

Energy Savings in Pumps

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Abstract—This study presents energy saving in general-purpose pumps widely used in industrial applications. Such pumps are normally driven by a constant-speed electrical motor which in most applications must support varying load conditions. This is equivalent to saying the loading conditions mismatch the designed optimal energy consumption requirements of the intended application thus resulting in substantial energy losses. In the held experiments it was indicated that combination of mechanical and electrical speed drives can contribute to lower energy consumption in the pump without negatively distorting the required performance indices of a typical centrifugal pump at substantially lower energy consumption. The registered energy savings were recorded to be within the 15-40% margin. It was also indicated that although VSDs are installed at a cost, the financial burden is balanced against the earnings resulting from the associated energy savings.

Keywords—Industrial motors, Pumps, Energy consumption, Energy savings, Variable speed drive.

I. INTRODUCTION

IN the past few decades almost all developing countries are becoming highly industrialized within a process of economic growth and industrial development. This is why energy efficiency improvement and energy savings has become one of the main objectives of the international and national energy policies. Considerable levels of Energy losses are an accepted reality in a large number of industries, and there is evident potential for energy efficiency improvements [1-8]. Past studies have indicated that implementation of a few selected options at little or no cost in the industrial sector could reduce GHG emissions by 10-30% of GHG emissions [9-10]. An estimation for use of energy in office buildings in Malaysia showed that about more than a half amount of total electricity power is used by air conditioners or in other words by electric motors [11]. In the UK, Electric motors consume 40% of total electrical energy that fans are responsible for 22% consumption of this amount of energy [12]. The consumption of electrical power in Iran has increased from 2,220 GWh to approximately 100,000 GWh, between 1976 and 2000 [13].

This experimental study presents energy saving by industrial motors controlled by a VSD for a highly frequent motor-pump arrangement. Section two presents the theoretical basis to the anticipated energy saving, and section three describes the methodology of the research. Section four indicates the results, and in section five the conclusions are presented.

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II. FORMULATION

A VSD is an electronic power converter that generates a multi-phase, variable frequency output that can be used to drive a standard AC induction motor, and to modulate and control the motor's speed, torque and mechanical power output. Utilization of VSD's in industrial applications results in considerable energy saving [21, 22].

The Affinity Laws (also called the cubic Laws) state that fan and pump output (flow) is directly proportional to its speed [22, 23].

As far as the economic viability of utilization of VSD systems is concerned the annual energy saving associated with application of VSD systems is presented by (1) [24].

$$AEC = \frac{P_{KW} \times N_{motors} \times YOPH}{\eta_{motor}} \quad (1)$$

Where, AEC is annual energy consumption (MW), PKW is electric motor power (KW), N_{motors} is number of electric motors, YOPH is yearly operation hours of electric motor (hours) and η_{motor} is electric motor efficiency.

Annual energy consumption when using variable speed drive depends on annual energy consumption without using VSD and speed reduction ratio. This can be calculated from (2).

$$AEC_{VSD} = AEC \times (1 - SR_{ratio})^2 \quad (2)$$

Where, AEC_{VSD} is annual energy consumption with VSD (MW) and S_{ratio} is speed ratio.

Annual energy saving when VSD is applied is therefore the difference between annual energy consumption without using VSD and annual energy consumption when using VSD (3).

$$AEC_{VSD} = AEC - AEC_{VSD} \quad (3)$$

Ultimately, when using VSD, annual financial saving can be calculated based on annual energy saving and the unit price of energy. The formula that is associated with the above cost savings are as follow (4).

$$AMS_{VSD} = AES_{VSD} \times UEPPKWH \quad (4)$$

Where, AMS_{VSD} is annual money saved with VSD (USD), AES_{VSD} is annual energy saving with VSD (MW) and UEPPKWH is unit energy price per KW hour (USD).

Payback period is obtained by dividing the incremental cost of VSD system by the annual value of saving as a result of application of VSD system for the considered year. Payback period can be expressed from (5).

$$PBT_{VSD} = \frac{C_{VSD}}{AMS_{VSD}} \quad (5)$$

Where, PBT_{VSD} is payback period (Years) and $CVSD$ is incremental cost of VSD (USD).

