Control Systems with Frequency Converters save Energy in Food Industry

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***Abstract* – A possibility to meet carbon emission (Kyoto commitment) and energy conservation targets when using electric motors in food industry is discussed in this paper. Typical applications where savings could be confidently expected would include: pumps, compressors, fans, conveyors, mixers, refrigerators. Some of the most common applications of variable speed systems with frequency converters are discussed and worked examples showing the benefits that can be achieved are given.**

***Keywords* – Energy conservation, Variable speed drives, Frequency converter**

I. Introduction

Energy conservation has become an increasingly important feature in any solution selected today. More than 65% of industrial electrical energy consumed is by the electric motors, which in turn accounts for around 10% of a country's CO^2 emission. To meet carbon emission and energy conservation targets governments world wide are realizing the need to encourage more effective use of motors in all areas of industry. Savings have to be achieved in food industry as well. In typical applications (pumps, compressors, fans, conveyors) levels of utilization are approximately 50% with power losses estimated to be between 40% and 80% of the motor full load rating. The latest developments in microcomputer based technology present financially attractive opportunities to reduce these losses. There are three methods of improving energy efficiency by investment in: high efficiency motor; motor controller; variable speed system (VSS). High efficiency motors and motor controllers are options for constant speed motors. A decision tree for selection procedure in this case is discussed in [1]. The next opportunity for saving energy is using VSS. Historically, they were not installed for energy saving reasons but to satisfy process requirements. As a result, the degree of sophistication was determined by requirements of the process and usually meant that the particular speed needed was preselected and controlled manually from the range available. Today many more options exist and modern electronics helped by the comparatively high cost of electricity, have brought about revolution in options. Infinitely variable and constantly changing speed can now be achieved at a relatively modest cost, determined mainly by the degree of flexibility required of the system. VSS have the objective to adjust the speed of the driven load in accordance with some measured parameter and they broadly fall into three categories: electronic variable speed systems; variable speed motors and electro-mechanical drives. The last two are not discussed in the paper. The electronic variable speed systems (EVSS) operate by electronically matching the speed of the motor, and the power input to it, to the requirements of the load. Hence the iron and other losses are reduced to minimum. EVSS could be separate to two main groups: DC and AC. Which solution is the right DC or AC EVSS, when choosing energy effective decision for control of electromechanical systems is discussed in [2].

Electronic variable speed systems (EVSS)

From the wide variety of AC EVSS frequency converters (FC) have become the most popular today. They convert the AC mains voltage to a DC voltage which is then inverted into a variable voltage, variable frequency AC supply. FC can be retrofitted to existing motors, but some derating of the motor (possibly by up to 10%) is necessary. They extend control down to zero speed and up to three/four times normal synchronous speed. The power factor of the supply current is normally high and relatively constant over the whole speed range. Since the output wave form is close to a pure sine wave there are few problems due to harmonics on the motor. The total efficiency of the VSS with FC as a drive control (Fig.1) depends on the losses in the motor and its control. Mechanical output power depends on the required torque (M) and rotating speed (ω). The presented results are based on the assessment of the total losses of a VSS with FC in two wide spread applications in food industry.

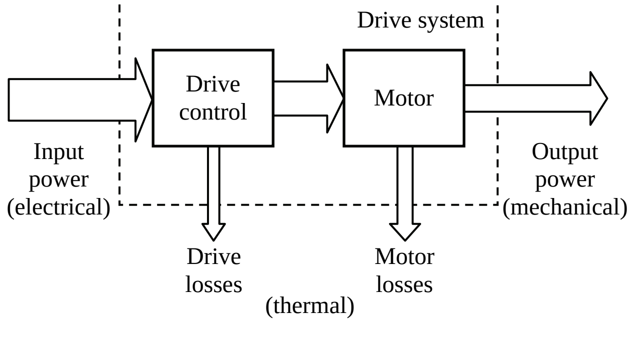

Fig. 1 The Efficiency of the Drive System

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Fans and Pumps

Fans and pumps are the worst offenders in the VSS efficiency. The need for flow rate control is widespread in food industry and the method selected has a significant bearing on the running cost. Pumps have much in common with fans and the laws governing their operation are similar. Head/flow and efficiency curves for a typical centrifugal pump operating at constant speed are shown in Fig.2. Pump's characteristic curve usually refers to certain specified speeds and densities of the medium being pumped. The design point in this example is selected so that maximum efficiency occurs at 100% flow. If the pump characteristics are examined when speed variation is introduced, the basic relationships which govern their operation are shown in Fig.3. The pump efficiency shows little reduction over the upper portion of the speed range, but rapidly decreases as the speed falls below 60% of the design value. Speed control of the pump (fan) is one method of changing the design point (Fig.4). The effect of speed control on the energy consumption of a centrifugal pump is evident from experimental results shown on Fig.5.

