VFD Application in Hydraulic Systems

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Abstract – These Recent hydraulic systems are more power consuming and noisy. Sometimes depending upon the application power requirement varies but as the motor speed is constant power consumption would be same for every application. To optimize the power consumption motor should use less current and voltage. As the power consumption depends on speed and voltage of the motor the motor speed need to be controlled. There are so many methods to control the motor speed and voltage supply. One of the efficient methods is using Variable frequency drive (VFD).

Index Terms – VFD, Hydraulic system, efficiency, power consumption.

1. INTRODUCTION

From the recent years, enormous progress is noticed in the fields of control techniques and design to meet the common requirements. One of the great achievement is applying the drive technology to fluid power applications to “full-electric” solutions. It results in electromechanical actuators with maximum efficiency, and ease of assembling with high precession is used as a better substitute for conventional hydraulic systems. Due to using the drives in hydraulic systems no need of hydraulic fluid maintenance [1, 2].By the by, electrohydraulic drives are as yet basic when the need emerges for expansive forces and high torques. The notable points of interest in fluid power incorporate high power density, vigor, and straightforward acknowledgment of quick direct developments under load. These highlights enable power through pressure to win the fight against electromechanical servo drives. This is particularly valid in key market sections, for example, plastic apparatus, stamping and framing presses, metallurgy, testing hardware, and other "heavy-duty applications"[3].

The present "electrification" incline in modern apparatus has likewise impacted the scene of fluid power, with variable frequency drives (VFDs) and servo drives supplanting customary fixed speed AC motors. The advanced electric drive innovation hydraulics opens another section on electrohydraulic-drive frameworks [4].

Machine developers would now be able to keep up qualities of "conventional hydraulics," strength and power density while obtaining preferences of electric drives: drive "knowledge" and simplicity of mix with production line Automation frameworks. Also, changing the direct speed to flow requests gives an expansion in vitality proficiency and drastically diminishes the perceptible commotion and sound pressure level, particularly amid part-load operations when not as much as most extreme pump flow is required [5].

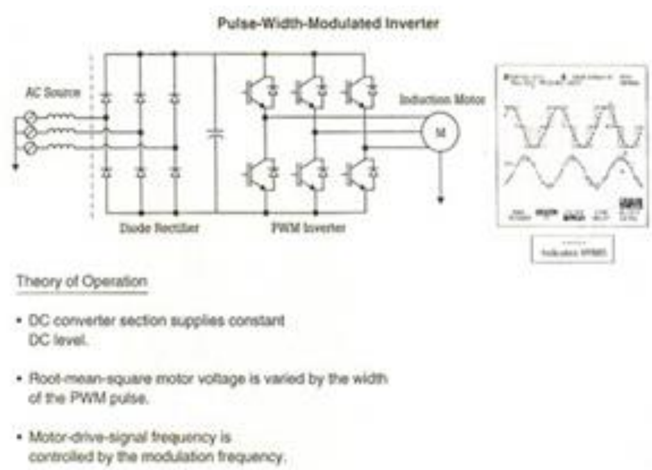

Figure 1 Schematic Diagram of VFD [1]

2. WORKING OF VFD

The main phase of a Variable Frequency AC Drive, or VFD, is the Converter. The converter is included six diodes, which are like check valves utilized as a part of pipes frameworks. They enable current to flow in just a single direction; the direction appears in the diode image. For instance, at whatever point A-phase voltage (voltage is like pressure in pipes frameworks) is more positive than B or C phase voltages, at that point that diode will open and enable current to flow. At the point when B-phase turns out to be more positive than A-phase, at that point, the B-phase diode will open and the A-phase diode will close. The same is valid for the 3 diodes on the negative side of the bus. Along these lines, we get six current "pulses" as every diode opens and closes. This is known as a "six-pulse VFD", which is the standard setup for current Variable Frequency Drives.

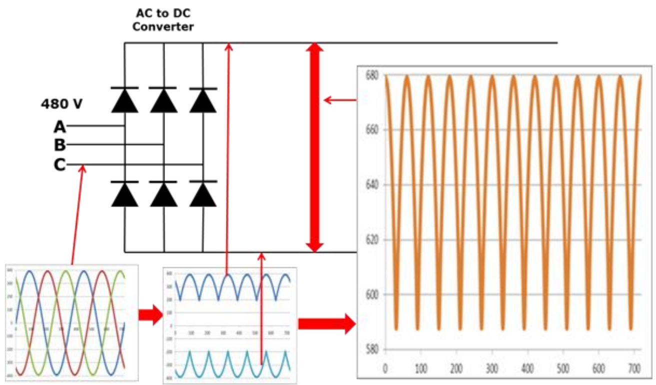

Fig 2 AC to DC converter circuit [6]

Assume that the drive is working under the voltage of 480V power system. The 480V rating is "arms" or the root-mean-square. The crests on a 480V system are 679V. As should be obvious, the VFD dc bus has a dc voltage with an AC swell. The voltage keeps running between roughly 580V and 680V.

