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ECONOMICAL GENERATION OF COMPRESSED AIR

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Abstract: The paper presents the project of modernization of the compressor unit in the pipe-making plant of the Aluminium Mill Impol d.d, located at Slovenska Bistrica. In the modernization the emphasis is put on energy saving in compressed air generation and on quality of the compressed air by automation of control and monitoring with the use of modern computer control components.

Key Words: modernization, automation, compressed air generation, energy saving

1 Introduction

One of the frequently used forms of energy in industrial production processes is the compressed air. This is one of the most expansive forms of energy if compared with other sources of energy. If compared with electric energy, it is about 10 times more expensive. In stationary production systems the compressed air is generated in compressor units, where the compressors are driven as a rule by electric motors.

Statistical data show that in industrial production 10% of the electric energy consumed is used for preparation of compressed air [1].

The other costs are the costs of capital and the costs of maintenance of the compressor unit and of the distribution pneumatic supply network. In the generation of compressed air the greatest investment is oriented towards the primary energy which is relatively poorly utilized.

Therefore, when designing or modernizing the compressor units, the greatest attention must be paid to economic use of energy.

The most important factors of bad efficiency and high costs in the generation of compressed air are: heat losses in compressor unit, pressure losses on components of the pneumatic distribution network and losses of compressed air due to incomplete tightness.

Fig.1 shows the principle of distribution of the supplier electric power into the compressor unit up to useful mechanical power on pneumatic actuators. In spite of its high price this energy medium is frequently used in industrial production due to many advantages such as: fast development of mechatronic components of automation (electronics-pneumatics), the use in aggressive working environments poser no problems,

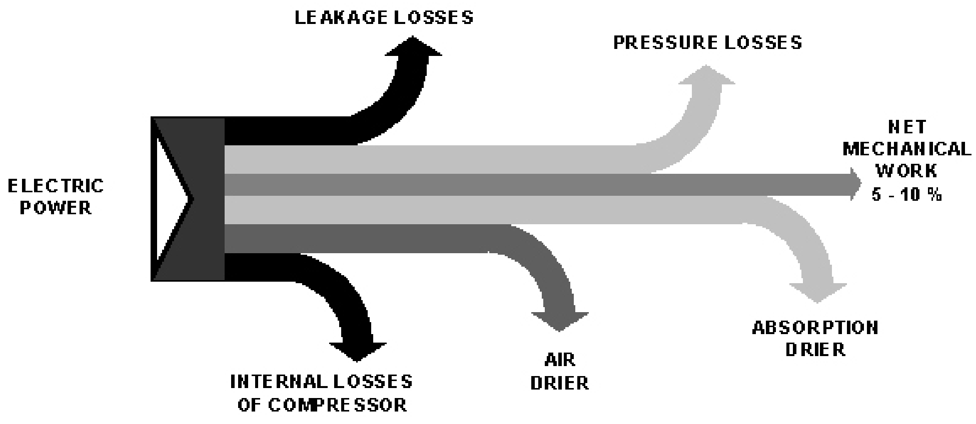


Fig.1: Principle of distribution of the supplier electric power into the compressor unit

this energy medium is ecologically not harmful, simple accumulation of energy, soft-elastic operation of actuators [2].

The world increasingly faces the tendency of energy saving. In pneumatic industrial energy systems that is achieved by incorporating electronic controllers into the control system of compressor units and pneumatic distribution network.

This paper will present the project of modernization and automation of the compressor unit in the pipe-making workshop of the aluminium works IMPOL at Slovenska Bistrica, Slovenia with strong emphasis put on energy saving and meeting the European industrial standards [1].

2 Analysis of energy losses in pneumatic supply system

Before execution of the modernization project two compressors of the company Kaeser CS 120 of 12 m^3/min capacity and Demag 110 of 10 m^3/min capacity with installed power of driving motors and other consumers of about 220 kVA were installed in the compressor unit. Taking into account that only 10% of the energy consumed are transformed into useful mechanical work on the pneumatic actuators the cost of losses in the production process can be clearly observed.

2.1 Heat losses in compressor unit

The principal portion of all losses occurs on the driving electric motor, compressor and in the non-isothermal process during the air compression. Due to infeasibility of measurement for the quantification of those losses they are estimated to be 70% of all losses. During modernization of the compressor unit strong emphasis was put on the reduction and useful utilization of the longest possible share of that thermal energy [3]. When analyzing the air consumption of both compressor units Kaeser and Demag in a certain time period, diagrams in Fig. 2a clearly non-uniform loading of the compressor unit Demag was established.

