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ENERGY CONSERVATION USING VARIABLE FREQUENCY DRIVE

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Abstract

Over the last few years in India, the cost of power electricity has increased significantly. Researchers and manufacturers are trying to find ways to minimize the use of power while maintaining or increasing the efficiency of electrical equipments. In this paper, we presents the working principle and operation of Variable Frequency Drive and how its conserve energy. Use of Variable frequency drive (VFD) has increased rapidly in HVAC applications. It is an electronics device and it has a ability to change utility power source to variable frequency to control variable speed in AC motor. In the AC system mostly induction motors are used. This AC induction motors convert electrical energy into mechanical energy and other usable forms. Therefore, for this purpose about two third of the electrical power is fed to motors. So energy conservation for motors in AC system is the major constraint. And this power conservation is achieved by using variable frequency drive at some extent. Generally, there are three types of major load applications used, they classified as Variable torque type load , Constant torque type load, & Constant Horsepower type load.

Index Terms: *Variable frequency drive, induction motor, energy conservation, pulse width modulation etc.*

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1. INTRODUCTION

Now a days energy conservation is the most important factor because in day to day life demand of the electricity can be increasing, this demand can only be meet by saving electrical power or by installation of new power generating units. A major electrical power is consumed by electrical motor in industries . Significant amount of power can be saved by use of the rigid and efficient type of drives. Variable frequency drives (VFD) is one of the energy efficient drive.

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 volts/hertz ratio must be maintained. it also used for step less speed control

of squirrel cage induction motors. The primary purpose to use the VFD for motors is to save energy and operating cost. It is found that in variable torque type of load, 20% reduction in speed of induction motor reduces about 45% energy consumption. Similarly for constant torque type of load applications twenty percent reduction in speed reduces about 20 % energy consumption.

2. VFD OPERATION

A variable - frequency drive (VFD) also know as adjustable-frequency drive or variable speed drive. VFD is made up of active/passive components of power electronics devices, high speed controlling unit & sensing devices. The basic function of VFD is to act as a variable frequency generator in order to vary the speed of motor as per the user demand. the basic principles behind VFD operation can be understand by the three basic sections of the VFD, they are the rectifier, dc bus, and the inverter.

In the AC system the supply voltage rises and falls in the pattern of a sine wave. When the voltage is positive in nature, current flows in one direction and when the voltage is negative in nature, the current flows in the opposite direction. The rectifier in a VFD is convert incoming ac power into direct current (dc) power. For each phase of power two rectifier is needed. One rectifier will allow power to flow only when the voltage is positive. A second rectifier will allow power to flow only when the voltage is negative. Since most large power supplies are three phase, there will be a minimum of 6 rectifiers used(see Figure 1).

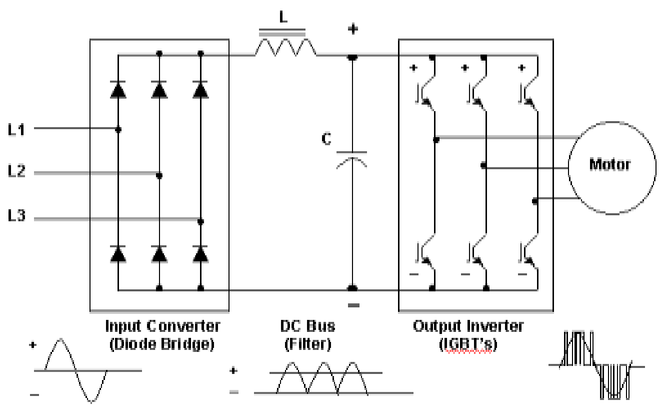

Fig-1: VFD Circuit Diagram

After the power from rectifiers it is stored on a dc bus. The dc bus contains capacitors to accept power from the rectifier, store it, and then deliver this power through the inverter section. The dc bus may also contain inductors, dc links, chokes to add inductance. The DC bus comprises with a filter section because where the harmonics generated during conversion of AC to DC are filtered. The last section consists of an inverter section. The inverter contains transistors that deliver power to the motor. The common choice is “Insulated Gate Bipolar Transistor” (IGBT) in modern VFDs. The IGBT is a switching device and it can be switch on and off several thousand times per second and control the power delivered to the motor. The IGBT uses a method named “pulse width modulation” (PWM), it is a inverter device which are used to produce pulses of varying widths which are combined to build the required waveform. A diode bridge is used in some converters in order to reduce harmonics. PWM inverter produce a current waveform that more closely matches a line source, which reduces undesired heating. It has almost constant power factor at all speeds which is closely to unity.

