# Energy Efficient Hydraulic Clamping System in Machine Tools using VFD

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*Abstract*—Many industrial applications require variable flow control of fluid (air, chemical gases, water and liquid chemicals). The traditional method of such flow control is to use an induction motor at constant speed with 50-Hz power supply and then control the flow by means of a throttle. Many fixed-speed motor load applications that are supplied direct from AC line power can save energy when they are operated at variable-speed, by means of VFD. Such energy cost savings are especially used in variable-torque centrifugal fan and pump applications, where the load's torque and power vary with the square and cube, respectively of the speed. This change gives a large power reduction compared to fixed-speed operation for a relatively small reduction in speed. Also by Using a variable frequency drive to control the fluid flow with a fully open throttle saves a considerable amount of power. As most of the drives operate at part load most of the time, the accumulated energy saving or the corresponding financial benefit, may be substantial over a prolonged period of time. Because this type of fluid flow control is common in industry, widespread application of variable-frequency drives with power electronics area can help in large energy conservation. The main aim of this paper is to reduce the energy consumption by the implementation of VFD and hence the proper control of fluid flows.

*Keywords*— Variable frequency drive, Adjustable speed drive, Variable voltage variable frequency drive, Energy conservation, Affinity law

## I. INTRODUCTION

Energy in its different form is the basic input for life. It is equally essential for the improvement quality of life. Energy crisis has a bearing on all socioeconomic development of a country and its sovereignty. There has been an enormous increase in the global demand for energy in recent years as a result of industrial development and population growth. Since, our conventional sources of energy or fossil fuels are running short; it is now the cry of the day to work harder for the development, improvement and up gradation of renewable sources of energy with protection, conservation and existing conventional sources. The reduction in the amount of energy consumed in a process or system, or by an organization or society through economy and elimination of wastage is called as energy conservation.

Energy conservation is necessary because with the ever increasing demand, need for electrical power can only be meet by conserving electrical power in addition to installation of new generating units. A major proportion of electrical power in a plant is consumed by electrical derives. Significant amount of electrical energy can be saved by the use of efficient and rigid type of electrical drives. Variable frequency drive is one of the many well-known energy efficient drives.

Within the industry, a variable frequency drive is commonly referred to as inverter. The speed controller is also known by other names such as, Variable Speed Drive (VSD), Adjustable Speed Drive (ASD), and Variable Voltage Variable Frequency Drive (VVVFD/VFD).

The growing popularity of variable frequency drives is due to its ability to control the speed of induction motors, which are the most commonly, used motors in industries. Traditionally, an induction motor is used for constant speed and constant torque applications and when variable speed or torque is required, a DC motor or wound ac motor is used. But now AC induction motors with Variable Frequency Drives are used for variable speed applications. Such drives reduce the energy consumption of motors and increase the energy efficiency of plants.

Energy crisis has a bearing on all socioeconomic development of a country and its sovereignty. Energy conservation is necessary because with the ever increasing demand, need for electrical power can only be meet by conserving electrical power in addition to installation of new generating units. Variable frequency drive is applicable for the air flow control to boiler of thermal power plants. At present, the air flow to boiler is controlled by a control vane mechanism associated with Forced Draft fan and induction motor. The replacement of control vane mechanism by means of a variable frequency drive or variable speed drive reduces the energy consumption of motor. A variable-frequency drive is a system for controlling the rotational speed of an alternating current electric motor by controlling the frequency of the electrical power supplied to the motor. It is a specific type of adjustable-speed drive. Variable-frequency drives are also known as AC drives or inverter drives.

## II. EASE OF USE

The use of variable frequency drive control offers several advantages. The most significant benefit is its potential to reduce electrical energy consumption and demand from motor-driven processes.

Figure 1 below compares the relative power requirements of a fan at different flow rates, using three types of throttling control: outlet damper control, variable inlet vane control, and VFD control. Although VFDs save far more energy than throttling, the technology has not yet achieved widespread adoption. According to the Bonneville Power Administration, throttling continues as “one of the most common and inefficient methods to control a fan or pump.”

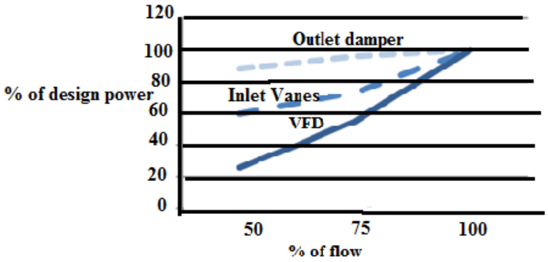


**Fig 1: Comparison between power and flow for different fan control types**

Variable frequency drives also have the potential to reduce system maintenance and related costs. Control with a VFD affords the capability to “soft start” a motor, which means the motor, can be brought up to its running speed slowly rather than abruptly starting and stopping. Similarly, running the motor at lower speeds extends the lifetime of other equipment components, including shafts and bearings.

