unbalance. VFDs, like other power equipment, are often subjected to voltage quality issues that are inherent in industrial power supply systems. Unbalanced voltage operation has been well covered in literature for sinusoidal powered induction machines. References such as [3]-[8] have discussed the subject of unbalanced voltage operation of VFDs.

II. IGBT

In the low power field where the MOSFET plays the major role, the switching frequency is normally subject to system efficiency and/or magnetic considerations instead of device limitations. In the medium power field, where the IGBT plays the major role, the situation changes. At the lower end, the limitation of the device does not dominate since the lower-rating IGBT is normally fast enough. However, when the power rating is higher, the IGBT switching speed decreases and the switching losses increase significantly. The practical switching frequency is thus subject to the limitation of the device.

III .PROPOSED TOPOLOGY

The block diagram below contains three separate sections to indicate the basic working principle of a VFD:

- The Rectifier

- The Filter
- The switching section that uses regular transistors, or insulated gate bipolar transistors (IGBT) to invert the DC voltage back to AC voltage with the proper frequency.

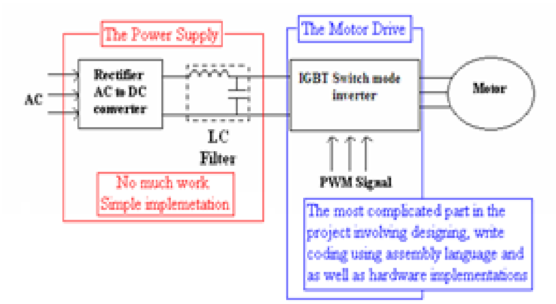


Fig. Schematic Diagram of an AC Motor

The VFD shown as three separate sections:

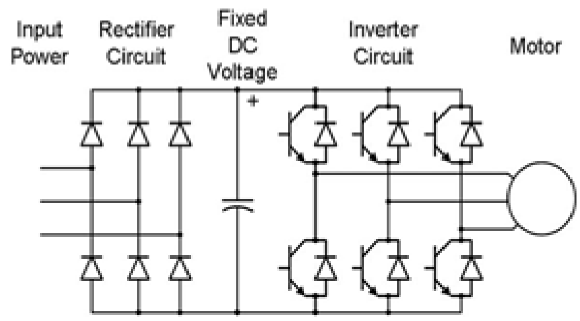
a. Rectifier stage: A full-wave, solid-state rectifier converts three-phase 60 Hz power from a standard or higher utility supply to either fixed or adjustable DC voltage. The system may include transformers if higher supply voltages are used.

b. Inverter stage: Electronic switches power transistors or thyristors - switch the rectified DC on and off, and produce a current or voltage waveform at the desired new frequency. The amount of distortion depends on the design of the inverter and filter.

c. Control system: An electronic circuit receives feedback information from the driven motor and adjusts the output voltage or frequency to the selected values. Usually the output voltage is regulated to produce a constant ratio of voltage to frequency (V/Hz).

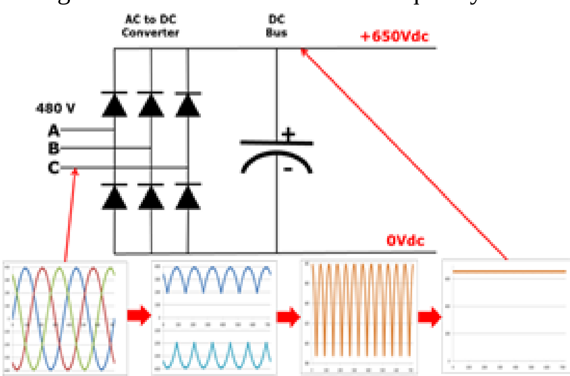
Controllers may incorporate many complex control functions. VFD connect to standard AC induction motors, and have capabilities of adjustable speed, torque, and horsepower control similar to the principles of DC drives. VFDs have made AC induction motors as controllable and efficient as their DC counterparts. AC induction motor speed depends on the number of motor poles and the frequency of the applied power. The number of poles on the stator of the motor could be increased or decreased, but this has limited usefulness. Although the AC frequency of the power source at 50 Hz, advances in power electronics make it practical to vary the frequency and make the induction motor working at different speed. Three phase motors are usually preferred, but some types of single phase motors can be used with single or three phase variable frequency drives. Motors that are designed for fixed-speed main voltage operation are often used, but certain enhancements to the standard motor works offer higher reliability and better performance. A simplified VFD working principle diagram is shown in below. The three major sections of the controller are as follows: Converter-Rectifies the incoming three-phase AC power and converts it to DC.

