Practical Aspects Regarding Implementation of Variable Speed Drives in Cooling Tower Fans

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Abstract: The paper includes solutions for increasing the efficiency of the electrical energy consumption in chemical industry using the frequency converters for the automatic speed regulation for the cooling tower fans application. The motivation in implementing a new solution and the structure of the electrical equipment, together with experimental results are presented.

Key-words: variable speed drive, frequency converter, energy savings.

1 Introduction

The variable speed drives (VSD) which are used for pumps and fans applications (defined by the square shape of the torque vs. speed characteristic) are covering approximately 40% from the total amount of the electrical power required for all applications Fig. 1 [1, 2, 3].

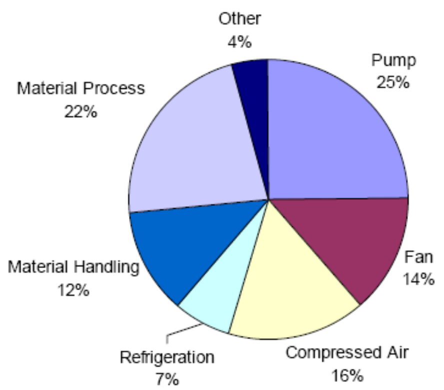

Fig. 1. Spreading of the installed power trough VSD, for different applications.

In the same time, the technical and economical potential regarding the cost reduction, for different applications, brings for the first page also the pumps and fan systems, Fig. 2, [1, 4].

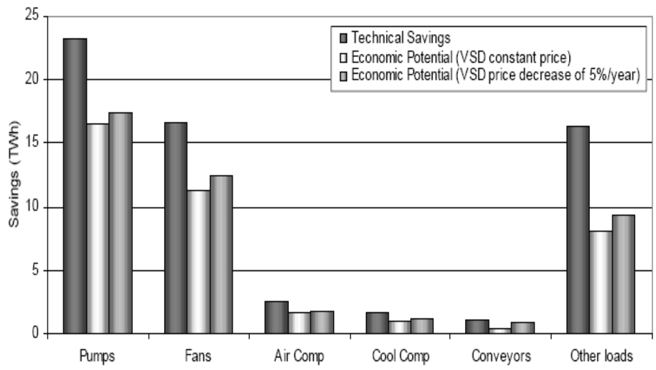

Fig. 2.Technical and economical potential for costs reduction for different applications.

These issues led the specialists in this field to focus their attention for an improvement of this category of hardware: on the one hand, pump and fan manufacturers have made technological progress that has led to a considerable increase of this equipment reliability and efficiency, on the other hand power and automation equipment manufacturers have substantially contributed to electrical power consumption optimization.

This latter issue highlighted two action categories:

- Utilization of power electronics equipment to supply electric drives, that allowed effective dosing of energy to the electrical machine, with the possibility of controlling one of the mechanical parameter (speed or shift torque);
- Automation of pumping and ventilation processes, which led to the subjective factor elimination, with its negative impact.

The positive impact of the power electronics equipment on electric drives performances results from

European Community market shares. Fig. 3 presents, for different power ranges, the percentage of the variable speed drives from all electric drives with induction machines. We have to notice the fact that most important weight is recorded for powers above 70kW. This is due to the price per kW for the power electronics equipment, which decreases with power rising, making the investments for this power range very efficient.

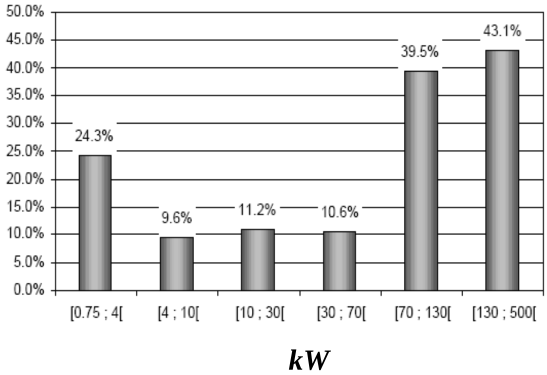

Fig. 3. Weight of variable speed drives related to the power range.

The paper presents the implications regarding the energetic consumption reduction as result of using systems with VSD for induction motors in water cooling applications for the chemical industry. Two types of electrical equipment are introduced, both designed, manufactured, approved and commissioned at the client, together with records regarding the energetic consumptions in order to point out the energetic efficiency of the technical solution.

