ENERGY CONSERVATION IN AUTOMATIC FLUID FLOW CONTROL USING VARIABLE FREQUENCY DRIVE

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ABSTRACT

The Pumping systems account for nearly 20% of the world's electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations Pumping systems consume a significant portion of the electricity. Actual energy savings will vary greatly depending on how the discharge pressure of the constant speed pump is controlled and how it is operated after the VFD is installed. In the present work, the flow of pump has been controlled by two different methods, simulation work has been carried out and comparative statement is given. In this paper MATLAB simulink is use to show the performance of energy conservation in automatic fluid flow control using VFD.

Keywords: Energy Conservation, Pulse Width Modulation, Matlab, Variable Frequency Drive, Variable Voltage Variable Frequency Drive

I. INTRODUCTION

Pumps are used widely in industry to provide cooling and lubrication services, to transfer fluids for processing, and to provide the motive force in hydraulic systems. Pumping systems account for nearly 20% of the world's electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations [1]. With raising energy costs, process plants are increasing their focus on the amount of energy consumed by rotating equipment. An improperly sized or poorly performing pump consumes unnecessary money. The performance curves for a pump are shown in figure1, which are some important characteristics used for the design,modification, selection and performance assessment..Figure.1

Basic criteria for selecting a pump are Head-Flow requirement and pump size. Pump efficiency varies with flow rate and head and it is highest at one point only, which is called best efficiency point. A pump is selected on the basis that pump curve and system head flow curve should be matched and pump is operated on the desired operating point.

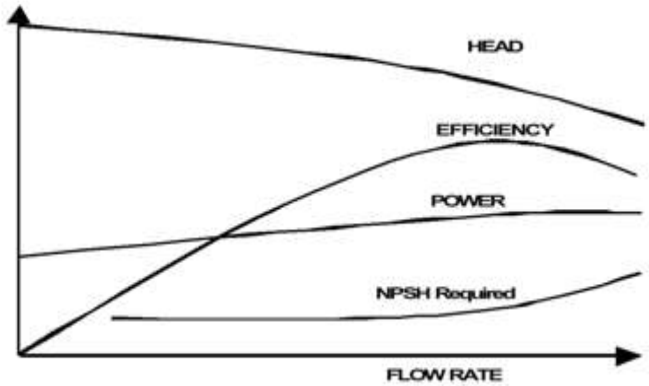


Figure 1 Pump Performance Characteristics

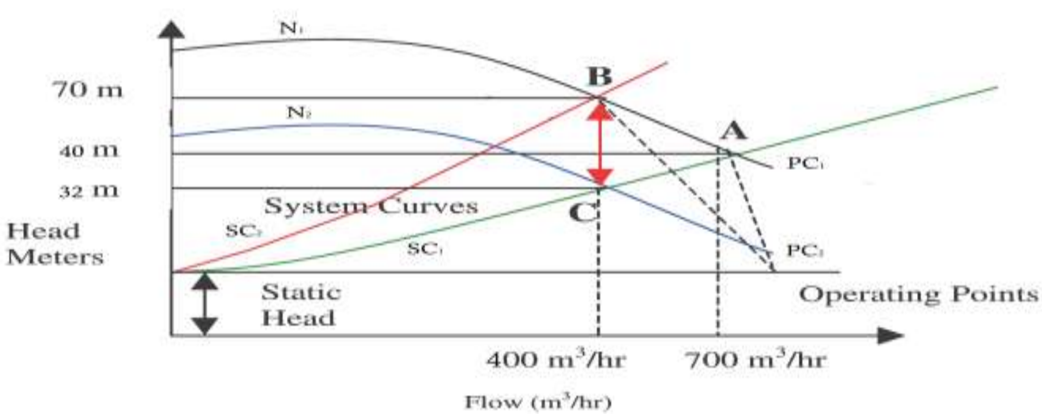
An over-sized pump is derated by the various methods such as:

- Throttling
- Variable speed drive
- Impeller trimming
- Bypass control.

