



AUTOMATION SYSTEMS BASED ON ADJUSTABLE SPEED DRIVES

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Abstract: *In the paper are presented some relevant applications implemented in several industrial areas with adjustable speed drive systems with AC induction motors and frequency converters. There are pointed-out the major benefits related with these modern automation systems based on adjustable speed drives.*

Key Words: *Adjustable Speed Drive/Pump control/Fan Control*

1. INTRODUCTION

Nowadays, the adjustable speed drives (ASDs) based on AC motors controlled by frequency converters represent a standard element in all automated process plants. There are some major advantages where using AC motors speed adjustment: energy savings, process optimization, smooth machine operation, less maintenance, improved working environment, [1, 2]. It can be stated that ASD speed control for AC induction motors is a technology which has revolutionised the process industry. The main industrial processes can be divided into two categories: material treatment and material transport, respectively. The common basic requirement of both of these main categories is the need to be able to adjust the process, [1].

The major goal of this paper is to present the main results obtained in practical industrial implementation of adjustable speed drive systems, based on AC induction motors driven by frequency converters in various process industry since the last over ten years. The industrial drives are designed for industrial applications, and especially for applications in process industries such as pulp and paper, metals, mining, cement, power, chemical, and oil and gas industries. These industrial drives are highly flexible AC drives that can be configured to meet the precise needs of these applications. These drives cover a wide range of powers and voltages, including voltages up to 6000V. The industrial drives come with a wide range of inbuilt options. A key feature of these drives is programmability, which makes adaptation to different applications easy. The industrial drives are designed with current ratings to be used in industrial environments for applications requiring high overloadability. The heart of the drive is DTC, that provides high performance and significant benefits: e.g. accurate static and dynamic

speed and torque control, high starting torque and long motor cables. Inbuilt drive options make the installation work fast and easy. For easy drive programming, a detachable, multilingual alphanumeric assistant control panel, which is provided with various assistants and a built-in help function to guide the user, [1].

2. INDUSTRIAL APPLICATIONS OF PUMP CONTROL BY ASDs

Centrifugal pumps are used in a large number of industrial and commercial applications. The traditional approach to flow control, based on valves, results in an increase system pressure, waste energy, and cause the pump to operate at reduced efficiencies. Using ASDs in these kind of applications can achieve some important benefits, such as: reduced flow by providing adjustable speed pump operation, reduced system pressure and operation near the pump's maximum efficiency point, which results in energy savings, and reduced maintenance costs. Many previous papers have presented and reported significant aspects regarding the energy savings through adjustable speed operation of centrifugal pumps, [3, 4, 5, 6].

The manufacturers of frequency converters for power drive systems have developed some useful software packages designed for pump control, such as *Pump and Fan Control* (PFC), and *Intelligent Pump Control*, [1]. These applications softwares enable the control of multimotor pumping (or compressors, as well) stations. A typical pressure control system, is composed by several pumps connected in parallel, in which one pump (the master pump) is controlled by a frequency converter and the other pumps (the auxiliary pumps) are switched on and off by means of contactors. While directly controlling one motor, the drive is able to start/stop additional direct-on-line motors whenever a higher capacity is needed. This is the typical configuration where PFC control is applicable. Another pressure control system is achieved with three frequency converters in ring connection, controlling three pumps, in order to have a replacement for a failed unit. This represents the typical configuration for *Intelligent Pump Control*. These configurations, described above, have been proved to be very useful and reliable in all industrial implementations of ASDs in pumping systems.

A relevant example of an industrial implementation ASD pumping system is presented in Fig. 1, where the pumping system comprises two stages: a treatment stage, and a distribution stage. The first stage is designed to provide the intake water from a natural source (a river), and for water treatment. This pumping stage is served by two pumps driven by two AC motors of 30kW each of them. The control of the drive is done by an „electrical adjustable speed drive”, named as *AER 2x30kW* equipment, which consists in a frequency converter and the afferent electrical apparatus. The control philosophy is based on two control loops:

- an inner flow control loop, from a flowmeter (*TD*), designed as to provide a stable speed response for the motor with adjustable speed runing;
- an outer control loop, which controls the level in the Storage Basin; with a level transducer (*TN*); this

control loop is needed to synchronize the operation of the two pumping stages, in order to balance the flow.