2. General considerations

Cooling towers (Fig. 4) represents an important technological part in chemical industry. This is the main reason in whishing to increase the efficiency of the ventilation process and system reliability. These are the major objectives to be considered for manufacturing and implementing the VSD in this application [5].

The requirements for a ventilation system with variable speed drive for a cooling tower are:

- start/stop of the fan, with controlled ramp, to avoid the mechanical stress due to the large inertia moment and to reduce the maintenance costs;
- speed regulation to maintain the water temperature in the tower collecting reservoir to a prescribed value and for optimal energy consumption, independently from the environmental temperature;
- the possibility of operating at very low speeds, even to reverse the speed when the environmental temperature has very low values, to avoid the overcooling of the water and so, ice deposits on fan blades;
- eliminating of electromechanical regulation systems (blade angle control, gearbox etc.);
- avoiding of operating at critical resonant frequencies.

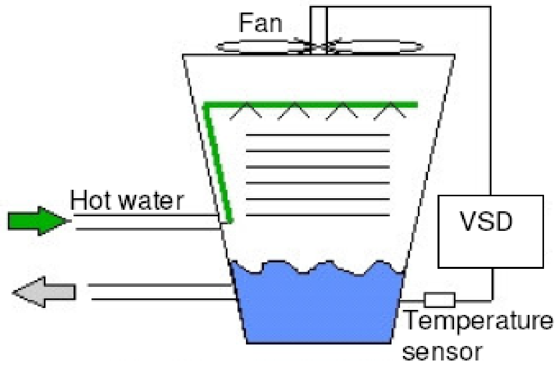

Fig. 4. The configuration of one cooling tower.

The basic equations for an variable speed ventilation system are:

$$Q'_{v1} = \frac{n'}{n} Q_{v1} \tag{1}$$

$$p'_{tF} = \left(\frac{n'}{n}\right)^2 p_{tF} \tag{2}$$

$$P'_F = \left(\frac{n'}{n}\right)^3 P_F \tag{3}$$

The active power P_{v1} absorbed from the grid by the motor that drive the fan, in rated operating regime, is calculated as follows:

$$P_{v1} = \frac{\rho \cdot Qvn \cdot p_{tF}}{(\eta_k \cdot \eta_t \cdot \eta_m \cdot \eta_c \cdot 1.20) \cdot 1000} = \frac{P_F}{\eta_k \cdot \eta_t \cdot \eta_m \cdot \eta_c} [kW] \tag{4}$$

The air density ρ_1 trained by the fan depends on the temperature:

$$\rho_1 = \rho_x \cdot \frac{T_x \cdot p_{sa1}}{T_1 \cdot p_{sa2}} \tag{5}$$

Where:

- p_{tF} – fan generated pressure (total value) [kPa];
- Q_{v1} – fan flow [m^3/s];
- ρ – density (air /gas) [kg/m^3];
- P_F – hydraulic power;
- P_R – fan power;
- η_k – fan efficiency;

-η_t – mechanic transmission efficiency;
-η_m – motor efficiency;
-η_c – frequency converter efficiency;
-n – fan rated speed;
-n' – real (actual) fan speed
-ρ_x represents the known value of density at T_x temperature;
-p_{sa1}, T_1 pressure, respectively temperature at ρ_x density;
-p_{sa2}, T_2 pressure, respectively temperature with known values

In Table 1, are given the densities for different temperature values, for dry air at 1013 mbar pressure [6].

Table 1

Temperature [°C]	Density [kg/m^3]
0	1.2930
10	1.2471
20	1.2045
30	1.1647
40	1.1267
50	1.0924
60	1.0595
70	1.0287
80	0.9998
90	0.9719
100	0.9458

For usual values of the parameters in equation (4), the electric power P'_{V1} absorbed from the power network by the drive at n'- speed value, may be estimated according to values given in Table 2:

Table 2

n'/n	P'_{V1}/P_{V1}
0.9	0.78
0.8	0.61
0.7	0.47
0.6	0.37
0.5	0.30
0.4	0.23
0.3	0.18
0.2	0.15

Fig. 5 presents the power absorbed from the grid by the electrical motor which drives the fan, depending on the flow modification methods [3], and equations (1) - (5) together with the values from table 2 are sustaining the energetic advantages of using the variable speed for ventilation systems and also is offering the possibility of an approximate calculation of the economical efficiency of the investment. Moreover, the variable speed brings other positive effects in the analyzed applications, such as: reduction of mechanical stress by controlling the torque and currents of the electrical motor which drives the fan, reducing the process and maintenance costs etc.