Suppose consider a system having a system curve as shown in figure 2 by line SC1. The pump curve is line PC1 which intersect system curve at operating point A, where the flow rate is 700m3/hr and head is 40 meter. But,the actual requirement of flow is 400m3/hr. Hence the flow rate can be reduced by closing the throttle valve which inserts the artificial resistance to the system and system curve is lifted over the first one. The new operating point becomes B at which desired flow rate 400m3/hr is achieved but at higher head. Hence, pump has to overcome additional head (BC) and for that pump consumes more electrical power. Thus by throttling valve operation to control flow rate is not efficient method.

The another best option is to reduce the speed form N1 to N2 hence pump curve is shifted below and intersect original system curve at point C, which is the best efficiency point (BEP) for the pump where desired flow and head are achieved and also the overall efficiency

figure 2 Flow control methods



II. I

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.

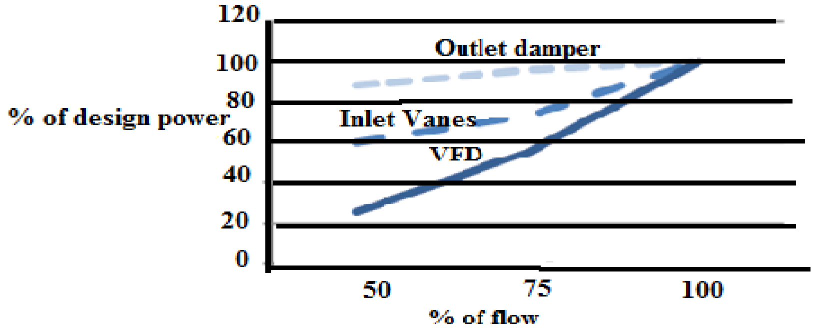


Figure 3 Comparison between power and flow for different fan control types

Figure 3 above 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."

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 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) Programmable Logic Controller (PLC).Hence VFD is able to compute intelligence and communication systems.

III. VFDS OPERATION AND ENERGY SAVING PRINCIPLES

A VFD can reduce energy consumption of a motor by as much as 60%. This is due to the fact that they control the speed of the motor by altering the frequency and therefore the power supplied to it.

Even a small reduction in the rotational speed can give significant saving in the energy consumed by the motor. In order to do 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 and performance of rotary machines such as pumps and fans. Most HVAC equipment is designed to perform during peak loads. These loads occur rarely during the operating year. To control flow during off-max load conditions, flow control devices such as dampers, valves, inlet guide vanes and bypass systems are used .These "throttling" devices are effective, but not energy efficient. Using variable frequency drives (VFD) varies the speed of fans and pumps, referred to as the "affinity laws", allows the equipment to meet the partial load requirement and save energy. Affinity Laws are used in hydraulic and HVAC system to express the relation between several variables involved in pump and fan performance such as (such as, shaft speed, and power). They apply to pumps, fans, and hydraulic turbines.

Flow is directly proportional to speed;
$Q2/Q1 = N2/N1$
Torque required is proportional to speed squared;
$T2/T1 = (N2/N1)^2$
Power is proportional to the cube of the shaft speed;
$P2/P1 = (N2/N1)^3$

IV. HOW DOES A VFD WORK?

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. The conversion process incorporates three functions:

Rectifier stage: A full-wave, solid-state rectifier convert three- phase 50 Hz power from a standard 208, 460, 575 or higher utility supply to either fixed or adjustable DC voltage. The system may include transformers if higher supply voltages are used.

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.

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. Converting DC to variable frequency AC is accomplished using an inverter. Most currently available inverters use pulse width modulation (PWM) because the output current waveform closely approximates a sine wave

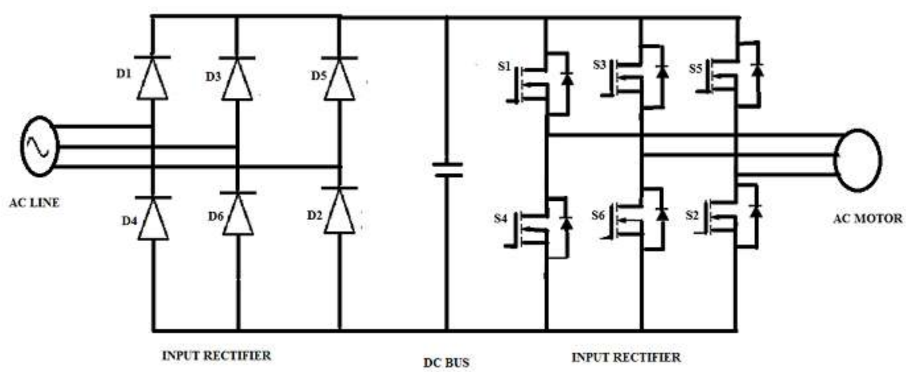


Figure 4 VFD operated motor

The advantages of VFD in addition to energy saving are:

- 1 Improved process control because VSDs can correct small variations in flow more quickly.
- 2 Improved system reliability because wear of pumps, bearings and seals is reduced.
- 3 Reduction of capital & maintenance cost because control valves, by-pass lines, and conventional starters are no longer needed.
- 4 Soft starter capability: VSDs allow the motor the motor to have a lower startup current.

V. SIMULATION & SIMULATION RESULTS

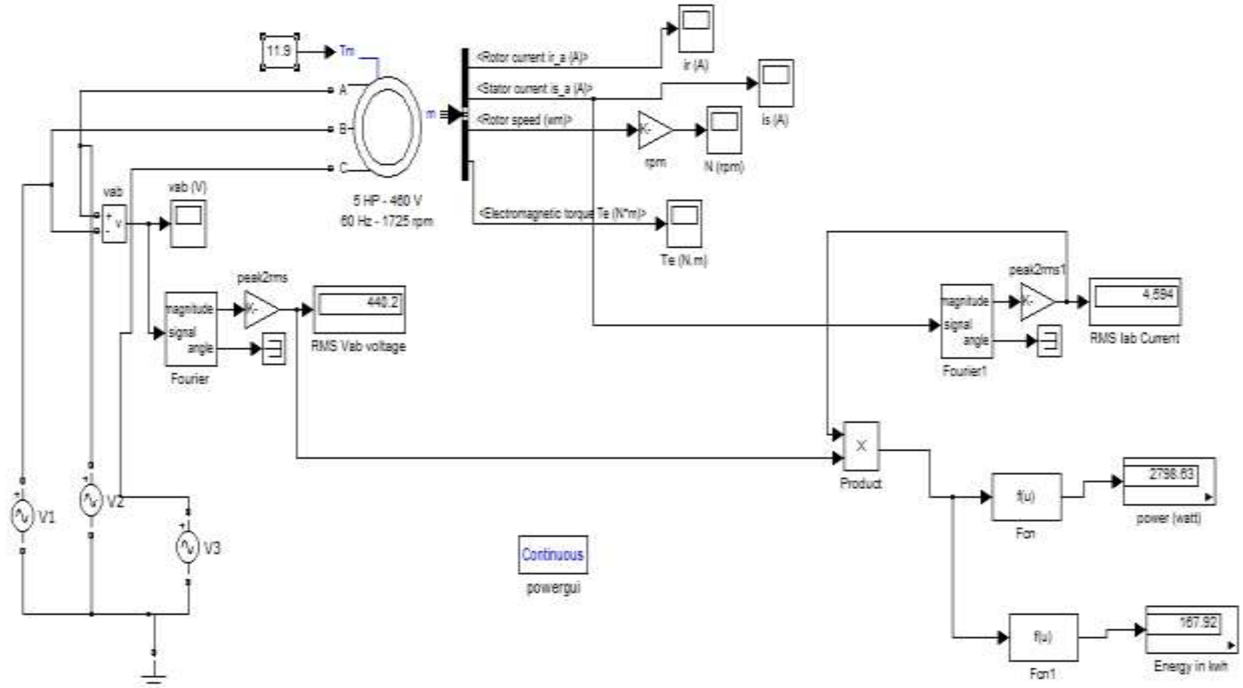


Figure 5 Simulation Model of Direct mode of supply to 5 hp Induction motor and measurement of Energy.