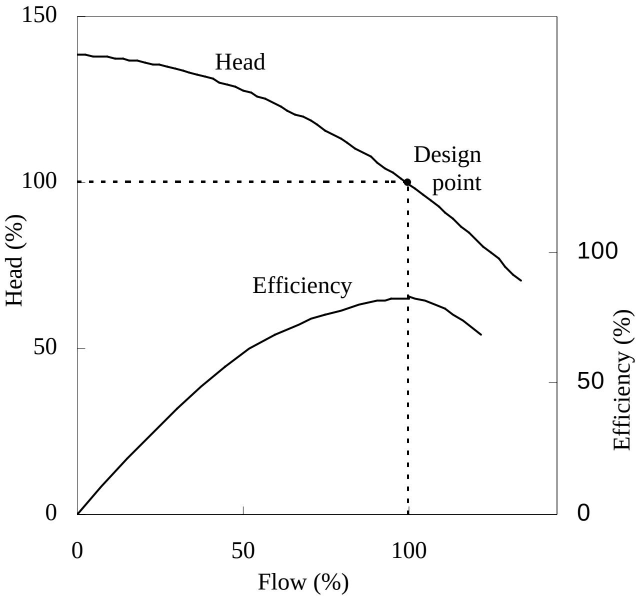

Fig. 2 Typical Centrifugal Pump Head/Flow Efficiency Curves for a Constant Speed Conditions

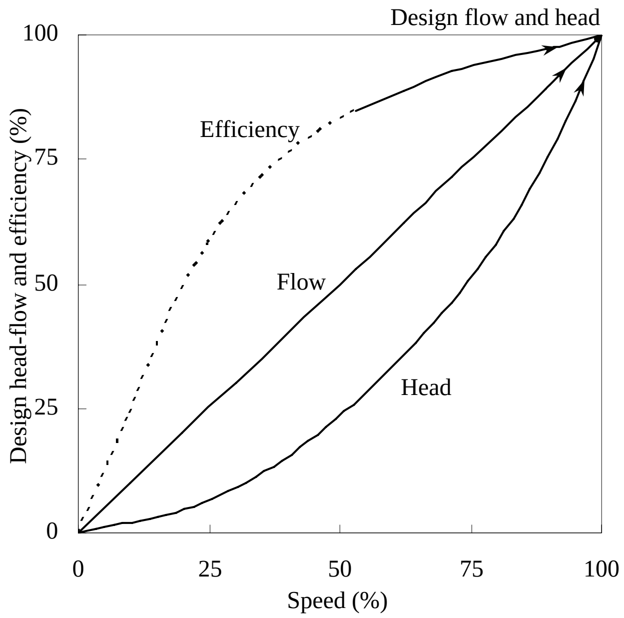

Fig. 3 Typical Centrifugal Pump Efficiency, Flow and Head Characteristics for Variable speed