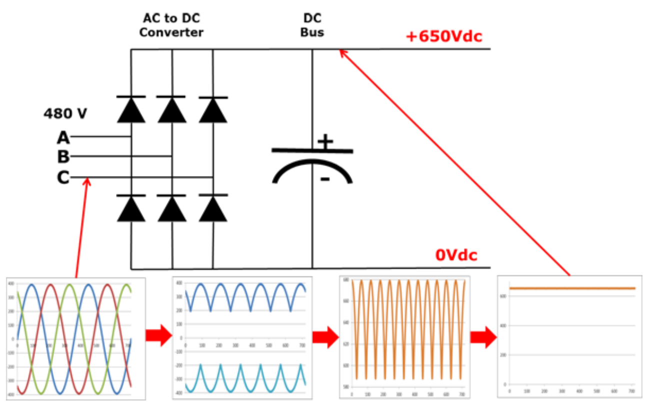

Fig 3 AC to DC converter circuit with DC Bus [7]

We can dispose of the AC swell on the DC bus by including a capacitor. A capacitor works in a comparable manner to a supply or aggregator in a pipes system. This capacitor assimilates the air conditioner swell and conveys a smooth dc voltage. The AC swell on the DC bus is ordinarily under 3 Volts. Subsequently, the voltage on the DC bus turns out to be "approximately" 650VDC. The real voltage will rely upon the voltage level of the AC line nourishing the drive, the level of voltage unbalances.

Diode bridge converter circuit usually converts the power from AC-to-DC, is sometimes just referred to as a converter. The converter that converts the dc back to ac is also a converter, yet to distinguish it from the diode converter, it is usually referred to as an "inverter". It has turned out to be normal in the business to allude to any DC-to-AC converter as an inverter.

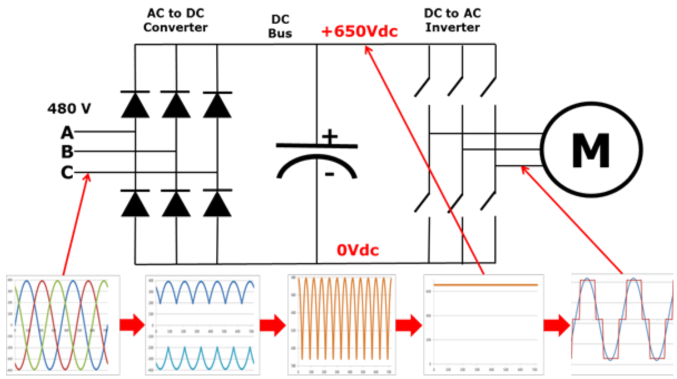

Fig 4 Circuit Diagram of VFD [8]

"Note that in a practical VFD, the switches demonstrated would really be transistors."

When we close one of the top switches in the inverter, that phase of the motor is associated with the positive dc transport and the voltage on that phase ends up noticeably positive. When we close one of the bottom switches in the converter that phase is associated with the negative dc b and ends up noticeably negative. Subsequently, we can make any phase on the motor end up plainly positive or negative voluntarily and can in this manner generate any recurrence that we want. In this way, we can make any phase be sure, negative, or zero.

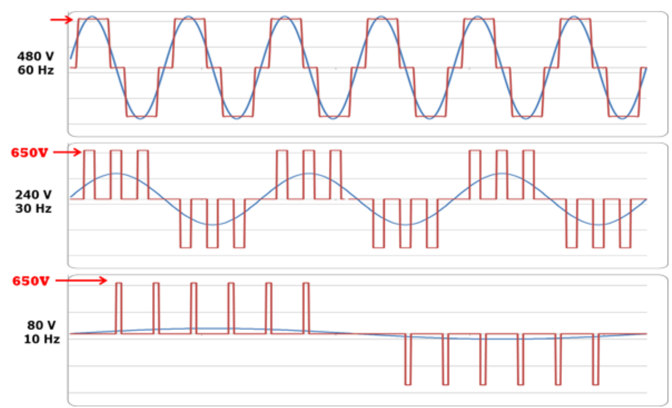

Fig 5 VFD Waveform [9]

The blue sine-wave appears for correlation purposes as it were. The drive does not produce this sine wave.

Notice that the output from the VFD is a "rectangular" waveform. VFD's don't create a sinusoidal output. This rectangular waveform would not be a decent decision for a universally useful dissemination system yet is flawlessly sufficient for a motor.