The control block diagram of the first stage is presented in Fig. 2, where: Q^* is the reference water flow, Q – the actual water flow, *CSF* – the frequency converter, *MP*- the pump motor, *B*- the storage basin.

The second pumping stage is for civil water distribution, and comprises a pumping system with two 160kW AC induction motors. The electrical supply and control is assured by an *AER 2x160kW* equipment. The control of this stage is based on a pressure control loop, from a pressure transducer (*TP*), and is independent of the operation of the first stage. A picture of *AER 2x30* equipment is given in Fig. 3. The cabinet shown in Fig. 3 consists in a frequency converter, a soft-starter for the auxilliary motor and the switching, protection, control and signalling devices.

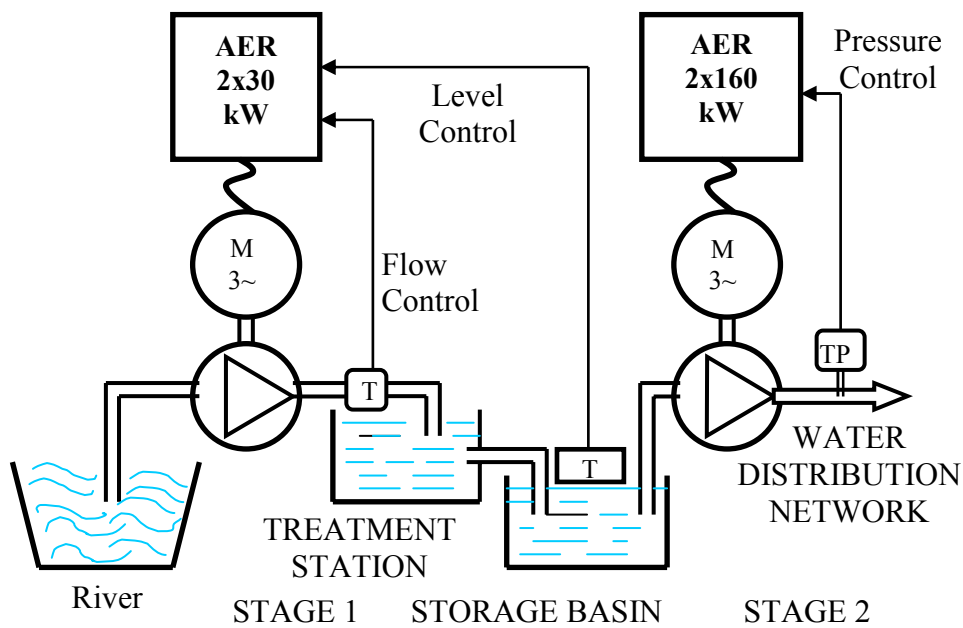


Fig.1. The schematic diagram of a complex pumping system.

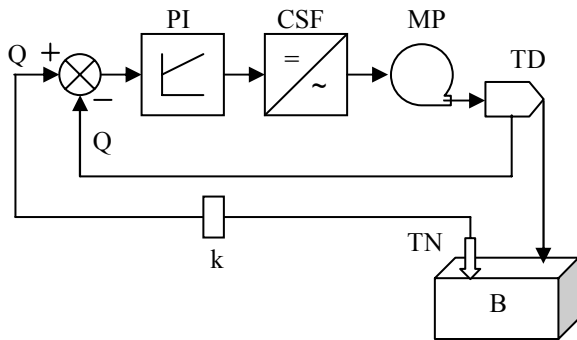


Fig.2. The control block diagram of the first pumping stage.



Fig.3. The AER 2x30 control cabinet..

3. INDUSTRIAL APPLICATIONS OF FANS CONTROL BY ASDs

In many industrial processes, cooling towers play a major role in the process development. A cooling tower is a counter-flow or cross-flow heat exchanger that removes heat from water by transferring it to air. A straight method to reduce the fan motor absorbed power is to control the air flow. Air flow controlling for fans is accomplished by various means, using: outlet dampers, or inlet guide vanes, variable pitch fans, eddy-current couplings, or adjustable speed drives (ASDs). Thus, cooling towers can be a good application for ASDs. The using of variable electrical drives has the following advantages: maximization of the energy savings, the possibility of closed control of leaving water temperature, soft starts of the motor and fan that reduce the stress of the fan drive system, built-in diagnostic and control capabilities, [7, 9, 10].