From the point of view of energy consumption the existing combination of compressors is not economical. The costs of energy losses themselves idle run of the driving motor of the Demag compressor are estimated to be 7000 €/year [4].

2.2 Leakage losses

Leakage of compressed air in the pneumatic system due to bad design and maintenance of the supply network and of the pneumatic components represents the least justifiable net losses (Table 1). On the basis of the equations (1) and (2) of hydrodynamics [5]:

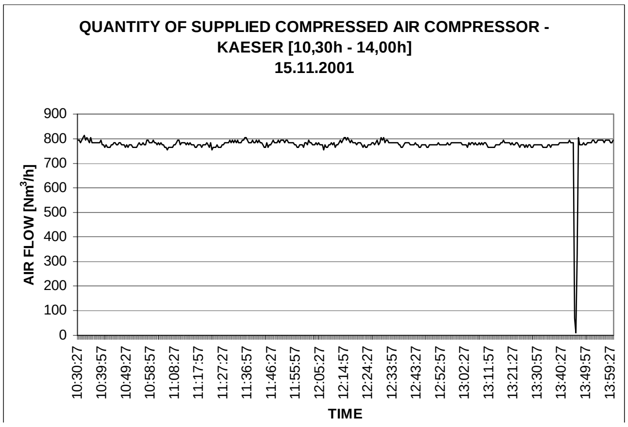
$$q_m = \mu A \sqrt{2\rho(p_1 - p_2)} \qquad \left[\mathrm{kg\,s^{-1}}\right] \qquad (1)$$

$$q_v = \frac{q_m}{\rho} \qquad \left[\mathrm{m^3 s^{-1}}\right] \qquad (2)$$

it is possible to calculate the quantity of the lost compressed air due to leakage. The comparison calculation has been made for the pneumatic supply network of 6 bar pressure level and 4-shift weekly work of the compressor unit.

Table 1. Costs of leakage

Diameter of leakage hole	Leakage	Annual cost of leakage
0.4 mm	0,012 m^3min^{-1}	52 €
3 mm	0,66 m^3min^{-1}	1800 €



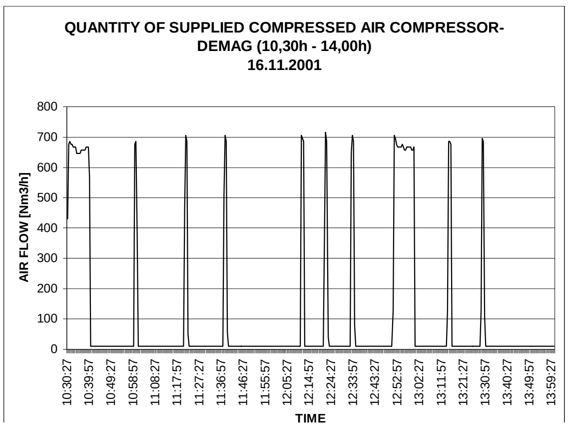


Fig.2: Quantity of supplier compressed air

The experimental analysis showed 5.16 m^3min^{-1} of losses of compressed air due to leakage, i.e. 38.2% of capacity of the compressor unit.

2.3 Pressure losses
Pressure losses in the pneumatic system represent a minor share of losses. They are controlled by correct sizing and designing of the supply network, by routine maintenance of components such as filters, preparation groups, driers. Modern types of those components incorporate the clogging indicators which warm of the required maintenance works in time.

2.4 Losses on driers
The air driers are incorporated in the pneumatic supply network to ramose moisture from the compressed air and are consumers of the supplied thermal energy. Also pressure losses occur on the driers. Two cooling drying units Ingersoll and Demag were mounted in the compressor unit.

3 Concept of modernization and automation of compressor unit and pneumatic distribution network

The reason for modernization and automation of the pneumatic energy system in the previously mentioned factory complex were the actual difficulties in work before modernization:

- bad energy efficiency of the complete system.
- bad quality of air and, consequently, frequent defects on the pneumatic control components: excessive percentage of moisture in the compressed air, presence of impurities, fluctuating pressure of the system.
- non-coordinated operation of the two compressor units with driers and the resulting unstable working of the system during peak loadings.
- difficulties in operation during the transition from the summer to the winter mode of work and inversely, due to the locking temperature control in the compressor unit.
- the pneumatic system was not monitored and was hard to control. Operation of components and consumption of compressed air were hard to supervise.