IV. POWER CIRCUIT



AC motor characteristics require the applied voltage to be proportionally adjusted by the VFD whenever the frequency is changed. E.g., if a motor is designed to operate at 460 Volts at 60 Hz, the applied voltage must be reduced to 230 Volts when the frequency is reduced to 30 Hz. Thus the ratio of volts per hertz must be regulated to a constant value (460/60 = 7.67 in this case). The most common method used for adjusting the motor voltage is called pulse width modulation (PWM). With PWM voltage control, the inverter switches are used to divide the simulated sine-wave output waveform into a series of narrow voltage pulses and modulate the width of the pulses. With a standard AC across-the-line motor starter, line voltage and frequency are applied to the motor and the speed is solely dependent on the number of motor stator poles. In comparison, a VFD delivers a varying voltage and frequency to the motor, which determines its speed. The higher the frequency sup plied to the motor, the faster it will run. Power applied to the motor through the VFD can make the motor working speed lower than the nameplate base speed, or increase the speed to synchronous speed and higher. Motor manufacturers list the maximum speed at which their motors can safely be worked.

The first stage of a Variable Frequency AC Drive, or VFD, is the Converter. The converter is comprised of six diodes, which are similar to check valves used in plumbing systems. They allow current to flow in only one direction; the direction shown by the arrow in the diode symbol. For example, whenever A-phase voltage (voltage is similar to pressure in plumbing systems) is more positive than B or C phase voltages, then that diode will open and allow current to flow. When B-phase becomes more positive than A-phase, then the B-phase diode will open and the A-phase diode will close. The same is true for the 3 diodes on the negative side of the bus. Thus, we get six current "pulses" as each diode opens and closes. This is called a "six-pulse VFD", which is the standard configuration for current Variable Frequency drives.



We can get rid of the AC ripple on the DC bus by adding a capacitor. A capacitor operates in a similar fashion to a reservoir . This capacitor absorbs the ac ripple and delivers a smooth dc voltage. The AC ripple on the DC bus is typically less than 3 Volts. Thus, the voltage on the DC bus becomes "approximately" 650VDC. The actual voltage will depend on the voltage level of the AC line feeding the drive, the level of voltage unbalance on the power system, the motor load, the impedance of the power system, and any reactors or harmonic filters on the drive.

The diode bridge converter that converts AC-to-DC, is sometimes just referred to as a converter. The converter that converts the dc back to ac is also a converter, but to distinguish it from the diode converter, it is usually referred toas an "inverter". It has become common in the industry to refer to any DC-to-AC converter as an inverter.

V. THREE PHASE 180 DEGREE MODE BRIDGE INVERTER

The ideal circuit is drawn before it can be divided into three segments namely segment one, segment two & segment three and we will use these notational in the later section of the article. Segment one consists of a pair of switches S1&S2, segment two consists of switching pair S3 &S4 and segment three consists of switching pair S5&S6. At any given time both the switches in the same segment should never be closed as it leads to battery short circuits failing the entire setup, so this scenario should be avoided at all times.

Now let's start switching sequence by closing the switch S1 in the first segment of the ideal circuit and let's name the start as 0º. Since the selected time of conduction is 180º the switch S1 will be closed from 0º to 180º.

But after 120º of the first phase, the second phase will also have a positive cycle as seen in the three-phase voltage graph, so switch S3 will be closed after S1. This S3 will also be kept closed for another 180º. So S3 will be closed from 120º to 300º and it will be open only after 300º.

Similarly, the third phase also has a positive cycle after 120º of second phase positive cycle, as shown in the graph at the beginning of the article. So the switch S5 will be closed after 120º S3 closing i.e. 240º. Once the switch is closed it will be kept closed for coming 180º before being opened, with that the S5 will be closed from 240º to 60º (second cycle).

Up until now, all we did was assume that's the conduction is done once the top layer switches are closed but for current flow from the circuit must be completed. Also, do remember that both switches in the same segment should never be in the closed at the same time, so if one switch is closed then another must be open.

For satisfying the above both conditions, we will close S2, S4& S6 in a predetermined order. So only after S1 gets opened we will have to close S2. Similarly, S4 will be closed after S3 gets opened at 300º and in the same way S6 will be closed after S5 completes the conduction cycle. This cycle of switching between switches of the same segment can be seen below figure. Here S2 followsS1, S4 follows S3 and S6 follows S5.

By following this symmetrical switching we can achieve the desired three-phase voltage represented in the graph. If we fill in the beginning switching sequence in the above table we will have a complete switching pattern for 180º conduction mode as below. It can be seen in the output graphs of both 180º switching cases that we have achieved an alternating three-phase voltage at the three output terminals. Although the output waveform is not a pure sine wave, it did resemble the three-phase voltage waveform. This is a simple ideal circuit and approximated waveform for understanding 3 phase inverter working. You can design a working model based on this theory using thyristors, switching, control, and protection circuitry.