There are a lot of previous works focussed on the applications of ASDs in water temperature control of cooling towers, especially in the field of HVAC applications. The results show that the potential savings are not strongly dependent of the approach temperature, but are dependent on the range in colder climates. There are presented analytical method, simulations and measured results, for single fan and dual-duct constant air volume system and variable speed fan systems.

A simplified picture of the controlled process consisting in a water cooling tower is presented in Fig. 4. The application is to drive the fans of four water-cooling towers for forced water-cooling, with water flow of 1200 m³/h each of them. Two motors are driven with adjustable speed, by means of two ASDs, and the others two are driven with fixed speed, being fed directly from the supply electrical grid, [8, 9, 10].

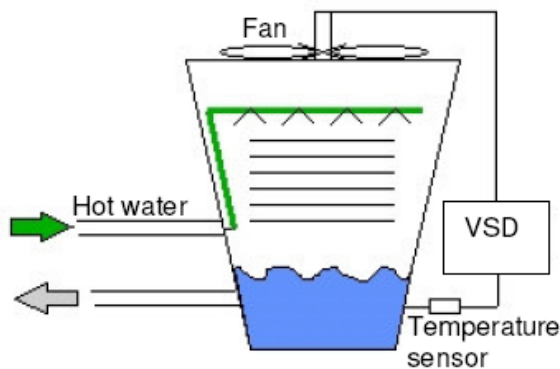


Fig.4. The configuration of a water cooling tower.

Different types of these equipments, were developed, designed, manufactured, approved and commissioned at various clients, [8]. Each of these configurations represents an automatic control system, and have been designed in order to satisfy the process requirements, versus the economical constraints.

The first one, called “Parallel Drive” (PD), presented in Fig. 5,a, supplies in parallel two or more induction motors, from a single frequency converter (FC), which has a the rated power twice of one single motor.

The fans speed is the same and the PID controls the water temperature. Each motor is protected to short-circuit and overload. In case of frequency converter fault, the drives can be supplied to the grid, at constant speed.

The second configuration, where each of the two induction motors is supplied independently by its own FC, is the “Independent Drive” (ID) configuration, Fig. 5,b. In order to maintain the stability of the temperature loop, one unit is “master” (and it is responsible for the process control) and the second is “slave” (it receives the speed reference from the “master” unit). For both drives, which run at the same variable speed, it is possible to run at constant speed, connected to the grid when a fault occurs at the FC.

Another configuration, the “Alternate Drive with Softstarter” (ADS), Fig. 5,c, proposes a “tandem” between a FC and a softstarter (SS). Each motor is provided with three supply possibilities: one from frequency converter, the second from softstarter and the third, from the electrical grid.

The second unit is connected/disconnected from the grid, via a softstarter, for smooth start/stop transients, when one unit is insufficient, or two units are too much.

In the case of the frequency converter is fault, the units are connected alternatively to the grid via the same softstarter.

Finally, we propose the “Independent Drive with Softstarter” (IDS) configuration, Fig. 5,d. It provides the same operational facilities like ID configuration, but the grid connection is made via a softstarter.

Table 1 presents synthetically the technical and economical performances of the analyzed solutions.

Table 1. Evaluation of Drive configuration

Configuration	Less costs	Redundancy	Technical performances
PD	+	--	+
ID	-	-	++
ADS	++	+	-
IDS	--	++	++

PD and ADS are need less initial (investments) costs, ID and IDS are cheaper. ID is technical superior than PD because of better motor control and protection. The ADS is the single configuration which works discontinuously because one unit is connected or disconnected, working at constant speed.

In terms of redundancy, it is evident that the IDS configuration is better.

An application of a PD configuration is presented in Fig. 6, and has been designed for two cooling fans for water cooling towers, type HAMON, with two cells, for a water flow of 1200 mc/h each one.

Before the implementation of the ASD, water temperature variations were reduced, partial, by various auxiliary maneuvers (start/stop of the fans, redirect of the water flow), without the possibility of elimination. This operating regime results in 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.

