VARIABLE FREQUENCY DRIVE AND ITS INDUSTRIAL APPLICATIONS

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ABSTRACT

The paper presents the working principle of VFD, its performance and the use of Pulse Width Modulation (PWM) in the three phase inverter to control or maintain the ratio of voltage to frequency. Also discusses speed control of AC motor using Variable Frequency Drive (VFD). The speed of AC motors remains constant because it takes rated power from supply and therefore it causes problems when less motor speed is needed. The VFD mechanism provides an approach for variation in speed of AC motors. Motor control device that protects and controls the speed of an AC induction motor. Aspects of motor design and application will be reviewed, including typical construction, torque production. Understanding the effects of variable frequency on the motor's characteristics will help in the selection process of a motor and control unit matched to the application. The common applications of VFDs are in air handler, chiller, pumps and tower fans. A better understanding of Variable Frequency Drives with leads to improve in application and selection of both equipment.

Keywords: - *VFD, Induction Motor, Frequency, Speed*

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1. INTRODUCTION

Large part of electrical energy production is used to be converted into mechanical energy via different kinds of electric motors –DC Motors, Synchronous Motors and Induction Motors. This is because it is one of the most widely used motors in the world. The major reason behind the popularity of the Induction Motors are [4]:

I. Induction Motors are cheap compared to DC and Synchronous Motors. In this age of competition, this is prime requirement for any machine. Due to its economy of procurement, installation and use, the Induction Motors is usually the first choice for an operation.
II. Squirrel cage Induction Motors are very rugged in construction. There robustness enables them to be used in all kinds of environment and for long duration of time.
III. Induction Motors have high efficiency of energy conversion. Also they are very reliable.
IV. Owing to their simplicity of construction, Induction Motors have very low maintenance cost.

The Variable Frequency Drive (VFD) industry is growing rapidly and it is now more important than ever for technicians and maintenance personnel to keep VFD installations running smoothly. Variable Frequency Drives (VFD) change the speed of motor by changing voltage and frequency of the power supplied to the motor. In order to maintain proper power factor and reduce excessive heating of the motor, the name plate volts/hertz ratio must be maintained. This is the main task of Variable Frequency Drive.

a. Variable Frequency Drive (AC drives) are used to stepless speed control of squirrel cage induction motors mostly used in process plants due to its ruggedness and maintenance free long life.

b. VFD control speed of motor by varying output voltage and frequency through sophisticated microprocessor controlled electronics device.

c. VFD consists of Rectifier and inverter units. Rectifier converts AC in DC voltage and inverter converts DC voltage back in AC voltage.

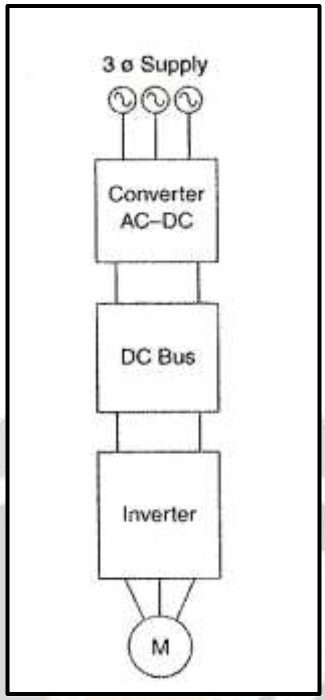

Fig-1 Block diagram of VFD

2. OPERATION

For understanding the basic principles behind VFD operation requires understanding three basic section of VFD: the Rectifier unit, DC Bus and the Inverter unit.

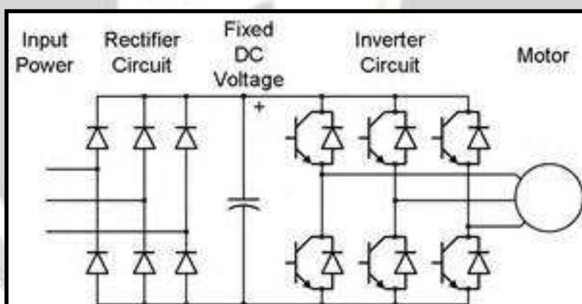

Fig-2 Working

Rectifier: the working principle of rectifier is changing the incoming alternating current (AC) supply to direct current (DC). Different designs are available and these are selected according to the performance required of the variable frequency drive. The rectifier design will influence the extent to which electrical harmonics are induced on the incoming supply. It can also control the direction of power flow.

Intermediate circuit: the rectified DC supply is then conditioned in the intermediate circuit, normally by a combination of inductors and capacitors. The majority of VFDs currently in the marketplace use a fixed-voltage DC link.

Inverter: the inverter converts the rectified and conditioned DC back into an AC supply of variable frequency and voltage. This is normally achieved by generating a high frequency pulse width modulated signal of variable frequency and effective voltage. Semiconductor switches are used to create the output; different types are available, the most common being the Insulated Gate Bipolar Transistor (IGBT).

Control unit: the control unit controls the whole operation of the variable frequency drive; it monitors and controls the rectifier, the intermediate circuit and the inverter to deliver the correct output in response to an external control signal.