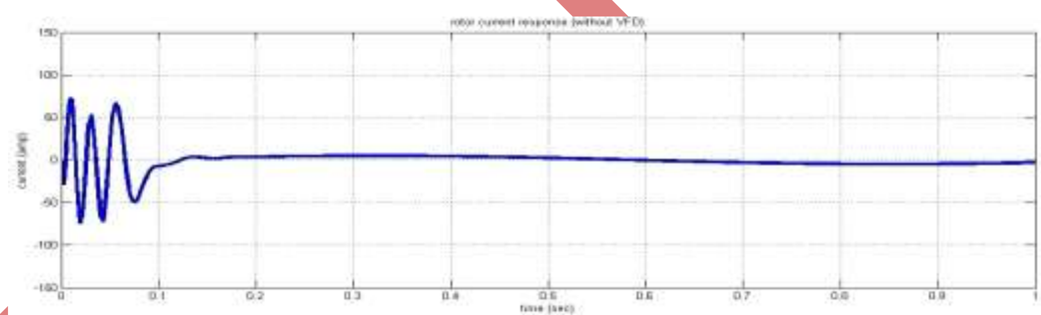


Figure 6 Rotor current response without VFD

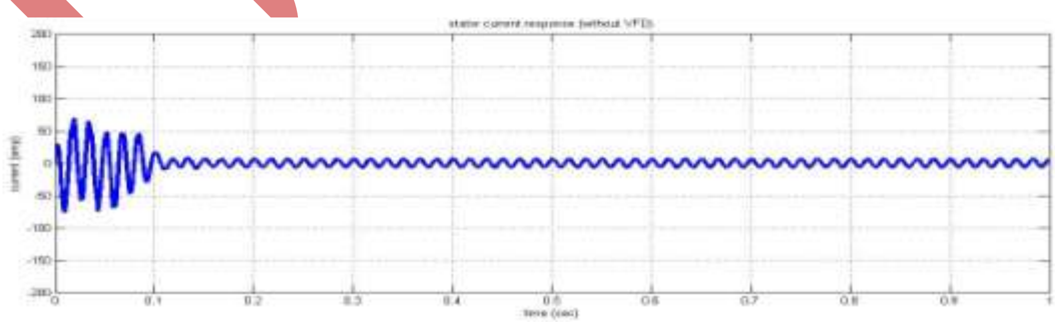


Figure 7 Stator current response without VFD

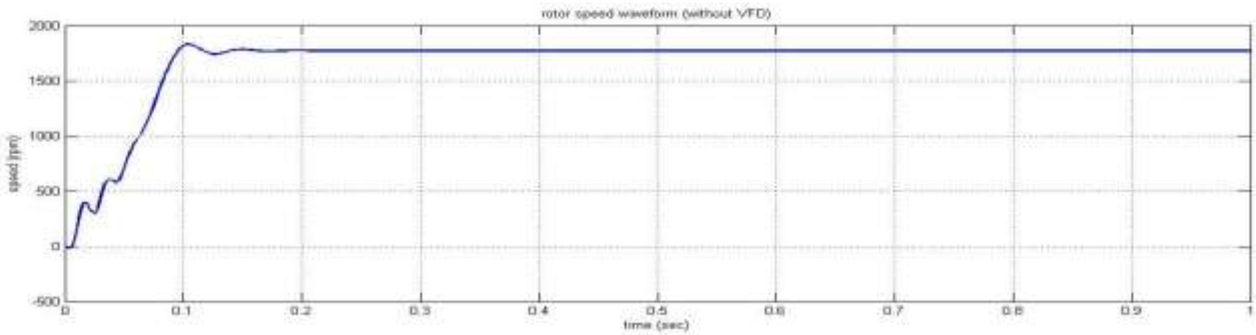


Figure 8 Rotor Speed Waveform without VFD