III. METHODOLOGY AND EXPERIMENTAL SETUP

A typical pump (max flow of 200 lit/hr) which is frequently used in industry was selected. The pump was driven by an electric motor (1.5 KW, 1500 rpm). The pump speed was initially adjusted by mechanically changing of center-to-center distance “d”. Such adjustment of pump speed is referred to as the Mechanical Adjustment. For each pump-motor arrangement, the motor speed, pump’s consumed power and flow rate were recorded. In the second set of experiments, the distance “d” is maintained fixed and the speed of the pump is varied with the aid of a VSD, which changes the motor speed by changing the AC voltage frequency. Such adjustment of pump speed is referred to as the Electrical Adjustment. Given the fixed mechanical setup, the same recordings of speed, power and flow rate were registered.

The pump speed was varied between 400 to 1,500 rpm, with the pump’s flow rate varied between zero to 170 lit/hr. The consumed power was measured with the aid of a Watt-meter with an accuracy of 5 W. An Optical Tachometer with an accuracy of 1 rpm was used to measure the pump’s speed. The flow rate was recorded by a rotameter. To control the temperature a PT100 Electrical Resistance Thermometer was used. All the measurement tools were calibrated; a Stroboscope was used for the Optical Tachometer and an Ohmmeter for the Electrical Resistance Thermometer; the rotameter was calibrated by using a Standard Orifice. The inlet and outlet temperatures of flowing water during the experiment were kept constant and equal to $18 \pm 1^\circ\text{C}$.

IV. RESULTS AND DISCUSSIONS

With reference to the Methodology and the Experimental set up described in the section 3, the experimental results were derived below.

It is notable that at a flow rate of 170 lit/hr, the only possible means of obtaining the required flow rate at various motor speeds was through the use of VSD mechanism which indicated a limit to the use of mechanical adjustment of speed.

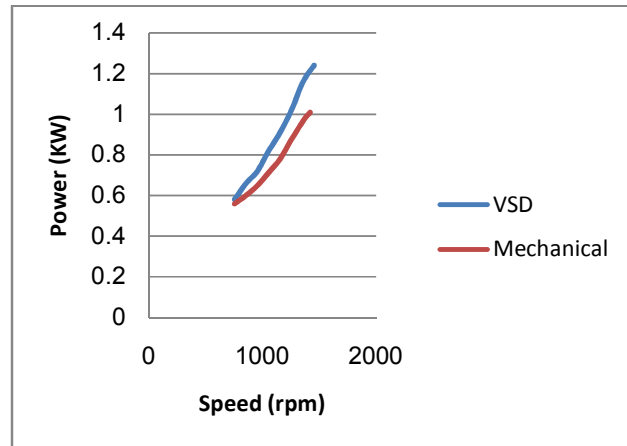


Fig. 1 Consumed Power at 40 lit/hr at d= 44.5cm

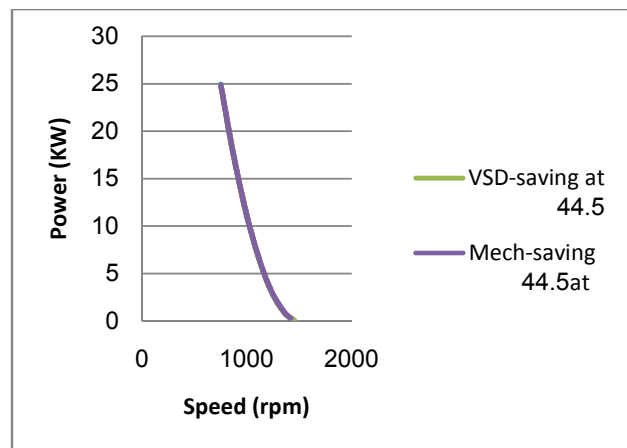


Fig. 2 Percentage energy saved with VSD and Mechanical Adjustment at 40 lit/hr at d = 44.5 cm