As we know that the synchronous speed of motor (rpm) is dependent upon frequency. Therefore by varying the frequency of the power supply through VFD we can control the synchronous motor speed:

$$N = \frac{120F}{P}$$

Where;

N = Speed in rpm

F = Frequency of the power supply in Hz.

P = Number of poles in the motor stator

2.1 CONSTANT V/F RATIO OPERATION

All Variable Frequency Drives (VFDs) maintain the output voltage – to – frequency (V/f) ratio constant at all speeds for the reason that follows. The phase voltage V, frequency f and the magnetic flux ϕ of motor are related by the equation[3]:-

$$V = 4.444\, f\, N\, \phi_m$$

OR

$$\frac{V}{F} = 4.44\, N\, \phi m$$

Where

N = number of turns per phase.

ϕ_m = magnetic flux

If the same voltage is applied at the reduced frequency, the magnetic flux would increase and saturate the magnetic core, significantly distorting the motor performance. The magnetic saturation can be avoided by keeping the ϕ_m constant. Moreover, the motor torque is the product of stator flux and rotor current. For maintaining the rated torque at all speeds the constant flux must be maintained at its rated value, which is basically done by keeping the voltage – to – frequency (V/f) ratio constant. That requires the lowering the motor voltage in the same proportion as the frequency to avoid magnetic saturation due to high flux or lower than the rated torque due to low flux.

3. INDUSTRIAL SEGMENTS

- Chemical industry
- Paper
- Printing
- Power plants
- Mining Metal industry
- Machine shops
- Plastics

Industrial processes are numerous, and the list above mentions just some of the industrial segments with VFD process. What they have in common is that they all require some kind of control using VFD.

3.1 AC Induction Motor

An induction motor consists of three basic components[4]:

Stator: Houses the stator core and windings. The stator core consists of many layers of laminated steel, which is used as a medium for developing magnetic fields. The windings consist of three sets of coils separated by 120 degrees electrical.

Rotor: Also constructed of many layers of laminated steel. The rotor windings consist of bars of copper or aluminum alloy shorted, at either end, with shorting rings.

Endshield: Support the bearings which center the rotor within the stator.

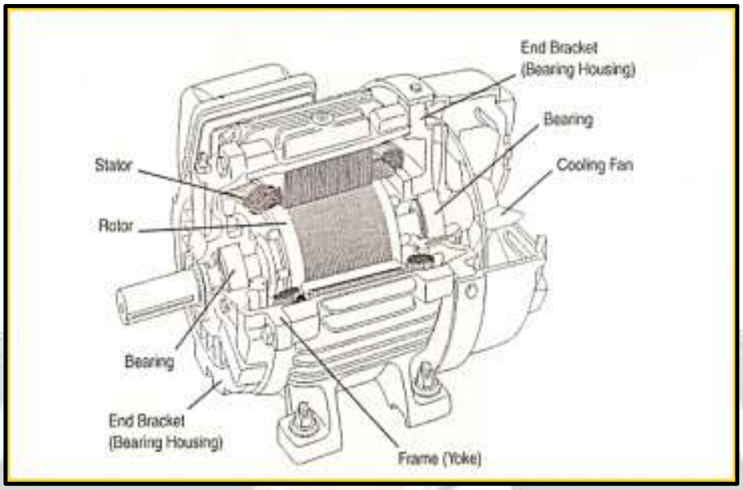

Fig-3 AC Induction Motor – Squirrel Cage Design

3.2 Characteristics for constant V/F

Torque is produced as the induction motor generates flux in its rotating field. This flux must remain constant to produce full-load torque .As shaft torque load increases, the slip increases and more flux lines cut the rotor windings, which in turn increases rotor current, which increases the rotor magnetic field and consequently the rotor torque.

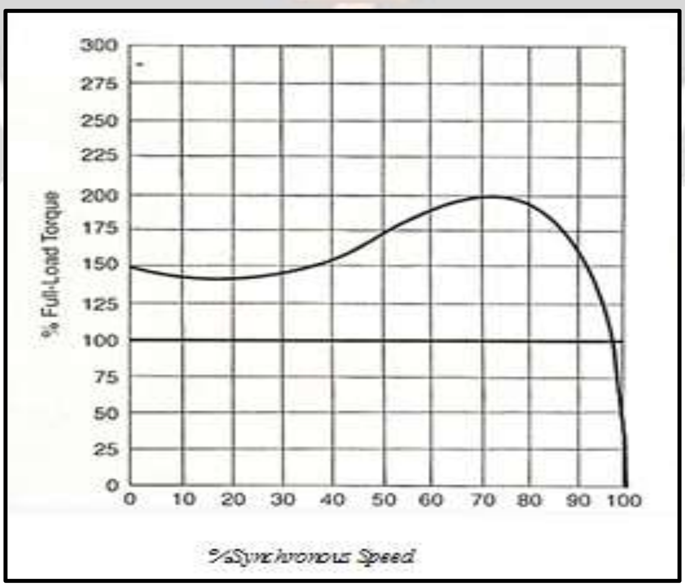

Chart-1 Typical speed versus torque curve

The starting current is very high, between 3 to 8 times the full load current. Depending on the size of the motor, this can result in voltage sags in the power system. The full torque is applied instantly at starting and the mechanical shock can eventually damage the drive system, particularly with material handling equipment, such as conveyors. In spite of the high starting current, for some applications the starting torque may be relatively low, only 1.0 to 2.5 times full load torque.