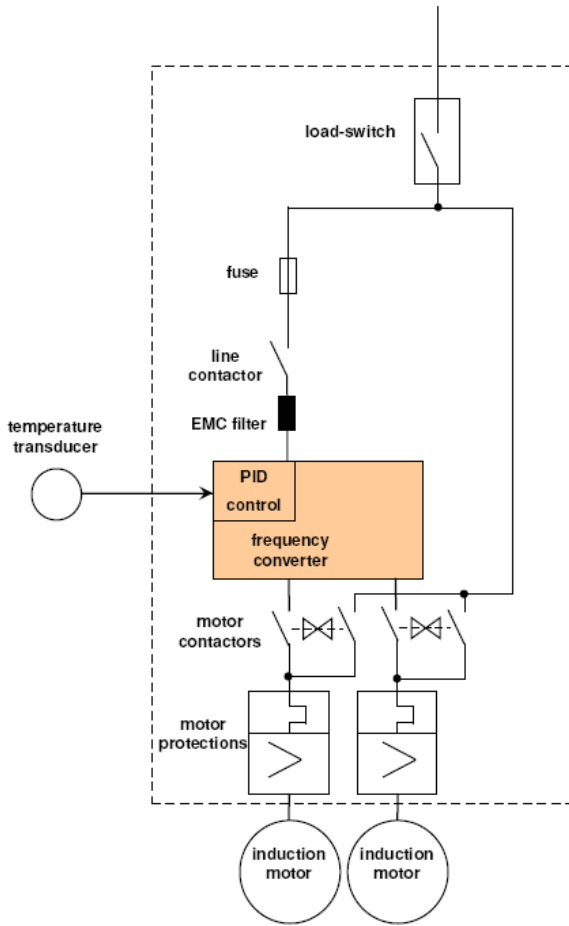


Fig. 5,a. "Parallel Drive" (PD) .

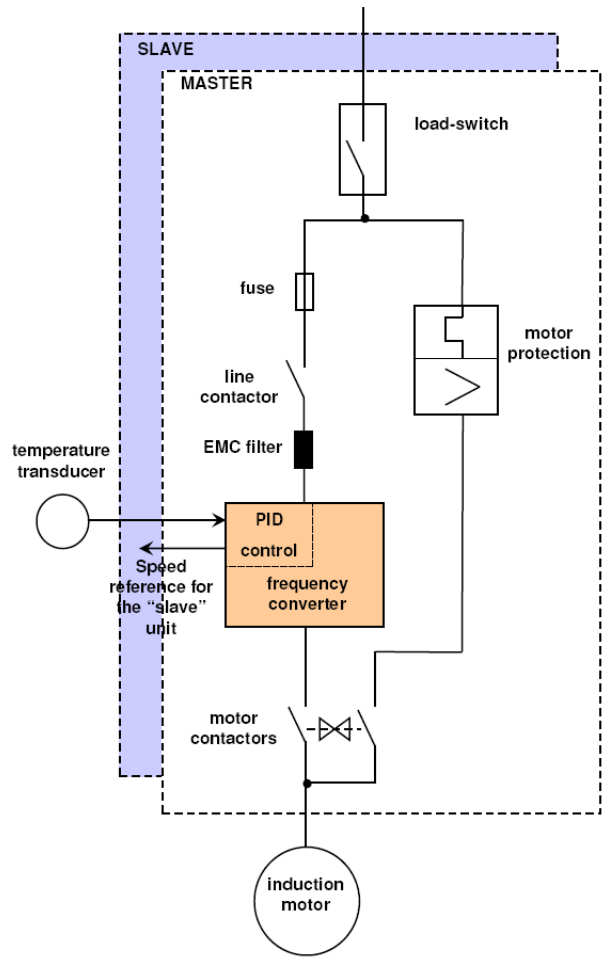


Fig. 5,b. "Independent Drive" (ID) .