In addition to enabling precise speed control of F applications such as conveyors or winders, other parameters such as pressure, flow and even temperature may be accurately controlled. The efficiency of the electrical supply is increased and more of the electrical current drawn is used to drive the load. Hence the implementation of VFD improves the power factor of the system. In addition to this VFD provides good dynamic response. This can be achieved by rapid adjustment of speed, torque and power and hence gives better control in high speed applications. In some applications it is also possible to operate motors at higher speeds than their nominal speeds.

The other advantage of VFD is that it is possible to interface VFDs to wider process control systems such as supervisory control, data acquisition (SCADA) systems and building management systems (BMS). Hence VFD is able to compute intelligence and communication systems.

## III. CALCULATION

**Motor Speed, $N = 120 f / p$**
(where f - frequency, p - no. of poles of motor)

**Case 1**: At frequency, $f1 = 10$ Hz
Speed of Motor, $N1 = 120 \times 10/4$; $= 300$ rpm

**Case 2**: At frequency, $f2 = 30$ Hz
Speed of Motor, $N2 = 120 \times 30/4$; $= 900$ rpm

**Pump Flow Rate, $Q = Vg \times N \times Vol.\ eff.$**
(where Vg - flow of fluid/rev,
N - speed of motor, Vol. eff – volumetric efficiency)

**Case 1**: At frequency, $f1 = 10$ Hz
flow Rate, $(Q1) = (5.5 \times 10^{-3}) \times 300 \times 0.9$;
$= 1.485$ lpm

**Case 2**: At frequency, $f2 = 30$ Hz
Flow Rate, $(Q1) = (5.5 \times 10^{-3}) \times 900 \times 0.9$;
$= 4.455$ lpm

**Power, $P = \sqrt{3} \times \cos\Phi \times V \times I \times \eta$**
(where Cos Φ - power factor, V – Voltage,
l - Current, η - Efficiency)

**Case 1**: At frequency, f1 = 10 Hz

Power, P1 = $\sqrt{3}$ x 0.73 x 97.5 x 1.6 x .78;

= 0.1538 kW (P min)

**Case 2**: At frequency, f2 = 30 Hz

Power, P2 = $\sqrt{3}$ x 0.73 x 274.5 x 1.9 x .78;

= 0.514 kW (P max)

### *A. Abbreviations and Acronyms*

VFD- variable frequency drive

ASD-adjustable speed drive

**Equations** ***: Motor Speed, N = 120 f /p***

(where f - frequency, p - no. of poles of motor)

**Pump Flow Rate, Q = Vg x N x Vol. eff.**

(where Vg - flow of fluid/rev N - speed of motor, Vol. eff - volumetric efficiency)

**Power, P = $\sqrt{3}$ x Cos Φ x V x I x η**

(where Cos Φ - power factor, V – Voltage l - Current, η - efficiency)

## IV. HOW DOES IT WORKS ?

As we know, the induction motors are the workhorse of industry, which will rotate at a fixed speed that is determined by the frequency of the supply voltage. Alternating current applied to the stator windings produces a magnetic field that rotates at synchronous speed. This speed may be calculated by dividing line frequency by the number of magnetic pole pairs in the motor winding. A four-pole motor, for example, has two pole pairs, and therefore the magnetic field will rotate 60 Hz / 2 = 30 revolutions per second, or 1800 rpm. The rotor of an induction motor will attempt to follow this rotating magnetic field, and, under load, the rotor speed "slips" slightly behind the rotating field. This small slip speed generates an induced current, and the resulting magnetic field in the rotor produces torque. Since an induction motor rotates near synchronous speed, the most effective and energy-efficient way to change the motor speed is to change the frequency of the applied voltage. VFDs convert the fixed-frequency supply voltage to a continuously variable frequency, thereby allowing adjustable motor speed. A VFD converts 50 Hz power, for example, to a new frequency in two stages: the rectifier stage and the inverter stage.