In the event that we need to decrease the motor frequency to 30 Hz, at that point we just switch the inverter output transistors all the more gradually. However, in the event that we lessen the frequency to 30Hz, at that point we should likewise decrease the voltage to 240V keeping in mind the end goal to keep up the V/Hz proportion.

This is called Pulse Width Modulation (PWM). Envision that we could control the weight in a water line by rotating the valve on and at a high rate of speed. While this would not be viable for pipes systems, it works exceptionally well for VFD's. Notice that amid the main half cycle, the voltage is a fraction of the time and OFF a fraction of the time. In this manner, the normal voltage is half of 480V or 240V. By beating the output, we can accomplish a normal voltage on the output of the VFD [10].

3. ADVANTAGES

- Sometimes getting a little more speed out of the motor can increase the flow just enough to satisfy the demand.
- When there is capacity in the motor and the VFD can be programmed to do this, a new, larger motor does not have to be purchased and installed.
- The VFD can run 10 to 20% higher in speed and make up for lost capacity in a flow-and-demand type of system.
- However, many motors – as built – are not balanced for these speeds.

4. OPERATION

To know the better use of VFD let us consider a simple hydraulic circuit which is operated in both cases (with using VFD and without using VFD).

A conventional hydraulic circuit consists of pump and motor as a prime mover. Which intends uses a constant speed and constant power supply irrespective of the load which presents on the system. Need to optimize the power input with any available methods. And find the savings for a yearly cost.

Component	Specification	Value
Motor	Volumetric efficiency Mechanical efficiency	90% 90%
Pump	Volumetric efficiency	90%
	Discharge	$0.0015 m^3/sec$ @1000 rpm
Hydraulic Cylinder	Diameter of Piston Diameter of Rod	2 inches 1 inch
Power	Per unit	5 Rupees

Table 1 Specifications of Motor, Pump, and Cylinder [11, 15]

4.1 Formulae

- $\text{Presuure(bar)} = F_{ext}/A_P$
- $V_{ext}(m/s) = Q/A_P$
- $P_{ext}(KW) = V_{ext} * F_l$
- $T_a(N \cdot m) = (P * 9550)/1000$ [3]

4.2 Manual calculations from Formulae and Specifications

Specification	Without VFD	With VFD
Pressure (bar)	21.9 bar	17.52 bar
Velocity (m/s)	0.047 (m/s)	0.047 (m/s)
Power (extraction)	2.76 KW	2.20 KW
Actual Power to pump	3.06 KW	2.44KW
Actual Torque (N-m)	29.22 N-m	29.22 N-m
Cost per Year (rupees)	56,700/-	46,166.67/-

Table 2 Manual calculations

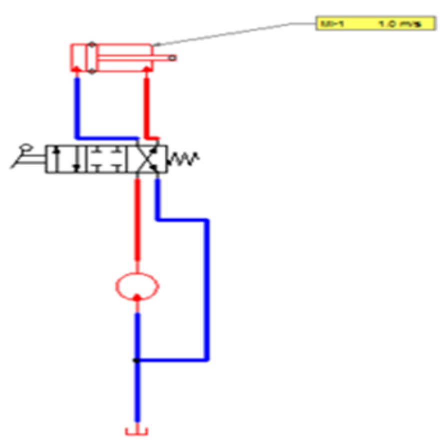

Fig 5 Hydraulic circuit simulation using Automation Studio [12]

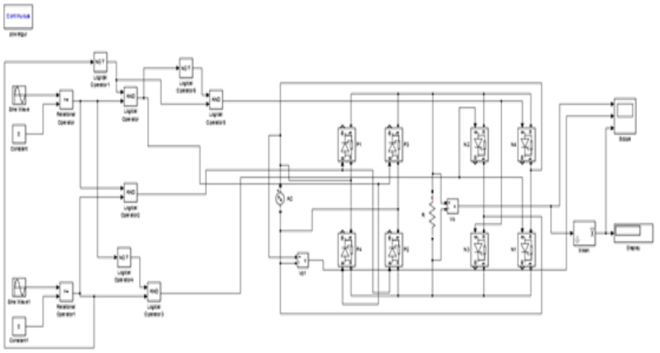

Fig 6 Modeling of VFD using SIMULINK Library [14]

As the output of VFD is in voltage we give this supply to the motor that is single phase induction motor.