2.1 Constant V/F Ratio Operation

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

$V = 4.44 \times f \times N \times \emptyset_m$ Or $V/_f = 4.4444 \times N \times \emptyset_m$..(1)

Where , N = number of turns per phase.

If the same voltage is applied to the motor at the reduced frequency, the magnetic flux greatly increase and saturate the magnetic core, significantly distorting the performance of motor. To avoid The magnetic Saturation by keeping the $\emptyset_m$ constant. Moreover, the motor torque is the product of rotor current and stator flux. For maintaining the rated torque of motor 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 produce high flux or lower than the rated torque due to low flux.

2.2 How VFD Change Motor Speed

When your production don’t need the motor to run at full speed then we can used the variable frequency drive to adjust the motor running speed. the VFD provides the frequency and voltage to change the speed of a motor output, this is done through Pulse Width Modulation Drives. we know that synchronous speed of motor is directly proportional to the supply frequency, therefore synchronous speed of the motor can easily vary by changing the value of the frequency. This is the main working phenomenon of the VFD.

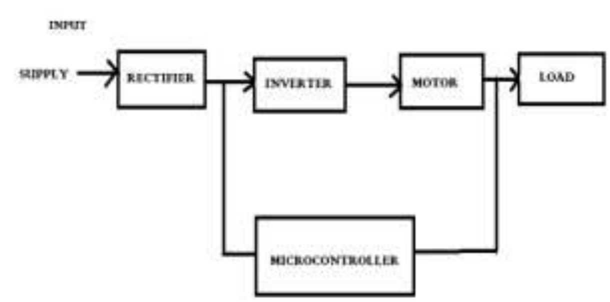

Fig-2: Block diagram of VFD

Generally For induction motor 3phase, 440volt supply is needed. Here we used VFD with induction motor for power conservation. The 3phase input supply is given to rectifier, which converts AC into DC. These DC gives input to inverter, which convert DC into AC. And this AC power supply is provided to induction motor.

The load is connected to the motor, when the load is change it will sense by the microcontroller, The microcontroller are used for controlling the speed of Induction Motor . and it gives feedback signal to inverter which changes the input supply of motor with respect to load and regulates the output voltage and Frequency for controlling the speed of an Induction Motor.

2.3 Energy Conservation Using VFD

The variable frequency drive offers several advantages. One of the most significant benefit is to reduce the electrical energy consumption and demand from motor driven processes. Using a VFD to control the motor is a more efficient means of the flow control .the power input to the motor varies with the cube of the speed ,so even small change in speed can greatly impact the power required by the load. In order to do energy conservation so we take a closer look to the so called affinity laws, which are used in hydraulics to express relationships between the variables involved in the operation of rotary machine and performance of rotary machines such as pumps and fans.

The affinity law state that : "motor speed is proportional to the flow of load(fan/pump) and motor speed is proportional to square time head of the load. and also motor speed is proportion to the cube times power consumed.

Flow α Speed

Torque α $(\text{Speed})^2$

Power α $(\text{Speed})^3$

i.e. if the motor speed is reduce by 10, The motor material flow is reduce by 10%. if the motor speed is reduce by 10% then the torque develop is reduce by 19%. if the motor speed is reduce by 10% then power consumption is reduce by 27%.

We have different type of load and according to type of load and their corresponding energy saving:

1. Variable torque (VT)
2. Constant torque (CT)
3. Constant power (CHP)

1. Variable type load

In the variable type load the load is varies with respect to time. the variable loads are chilled water pumps, pressure boosting pumps, cooling tower pumps, waste water pumps, syrup pumps etc also air fans, cooling tower fans, ventilation fans, dryer fans are the variable type loads.