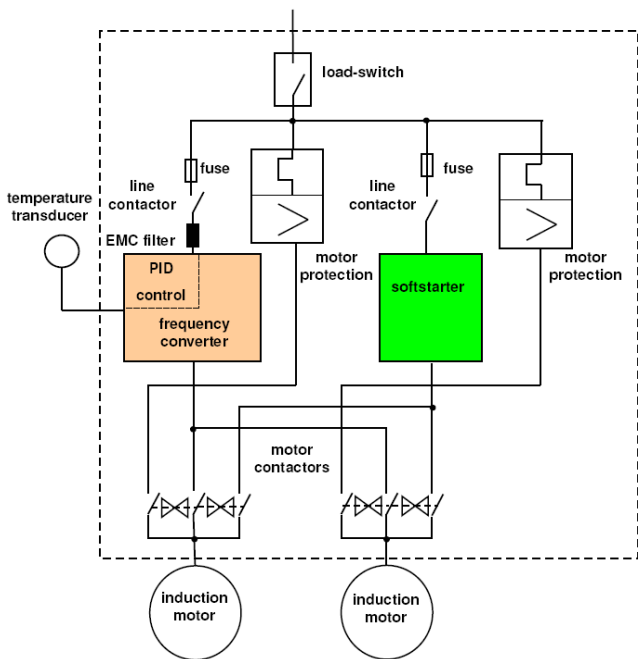


Fig. 5,c. "Alternate Drive with Softstarter" (ADS).

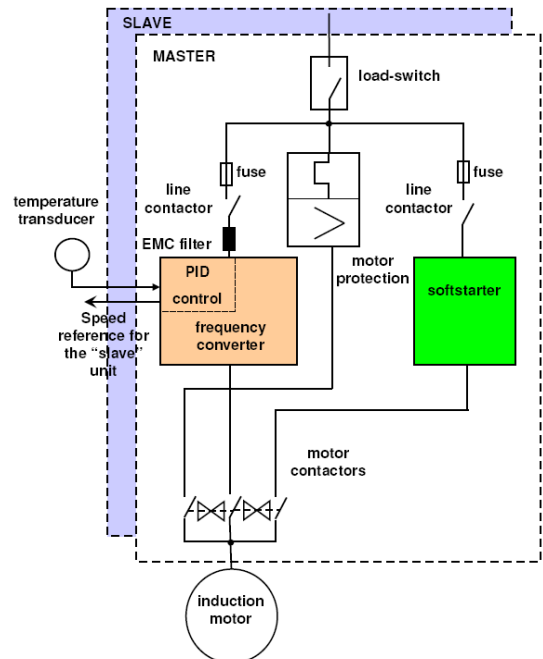


Fig. 5,d. "Independent Drive with Softstarter" (IDS).

Fig. 5. The explored fan drive configurations.

The ASD presented in Fig. 6 provides 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 to the power grid.



Fig. 6. Industrial implementation of a PD configuration.

The cooling tower with mechanical air draught type HAMON, where the ASD 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 application requires the simultaneous operation of two of such equipments. 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.

The analysis of the economic efficiency of implementing PD and ID equipments has been done using previous calculations and records of 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, [9].

Using “FanSave” software tool [1] it is possible to evaluate economical aspects regarding the efficiency of ASD in fan applications, as presented in Fig. 7.

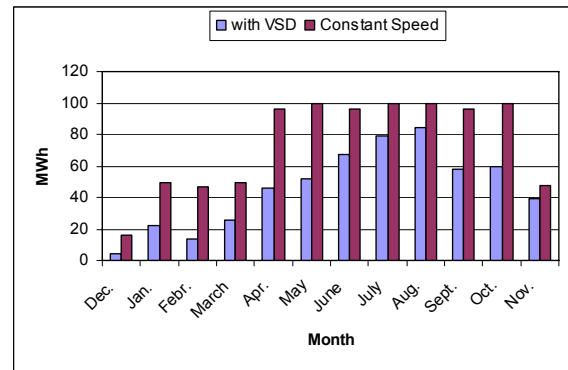


Fig. 7. Energy consumption for PD configuration equipment.

4. CONCLUSIONS

Pumps and fans can account for up to 40% of the total motor use in industrial applications. In this respect, adjustable speed drives with frequency converters and AC induction motors, utilized for pump and / or ventilation systems in various industrial applications proved experimentally their reliability and energetic efficiency, achieving considerable energy savings.

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