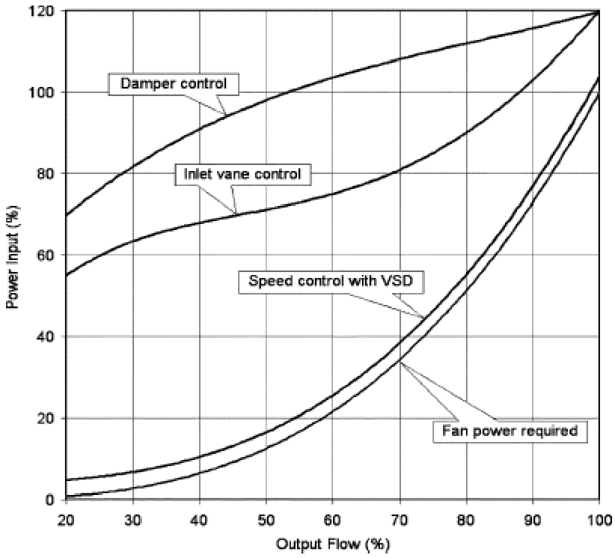

Fig. 5. The power absorbed by the electrical motor which drives the fan, depending on the flow regulation method.

3. Description of electric drive systems

In what follows, two configuration of variable speed drives (VSD) for ventilation systems are analyzed: the first one, which supplies in parallel two induction motors of 110kW each one, from a single frequency converter (Parallel Drive – PD), Fig. 6, the second one, where each of the two induction motors of 250kW each one, are supplied independently by its own frequency converter (Independent Drive – ID), Fig. 7. Both of the configurations allow, for redundancy reasons, the direct on line (DOL) connection, in case of power electronics failure [7].

The application where for the equipment in PD configuration has been designed is the driving of two cooling fans for water cooling, at a cooling tower with forced air draught, type HAMON, with two cells, for water flow of 1200 mc/h each one. The collecting reservoir is common, placed at the bottom of the cooling tower. Each cell contains one fan, with 5 blades made from armed polyester with glass fiber, DeltaNeu A.P.900, with a diameter of 8000 mm, which works at a rated speed of 165rpm, providing a flow of 400 cubic m/s, using a gearbox and transmission from an induction motor (P_n=110 KW, 1480 rpm,50 Hz). The thermal load is of 10-30 Gcal, according to the technological process loading. Depending on the season, on the air temperature and the atmospherically condition, the water is cooled with help of two fans, one fan, or even without forced ventilation, the optimal temperature required by the process being around 24°C.

The changes of the inlet air temperature in the cooling tower have direct influences on the cooled water temperature, leading to disturbances of the main parameters of the cooling system.

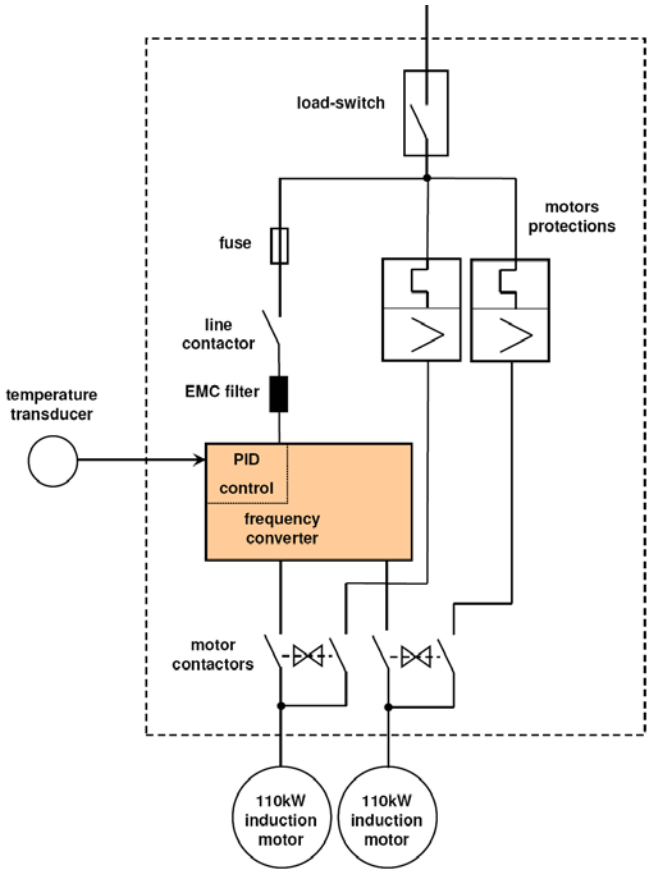

Fig. 6. Parallel Drive configuration - PD.