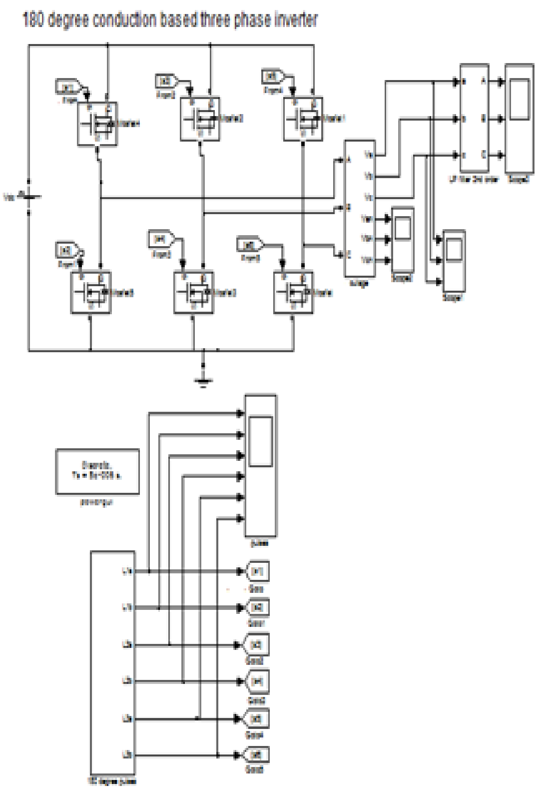
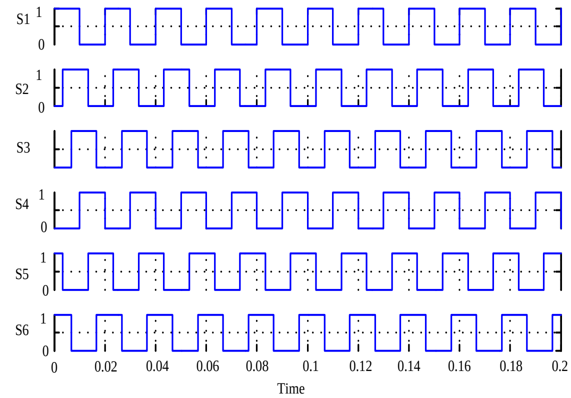


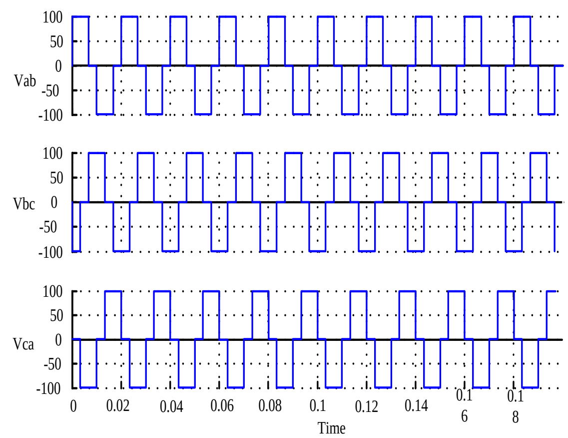
Fig. 180 Degree Conduction Of Three Phase Converter

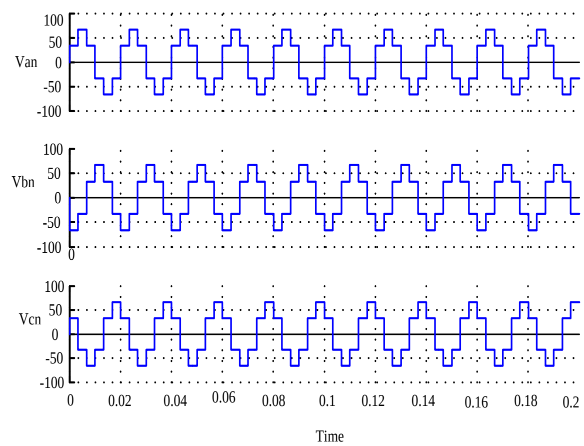
This is the simulation of three-phase inverter. The circuit diagram of 180-degree and 120-degree is same. The only difference is in the GATE pulse of switches.

The peak value of phase voltage (Va0) is 2Vs/3 and the peak value of line voltage is Vs. where Vs is the DC supply voltage. The waveform of the 180 degrees is as shown in below figure. This is a book image. We will compare this image with simulation results at the end of this blog.

VI.SIMULATION RESULT







VII. CONCLUSION

The technique presented in this paper wide range control of three phase induction motor which is not easily possible by voltage control .The v/f ratio is maintained for below rated speed and speed varies from 10 % to 95 %of the rated speed and the speed for the range above the rated speed of the motor was varied from 95% to 120 % of the rated speed by keeping stator voltage constant.

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