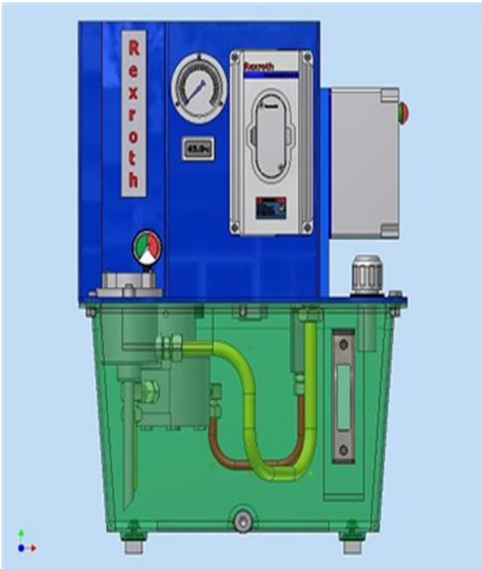


**Fig. 1: Hydraulic power pack with VFD.**

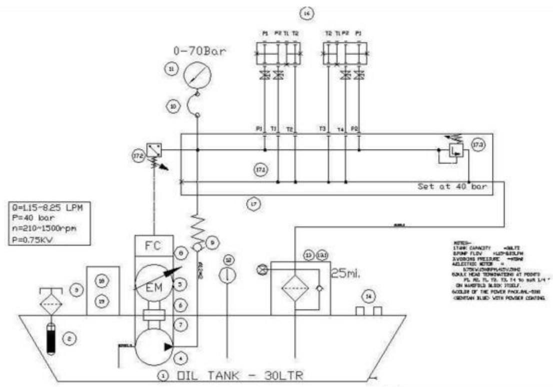


**Fig.2: Hydraulic circuit diagram**

**TABLE: VFD Readings**

| FREQUENCY{HZ} | VOLTAGE {V} | CURRENT (AMP) | TEMP (deg C) | PRESSURE (KG/M2) |
|---|---|---|---|---|
| **10** | **97.5** | **0.9** | **35** | **45** |
| **30** | **274.5** | **1.8** | **35** | **10** |

## V. CONCLUSION

In this study, it is found that, the speed control of induction motor using variable frequency drive can save energy according to affinity law. According to this assumption a small reduction in speed can save a large amount of energy.

Apart from speed control and energy savings, the uses of Variable Frequency Drives provide soft start, reduction in starting current, and also reduce tear and wear.

Total power consumed in 1 hour of operation with VFD

Assumptions: During operation (a). 25% of time for loading and (b). 75% for clamping.

P = [(P1 x 75% of time) + (P2 x 25% of tme)] x 60
= [(0.1538 x 45) + (0.514 x 15) x 60 kWh
= 877.86 kWh; = 0.244 kW

Total power consumed in 1 hour of operation without VFD
P = (P2 x 60) x 60 kWh = (0.514 x 60) x 60; = 850.4 kWh; = 0.514 kW

Power saved by VFD during 1 hr of operation

Power saved, P = Power without VFD – Power with VFD
= 0.514 - 0.244 kW; = 0.27 kW

Efficiency of Hydraulic System with VFD

Efficiency, ɳ = 0.27 / 0.51 = 0.525; = 52.5%

Hence, with the use of Variable Frequency Drive/Converter (VFD/FC), a total of 52.5% Electrical Energy is saved from one Hydraulic System.

## VI. INFERENCE

Assuming, an Industry has 10 machines fitted with VFD working for 2 shifts of 14 hours per day and 300 days in a year, paying at Rs. 10/- per Unit of Power consumed. Then money saved in a year is?

If, Power saved with VFD for 1 machine with 1 hr operation is 28 kWh (877.86 - 850.4 = 27.46 = 28), then

Power Saved in one year by 10 such VFD machines is 11,76,000 kWh (28 x 14 x 10 x 300).

Money saved by Industry: Rs.1,17,60,000/- (11,76,000 x10).


## ACKNOWLEDGEMENT

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of the people who made it possible and under whose constant guidance and encouragement the task was completed.

We extend our sincere thanks to Dr. G. Rathnakar, Professor & HoD, Dept. Mech. Engg., DBIT.

## VII. References


[1] J. W. Leonhard, “Control of electrical drives”, 2-nd Ed, Springer, 1996.

[2] Sergelen B., “Electric drive with two parallel synchronous motors Supplied by one current type frequency converter”, Prague, 2000.

[3] A. de Almeida, P. Fonseca, F. Ferreira, F. Guisse, A. Diop, A. Previ S. Russo, H. Falkner, J. Reichert, and K. Malmose, “Improving the penetration of energy-efficient motors and drives”.

[4] A. de Almeida, F. Ferreira, and D. Both, “Technical and economical considerations in the application of variable-speed drives with electric motor systems,” IEEE Trans. Ind. Appl., vol. 41, no. 1, pp. 18.

[5] Handbook on Energy Audits and Management ,Tata Energy Res. Inst (TERI) New Delhi 2000.

[6] F. J. Shinskey, Energy Conservation Through Control. New York: Academic. 1987.

[7] M. K. Langfeldt, “Economic considerations of variable speed drives,” presented at ASME Energy Technology Conference and Exhibition, Feb. 4, 1980.