4. Cooling Tower Fans

A chilled water system is made of three main elements: refrigeration unit (water chiller), chilled water distribution network, and a means of dissipating heat collected by the system. The towers dissipate this collected heat by cooling the condenser water. The cooling effect in evaporative type cooling towers is dependent on the ratio of water to air contact and wet bulb temperature.

Traditionally when the condenser water is flowing fully over the tower the fan or fans are cycled on and off to control the water temperature. Partial load operating characteristics have a strong influence on operating costs. As most operation is at less than design load, fitting a VFD and varying the speed of the fan is a far more efficient means of controlling the condenser water temperature. For maximum chiller efficiency the condenser water temperature should be as low as can be used by the refrigeration system dependent on outdoor air conditions (i.e. wet bulb temperature).

When outside air wet bulb temperature is lower than design, the tower can cool water to a lower temperature, (but can never reach the actual wet bulb temperature). Therefore, the controller setpoint should be at the lowest setpoint attainable (by the tower) to save chiller energy and not waste fan energy trying to reach an unobtainable value.[6]

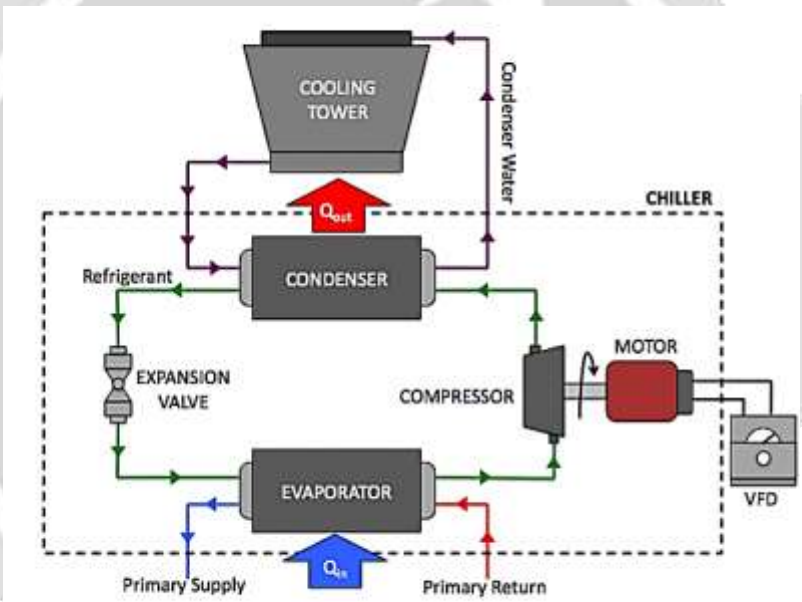

Fig-4 Cooling tower system

4.1. Benefits

- Reduced wear and tear.
- Improved control (straight line)
- More stable chiller operation.
- Fewer start/stops.
- Energy saving

4.2. VFD Features Used

- Power failure recovery.
- Speed search.
- Possible DC injection on start.
- Overspeed capability for increased performance

5. Benefits of VFD

Variable frequency drives provide the following advantages

• Energy savings

• Low motor starting current

• Reduction of thermal and mechanical stresses on motors and belts during starts

• Simple installation

• High power factor

• Lower KVA

Understanding the basis for these benefits will allow engineers and operators to apply VFDs with confidence and achieve the greatest operational savings

6. Conclusion

Thus, we conclude that

- Less energy is utilized when the motor works at lower speeds.
- The cost required to run the mechanism is low.
- VFDs provide the most energy efficient means of capacity control.
- VFDs have the lowest starting current of any starter type.
- VFDs reduce thermal and mechanical stresses on motors and belts.
- VFD installation is as simple as connecting the power supply to the VFD.
- VFDs provide high power factor, eliminating the need for external power factor correction capacitors.

7. Reference

[1] International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064, Gyan Vihar School of Engineering and Technology, Jaipur-302025, India

[2] Howard E. Jordan, Energy Efficient Electric Motors and Their Applications, Van Nostrand Reinhold Company, New York, N.Y., 1983

[3] International Journal of Innovative and Emerging Research in Engineering Volume 2, Issue 3, 2015

[4] Rupali Burungale et al Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 4(Version 8), April 2014, pp.35-37

[5] Phil Hayes, Barry Wood, Dennis G. Horn, "Mechanical Design of Induction Motors Applied on Adjustable Speed Drives", in IEEE Petroleum and Chemical Industrv Conference

[6] Honeywell VFD Application Guide_1469279797775