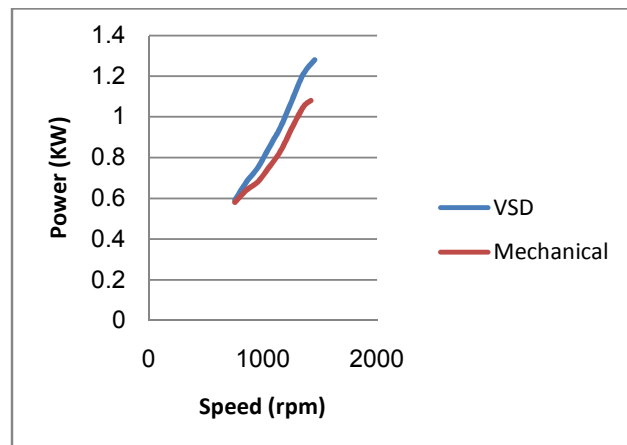


Fig. 3 Consumed Power at 70 lit/hr at d= 44.5cm

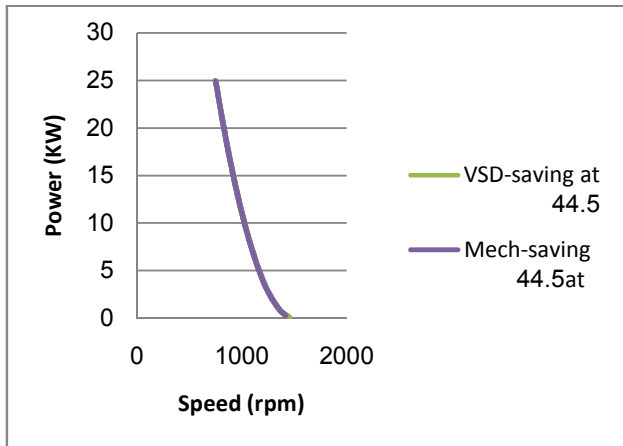


Fig. 4 Percentage energy saved with VSD and Mechanical Adjustment at 70 lit/hr at $d = 44.5$ cm