We get the frequency in the scope as follows

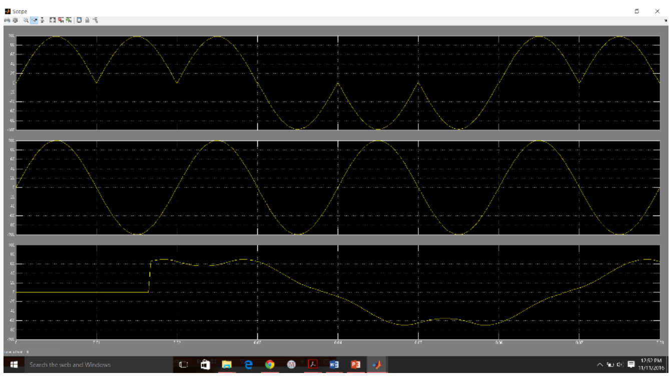

Fig 7 Simulation results of VFD

The simulation of the circuit is:

- The output of the VFD is given input to the motor which changes the frequency that changes the speed of the motor.
- Simulation is shown along with the corresponding graphs.

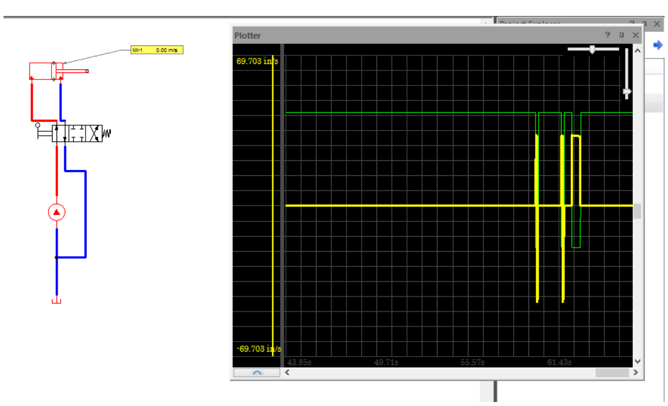

Fig 8 Simulation results Velocity to Time plot

5. ANALYSIS

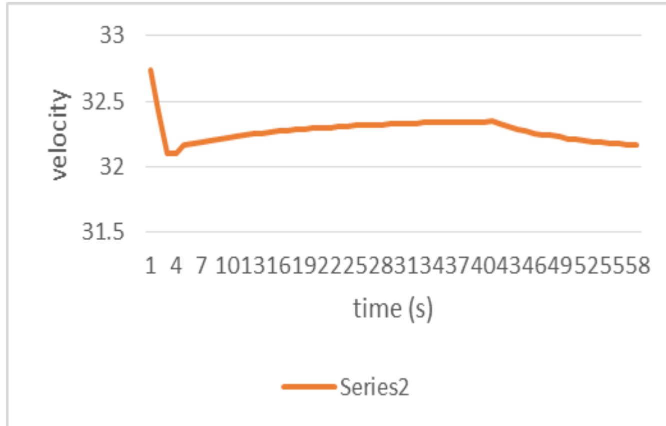

Fig 9 Analysis of Hydraulic system with VFD

Above readings are obtained from the AUTOMATION STUDIO circuit diagram simulation:

Graph of this as follows:

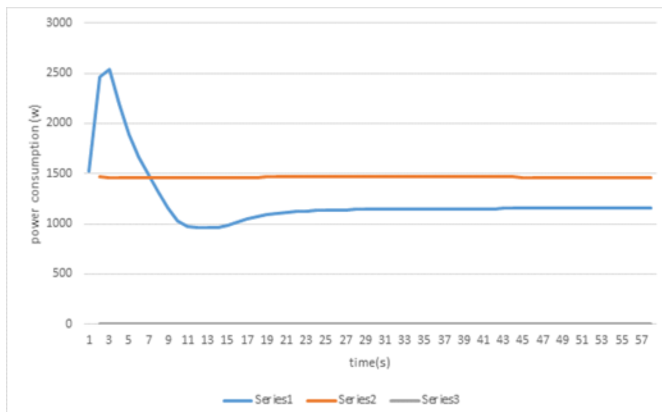

Fig 10 Comparison of power consumption without VFD and with VFD

Fig shows the energy comparison of the hydraulic circuit, with the pump operating in both variable- and constant-speed modes. Lowering the speed during long pressure holding considerably lowers the energy demand.

6. RESULT

- Power consumption without VFD = 1.47kw
- Power consumption with VFD = 1.17kw
- Therefore, running cost of the system without VFD = Rs. 22,050/-
- Running cost of the system with VFD =Rs. 17,550/

Hence, saving per year is running cost without VFD- running cost with VFD= Rs 4500/-

7. CONCLUSION

From above report, we have successfully compared a system using VFD and other without using VFD. We obtained results for the power consumption. We found that power consumption has been decreased with a sensible value. The life of the components also increased and as the system wouldn't be under the maximum pressure all the time.

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