Before the implementation of the VSD, water temperature variations were reduced, partial, by diverse auxiliary maneuvers (start/stop of the fans, redirect of the water flow), without the possibility of elimination. This operating regime has some negative effects increasing the electromechanical usage, excessive power consumption, and the cooled water temperature instability leads to unwished variations of the parameters from the technological processes, which leads also to supplementary controls.

The VSD offers the following operating modes:

Automat mode: in this operating regime, the control of the water temperature in the collecting reservoir and the maintaining of this parameter at the required value, is done by the frequency converter with help of its process regulator (PID type) incorporated, by controlling the motor speed. Both motors are supplied at same variable frequency, simultaneously, from one frequency converter that is accordingly sized to allow this possibility.

Manual mode: for this operating regime, the induction motors are connected DOL to the power network. This is a reserve operating regime, used only when the frequency converter is not operational (out of order). In this case, the equipment does not provide the automat control of the water temperature; the control is done discrete by connecting/disconnecting the induction motors from the power network.

The cooling tower with mechanical air draught type HAMON, where the VSD in ID configuration was implemented, is similar to the one previously described, but it has other parameters having two cells for a water flow of 4500 mc/h per cell.

The cooled water flow is of about 8000 – 8500 mc/h. Both cells are working; the collecting reservoir from the bottom of the cooling tower is common.

Each cell had initially one ventilation system (320kW, 1480rpm, 6kV, 50Hz), with gearbox, transmission, fan (4 blades, polyester armed with glass fiber, diameter 12400mm; speed 105rpm, flow 1030mc/s).

The original structure of the tower was replaced with thermo-formed filling material.

The thermal load is 40-45 Gcal depending on the technological process and the optimal temperature of the cooled water for the technological process is of 22°C.

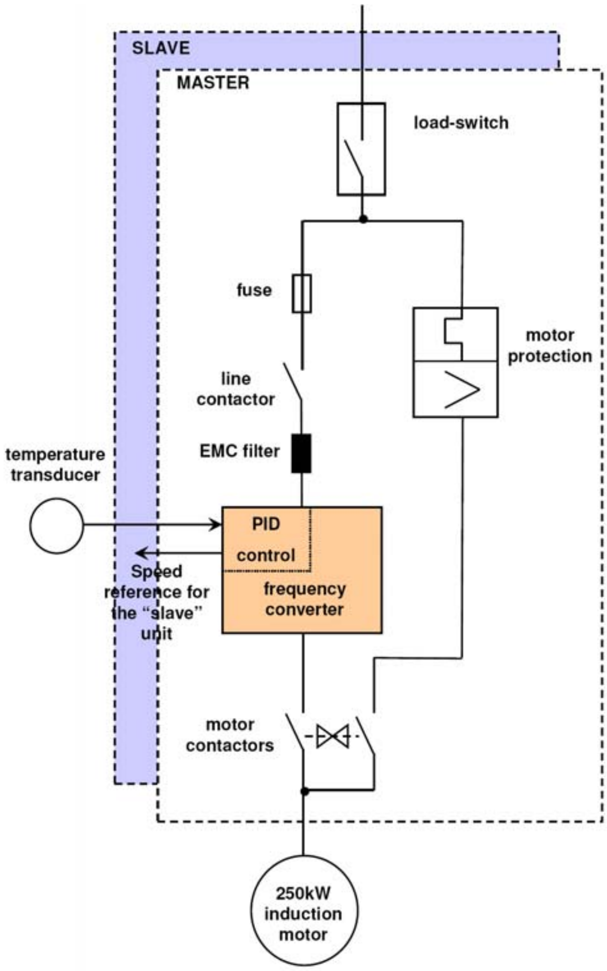

Fig. 7. Independent Drive configuration - ID.

The refurbishment of the cooling towers has led to a reduction of the electric power required from 320kW to 250kW per unit.