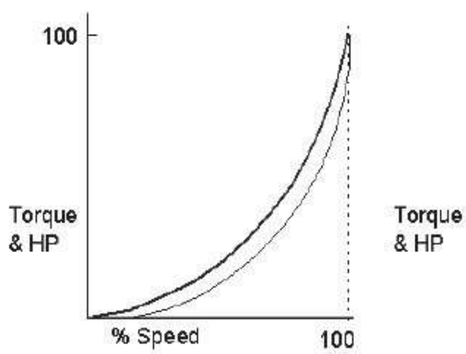

Fig-3:Torque V/s Speed Characteristics for Variable Torque load

According to affinity law

$pressure \propto speed^2$ …… (2)

$flows \propto peed$....... (3)

$power \propto speed^3$........ (4)

from the above we can say

$power \propto pressure \times flow$ ......*(5)*

we have a relation

$P2 = P1 \times (N2/N1)^3$........*(6)*

$= 100HP(1400/1500)^3$

$= 81.30Hp$

$$\textbf{Power saved } P1 - P2 = 100 - 81.30$$
$$= 18.69Hp$$

Operating cost can be calculate by using following formula:

Cost = power (Kw)*running time*cost/kwh....(7)

So, for variable torque type load, 20% reduction in speed reduces the 45% energy consumption.

2. Constant torque type load

In the constant torque motor the torque is constant but the motor speed varies. The application of Constant torque type loads in food processing equipment, machine tools, conveyor equipment, packaging machinery, wagon tippler, screw feeder, crane/hoist, compressor, lifts, winder etc. Characteristic curve for constant torque type load given in the figure

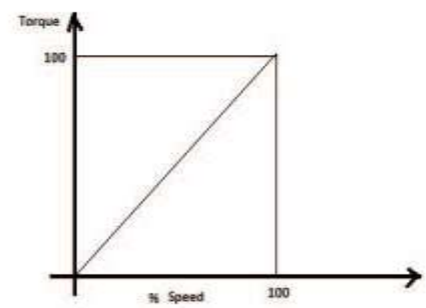

Fig-4: Torque V/s Speed Characteristics for Constant Torque type load.

Constant Torque type load

According to affinity law For constant type of load

$P = 2 \times pi \times N \times T$ ..... (8)

$power = speed$ ..... (9)

$P2 = P1 \times (N2/N1)$ ......(10)

$= 100HP \times (1400/1500)$

$= 93.33hp$

$$\textbf{Power saved } = p1 - p2 = 100 - 93.33 = 6.67hp$$

Operating cost can be calculate by using following formulae

Cost = power (Kw)*running time*cost/kwh......(11)

So, for constant torque type load using VFD, 20% reduction in speed of motor reduces 20% the energy consumption.

3. Constant power type load

In the constant power type load the power required for motor is almost constant. the constant power type loads are mainly blower motor, spindle motor, mixer etc, the characteristic curve for constant type of load is given in figure 5

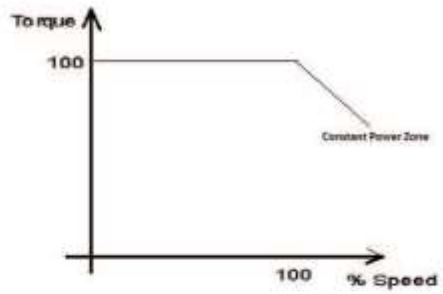

Fig-5: torque vs speed characteristics for constant power type load

From the Affinity law:

$P = 2 \times pi \times N \times T$ .... (12)

As in Constant power type of load applications power is constant, So no energy saving is possible.

2.4 Benefits of VFD

• large amount of energy saving at lower speed.

•low motor starting current : when the AC motors is started across the line , it can take large amount of current at the time of starting , this current is 7-8 times greater then the full load current. It will damage the equipment connecct to the same line. If we use VFD at start it will reduce the high starting current . a motor start at zero frequency and voltage, As the frequency and voltage increase it magnetizes the motor winding. which typically takes 50-70% of the motor full load current.

• high power factor : The vector sum of the active power (kW) and the reactive power (kVAR) is the Total Power and is measured in Kilovolt Amperes (KVA). Power factor is the ratio of active power and reactive power (kW/KVA). Motors draw reactive current to support their magnetic fields in order to cause rotation. Excessive reactive current is undesirable because it creates additional resistance. As the load on the motor reduced, the power factor becomes lower.

The VFDs include capacitors in the DC Bus that maintain high power factor on the line side of the VFD. Due to this capacitor reduces the additional power factor correction equipment to the motor or use expensive capacitor banks. In addition, VFDs often result in higher line side power factor values than constant speed motors equipped with correction capacitors.

3. CONCLUSION

It is found that the speed control of induction motor using variable frequency drive can save energy in variable torque type load and constant torque type load according to affinity laws and equations. As from these results a small reduction in speed of motor can save a large amount of energy.

Apart from speed control and energy savings, the uses of Variable Frequency Drives soft start, reduce the starting current, increases power factor and also reduce tear and wear.

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