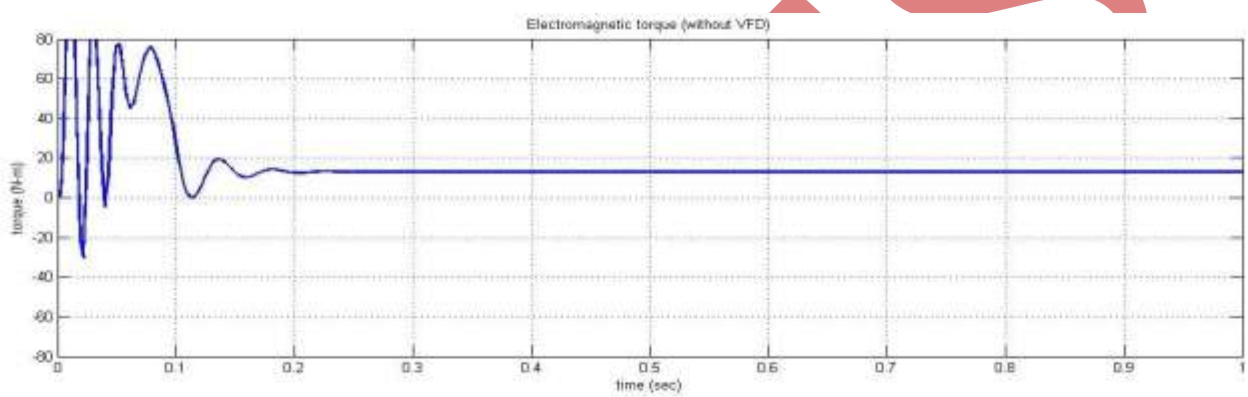


Figure 9 Torque Waveform without VFD

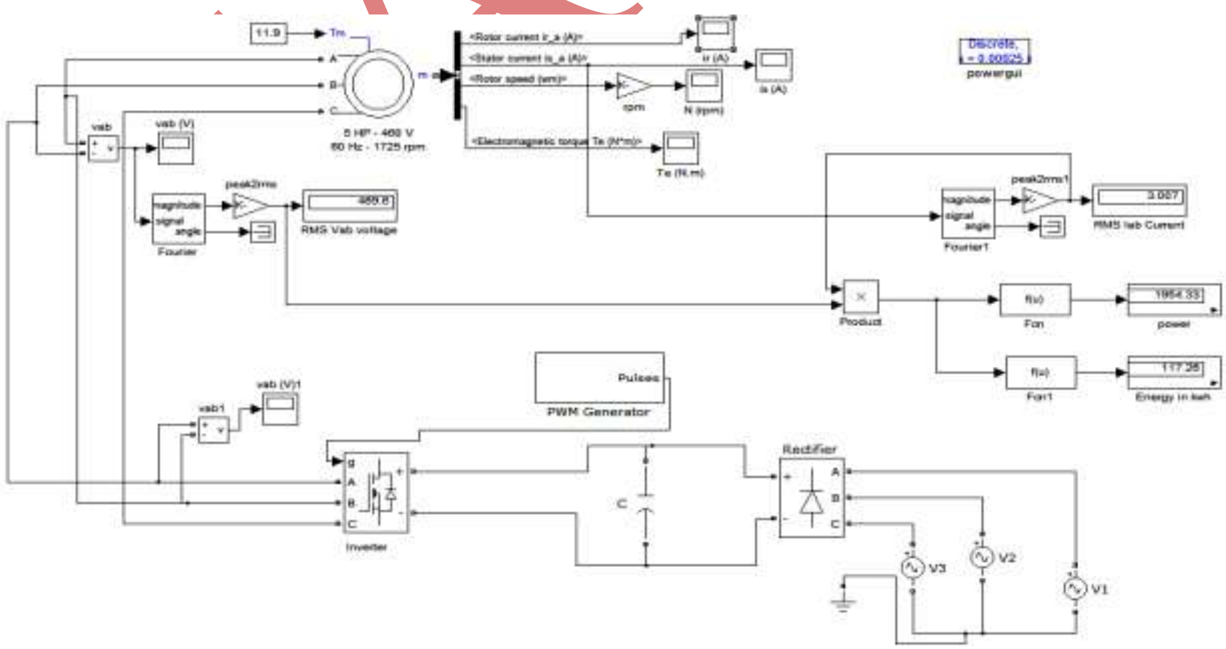


Figure 10 Simulation Model of Indirect mode of supply to Induction motor and measurement of Energy.