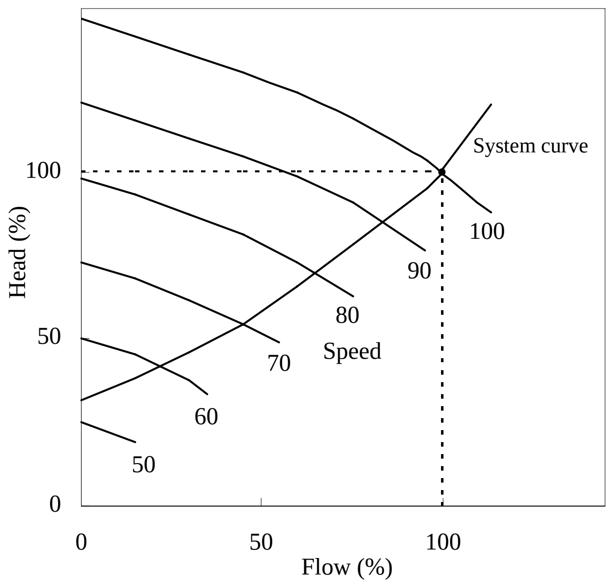

Fig. 4 Flow variation with Speed Reduction

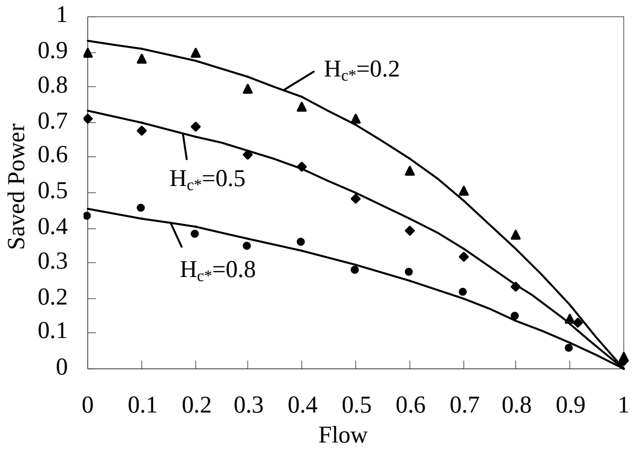

Fig. 5 Saved Power depending on Flow Rate at Static Delivery Head: H_{C*}=0.2; 0.5; 0.8

The extra power consumption, when the control of flow is at a constant speed, using "throttling" by means of a control valve, compared to the power consumed when flow is controlled by the speed. The FC used for the experiment is of type Altivar 58HU18M2 of Schneider Electric [3]. The centrifugal pump has been examined at three static delivery heads (H_{C*}). The extra power consumption is obtained by measuring the fixed speed power input and power input to drive. The results show that changing the 'throttling' with VSS reduces the consumed power. Speed control is more effective when the static delivery head is smaller.

Conveyors

Almost all technological processes in food industry use different kinds of conveyors for processing, transporting and packaging. The productivity Q_* of the conveyor depends on the force F_{C*} needed to replace the useful load and the velocity υ_* of movement. The equation in relative values is:

$$Q_* = F_{c*}\,\upsilon_* \tag{1}$$

When the conveyor is running at a constant speed $\upsilon_*=1=\text{const}$, the productivity is equal to the force $Q_* = F_{C*}$ .The better way to control conveyors is to keep up the force constant at rated value ($F_{C*}=1=\text{const}$). In this case productivity will vary proportionally to the speed $Q_* = \upsilon_*$. Using VSS to control the productivity of conveyor gives a possibility for saving energy

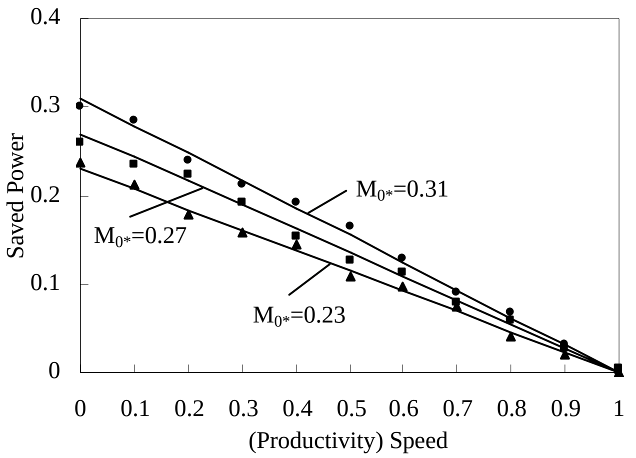

Fig. 6 Saved Power depending on Productivity at Ideal Running Torque M_{0*}=0.23; 0.27; 0.31

as compared to the constant speed work. The experimental data of saved power depending on productivity (speed) are presented in Fig. 6. The data are obtained from VSS with Lenze smd frequency converter ESM D251X3SFA [4]. The experiment has been made for three different values of the ideal running torque of motor (M_{0*}=0,23; 0,27; 0,31). It is evident from Fig. 6 that the saving effect from the speed control of productivity of the conveyor is as higher as bigger the torque M_{0*} is.

II. Additional Remarks

VSS with FC reduce energy wastage by changing the motor speed. This saves energy because the motor does not use more energy than required. There are several options for control the FC itself. FC Volt per Hertz is the control method of choice for applications where multiple motors are operated simultaneously from one motor control. Closed Loop Vector operation of FC uses mounted encoder to precisely control motor torque and associated operating speed. Drive segregate motor current into components that produce torque from the current that produce motor heating. By minimizing the heating component of current and accurately controlling the torque component of applied current, the motor will behave very much like a DC motor but without the maintenance. Direct Torque Control (DTC) brings even more savings, often up to 30% according to ABB [5].

III. Conclusion

In this paper ways for saving energy by using VSS with FC in food industry are given.

Speed control methods of pumps are most appropriate where the friction losses dominate in the system characteristic. In cases where the static delivery head is principal component, speed control will show less benefit.

In addition to the energy cost reduction achievable, other benefits can arise from the use of VSS. These include the elimination of problems created by water hammer, the reduction of hydraulic loading, improved product quality and increased resistant index of the conveyor belts.

References

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