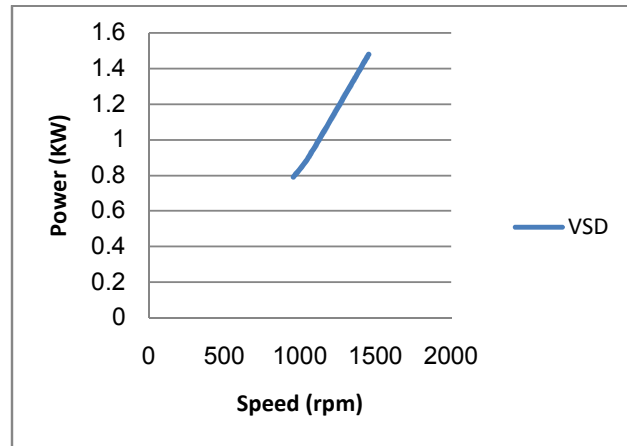


Fig. 7 Consumed Power at 170 lit/hr at $d = 44.5$ cm

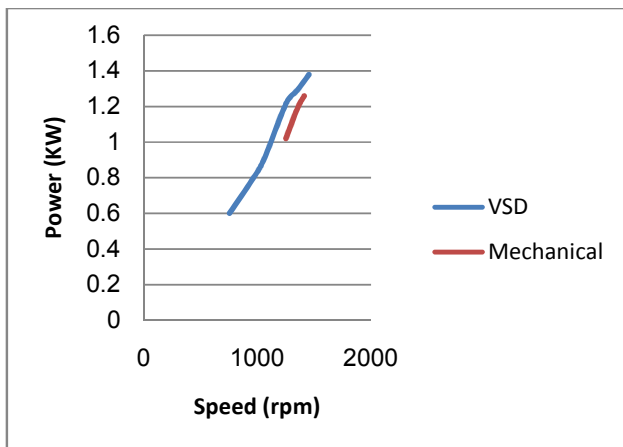


Fig. 5 Consumed Power at 140 lit/hr at $d = 44.5$ cm

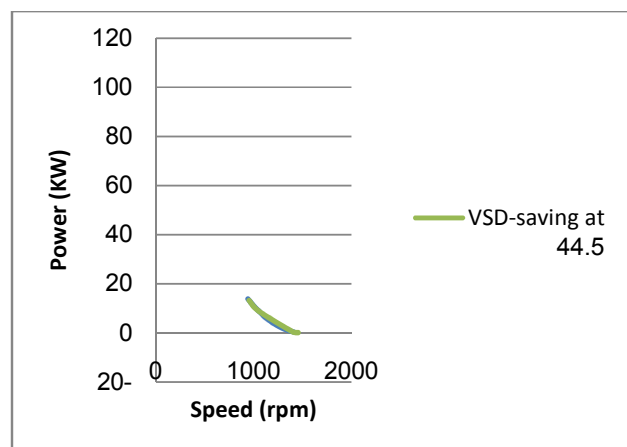


Fig. 8 Percentage energy saved with VSD at 170 lit/hr at $d = 44.5$ cm

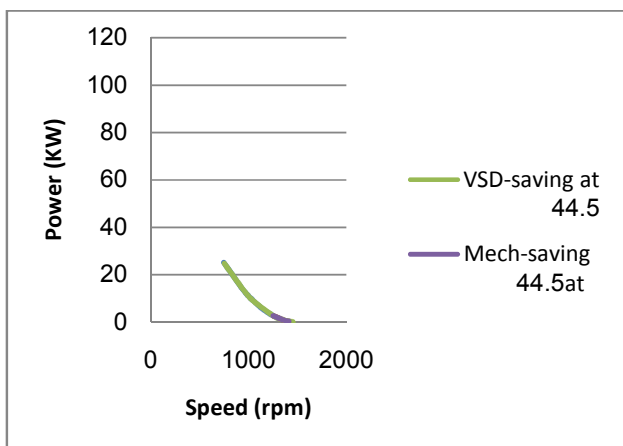


Fig. 6 Percentage energy saved with VSD and Mechanical Adjustment at 140 lit/hr at $d = 44.5$ cm

From Fig. 1 through Fig. 8 a very close correlation between the VSD and mechanical systems is evident; Furthermore, same figures indicate that the VSD system can operate in the full range of motor speed whereas mechanical adjustment lack such capacity. Referring to Fig. 5 through Fig. 8 it can be seen that speed adjustment of the motor, i.e. adjustment of the pump flow rate, may be achieved by the VSD system for the full-range of motor speed, while the same operation cannot be matched by the mechanical adjustment of speed, with such possibility being open to the mechanical-based systems only at higher motor speed at which higher consumption of power is realized.

From Fig. 5 through Fig. 8 it is evident that at larger values of flow rate, mechanical adjustment of speed cannot be used and performance-dominance of VSD systems fully prevails.

It is apparent that VSD-based system may deliver the same pump out-flow at lower speeds, i.e. lower power consumptions. From the same Figures it can be observed that for any given flow rate, the lower the motor speed the less power is consumed by the motor when VSD system is applied.

With regards to financial feasibility of VSD utilization and for the particular case of IR Iran, the Unit Energy Price per KWh is USD 0.05. Therefore, as an indication of the economic factors dominating the feasibility for utilization of VSD systems in practice, we can determine the payback period for the particular case under investigation. In doing so, we shall consider the case for which a 25% energy saving, equivalent to 4.83 MW/year is taken into consideration.

V.CONCLUSION

The study indicate that application of a VSD system to drive a pump, and with some degree of generalization to other turbo- machinery equipment, may imply fulfilling the same output characteristics of the pump at lower gross energy consumption of the overall system, with the results complying with the Affinity Law for such applications. Furthermore, comparing the VSD-based adjustment of the motor speed as oppose to the common mechanical adjustment of the speed, with both systems presenting very similar energy saving trend, indicated that while the VSD-based system is easier to apply, it may also drive the pump is a wider range of motor speed to cover a wider range of pump flow rates.

Financially speaking, the value of the Annual Energy Saved by application of VSDs indicates the economic viability of such systems, even in countries such as Iran where energy bills are subsidized by the government.

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