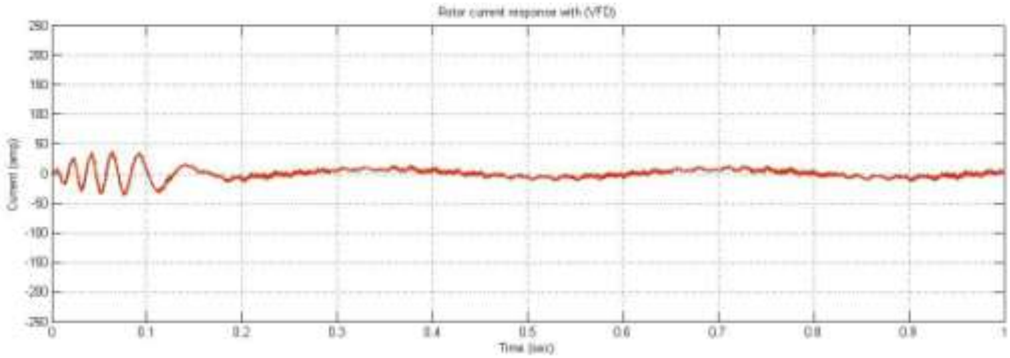


Figure 11 Rotor current response with VFD

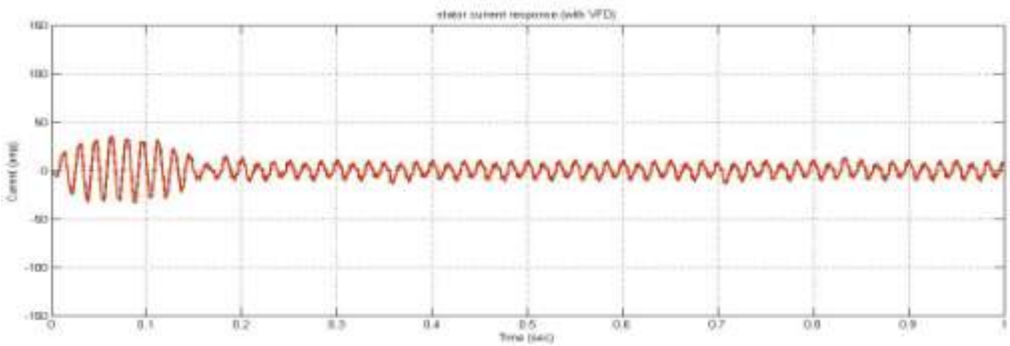


Figure 12 Stator current response with VFD

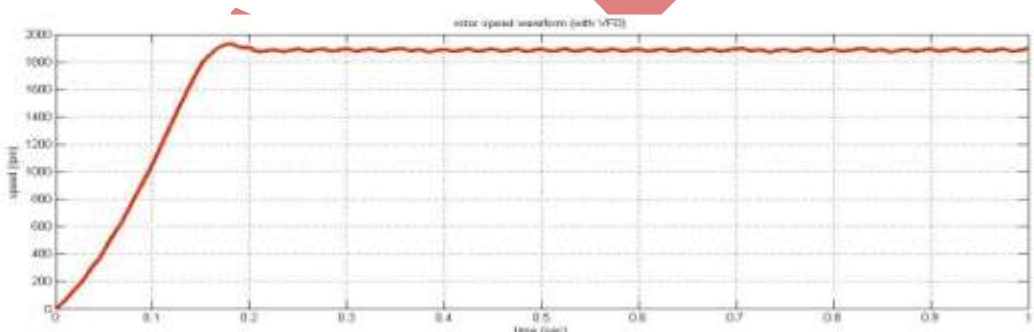


Figure 13 Rotor Speed Waveform with VFD

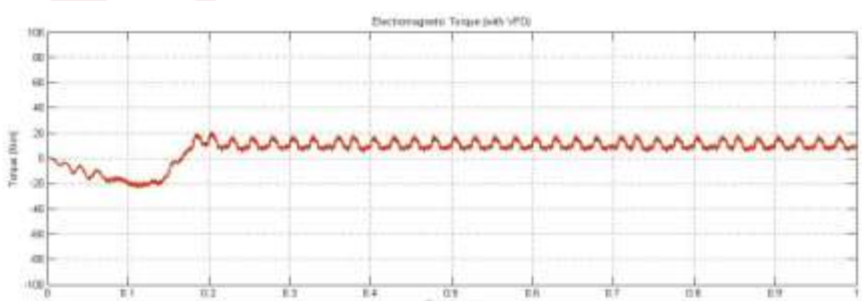


Figure 14 Torque Waveform with VFD

Table 1 Comparison Between with & without VFD in pumping system

Torque (N-m)	Without VFD				With VFD				Energy saving in Kwh	% Energy saving
	Current (ampere)	Power (Watts)	Energy (kWh)	Efficiency η %	Current (Ampere)	Power (watts)	Energy (kWh)	Efficiency η %		
8	4.043	2337.04	140.22	62.66	2.614	1698.52	101.91	65.14	38.31	27.32 %
10	4.233	2535.05	152.10	67.96	2.785	1809.63	108.38	71.08	43.72	28.74 %
12	4.625	2814.76	168.89	75.46	3.02	1962.85	117.77	79.62	51.12	30.26 %
14	5.248	3087.35	185.24	82.77	3.306	2148.85	128.93	84.90	56.31	30.39 %

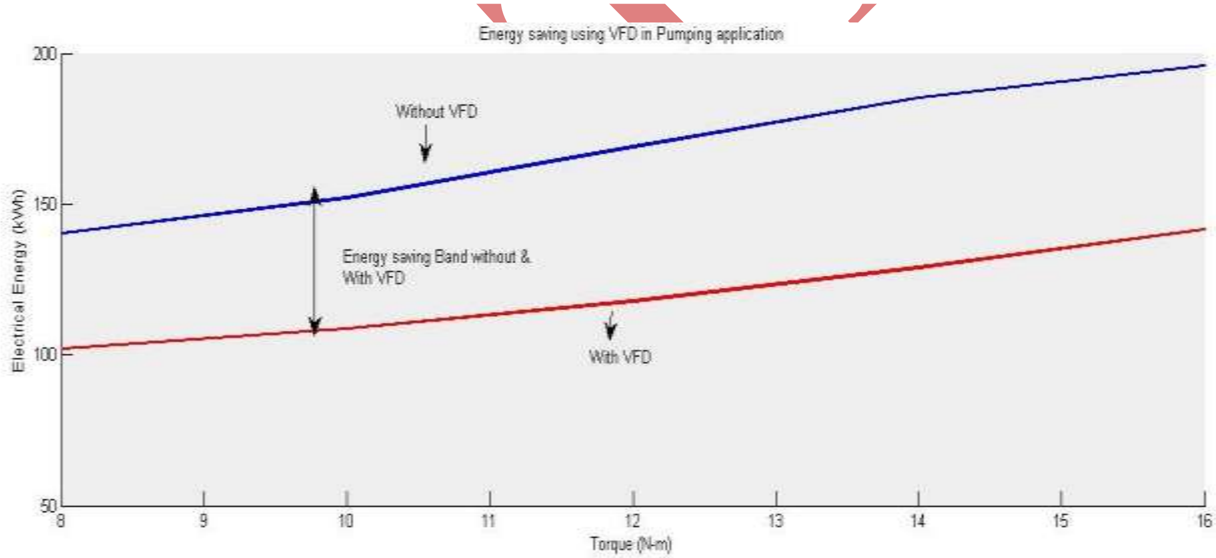


Figure 15 Energy Saving Band With & without VFD

From the above comparison table 1 we can clearly see that approximately 30% of energy saving is done after installation of VFD in pumping system.

From the figure 15 we can see that the saving of energy with and without VFD with the use of energy saving band. The energy saving band gives the clearly idea that how much electrical energy is save after installation of VFD.

VI. CONCLUSION

As by control the flow of pump with throttling (direct mode), net head increases and to overcome this extra head motor draw extra power. VFD offers a very good response to pumping system. Reduces the flow with VFD, motor consume very less power. So significant amount of power can be saved with the help of Variable Frequency Drive. VFD also serves as Soft Starter, during starting motor draws 6 times more current than rated current. While starting with VFD, motor draws very less current and also provide a smooth stopping of motor. So the losses occur in motor can be eliminated. Thus we can conclude that Variable frequency drives (VFD's) are often recommended as a way to save pumping energy and it will help for conservation of electrical energy for our future generation.

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