The equipment contains the same main elements as the one described before, the difference is that it drives only one induction motor.

The application requires two of such equipment to operate. The two frequency converters may operate independently, each one having its own temperature control loop. Because the collecting reservoir is common and to avoid antagonist operation, the two equipments work synchronized: one being the "master" and the second one the "slave" or else, the two operating modes can be selected from a turn-key placed on the front door of equipment. In this regime, the "master" frequency converter provides the control with help of its own regulator, driving in the same time the "slave" frequency converter in a synchronous mode.

Fig. 8 shows an example of equipment implementation.

Fig. 8. General view of VSD in PD configuration.

The manufactured configurations presented above have, each one, advantages but also, disadvantages:

- Supplying of two motors from one frequency converter is evident the cheapest solution, but it offers less operating safe; in case of frequency converter crashes it offers as operating alternative only the direct on line connection of the motors to the power network.

- In case of independent supply for the ventilation units, even if one of the frequency converters crashes, the temperature control can be easily take over by the second unit, the faulty unit can be stopped or can operate with direct on line connection to the power network, as needed. Of course, the investment is in this case higher, with approximately 30 – 50%, depending on the installed power.

Choosing one of the two presented solutions mainly depends on the ventilation system importance in the technological process and so, by the production loses due to the faulty operation that may appear.

4. Energetic efficiency of implementing VSD

The analysis of the economic efficiency of implementing PD and ID equipments has been done using the records and comparing the electric power consumption in similar operating conditions, for one year, also for the previous situation (without implementing VSD) but for the new one, too.

Figures 9 and 10 present the energy savings which varies between 10% and 85%, being more consistent during the cold periods.

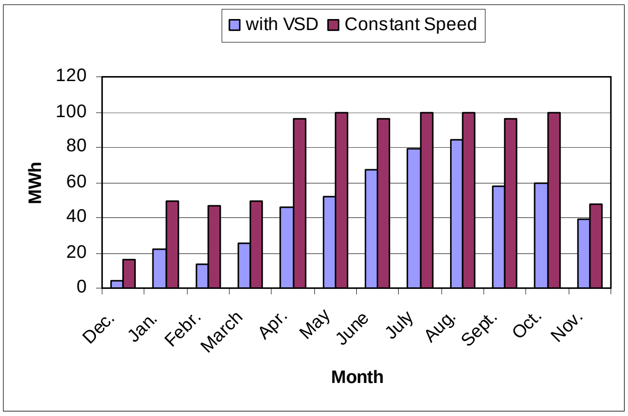

Fig. 9. Power consumption for PD configuration equipment

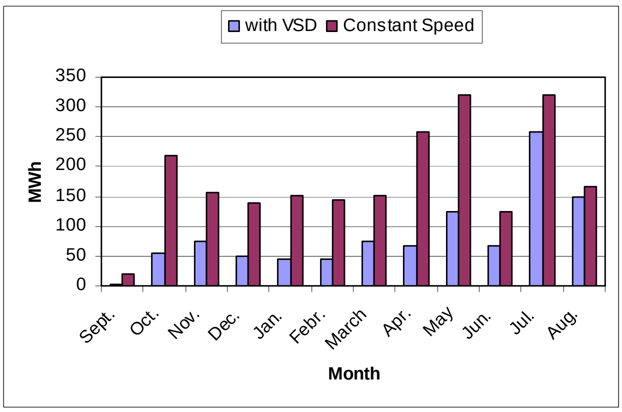

Fig. 10. Power consumption for two ID type equipment, in synchronized operation.

5. Conclusion

- VSD with frequency converters utilized for ventilation systems in cooling tower applications proved experimentally their reliability and energetic efficiency, achieving energy savings of about 360 MWh/year, for PD configuration, respectively 1100MWh/year for ID configuration. These experimental data may not be compared considering the installed power and the different applications where the equipment were implemented;

- The investment recovery time is about 2,5 years, calculated only by energy savings;
- Implementation of ASD in ventilation systems for cooling tower applications, proved along 4 years of operation, the following technical and economic positive effects, beside the energetic one, like: reducing the maintenance costs due to avoid of overloading the electrical and mechanical equipment, rising of the technological process performances by the cooling water temperature precise control, avoiding the ice deposits on fan wings and on the interior side of the cooling towers due to overcooling during winter etc.

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