On the basis of the preceding findings and additional requirements the following criteria to be met by the modernized system were in the foreground in modernization and automation of the complete system:

- satisfying the consumption with anticipated reserve 17 m^3min^{-1},
- quality of compressed air of 4th quality class according to ISO 8573.1,
- system pressure in the range of 5.9 to 6.1 bar,
- minimization of energy losses in compressor unit and supply distribution network,
- following up the technological parameters and operation of components such as filters, drivers, cyclones etc. by means of the control system.

The compressor unit was modernized according to the concept of alternating time operation of both compressor units Kaeser and Demag, whereas for covering the peak loadings a new compressor unit Comp Air 145 SR with control of the electric molar rotating speed and maximum capacity of 7.5 m^3min^{-1} was added.

Optimum control of the entire pneumatic system in terms of minimum energy losses and high-quality preparation of air is reached by temperature control in the compressor unit, pressure control in the pneumatic system and monitoring system of quality of air and of components such as filters, driers and oil/water separators. Meat losses in the compressor unit with control principle of operation are conveyed into heating of the workshop for feeding the driers, whereas the project of a heat exchanger for heating the sanitary water (problem of exploiting the heat losses during summer months) is in preparation. The control and monitoring system is designed with the controller Siemens Simatic S7 300 with programme support Step 7. Fig.3 shows the arrangement of components in the compressor unit with illustration of information communications.

The industrial computer, on which the application for remote control and monitoring of the compressor unit run, is stationed in the technological maintenance room at about 200 m from the compressor unit. The linkage between the industrial computer and the controller in the compressor unit with basic data on intercommunication is shown in Fig.4.

Monitoring is designed with the SCADA monitoring system and IFIX application ensuring the graphical and pictorial access to data and the possibility of remote control of compressor unit components.

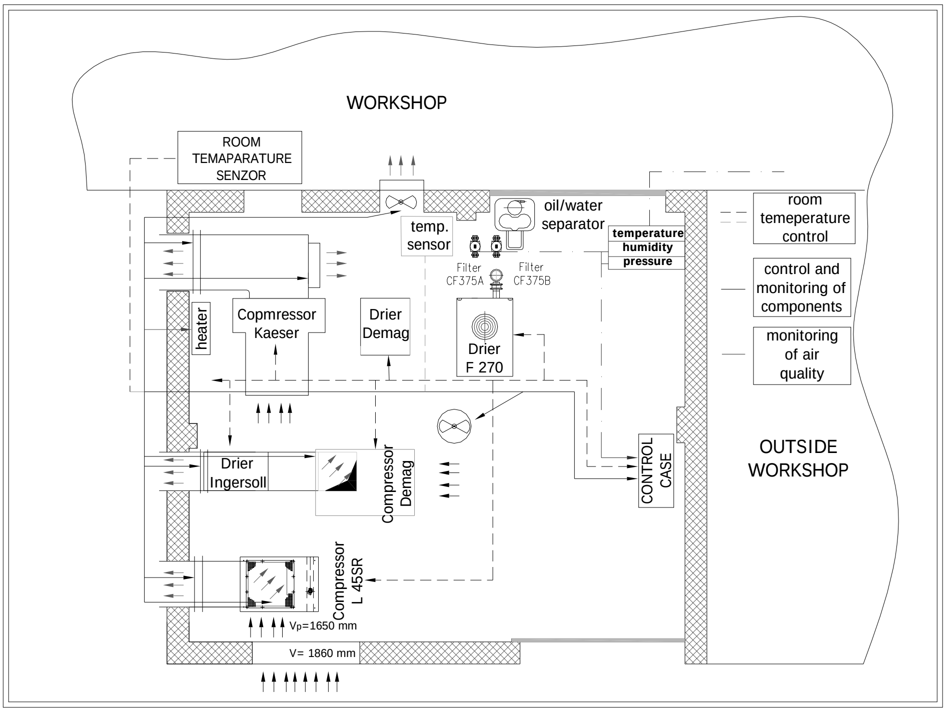


Fig.3: The arrangement of components in the compressor unit

INDUSTRIAL COMPUTER

Intel Pentium IV
CPU 1,7
128MB RAM
Windows 2000
OPC Server
SCADA system-application IFIX
Communication card Siemens
6Gk1561-3AA00
Network Card TOKEN RING

SIGNAL AMPLIFIER

6ES7972-0AA01-0XA0
Data transfer up to max. 1000m

CONTROLLER

Siemens SIMATIC S7 -300
CPU 314 IFM
Communication MPI
(multi point interface)
Velocity transfer 187.5 kbaud
Communication programme
SIMATIC NET

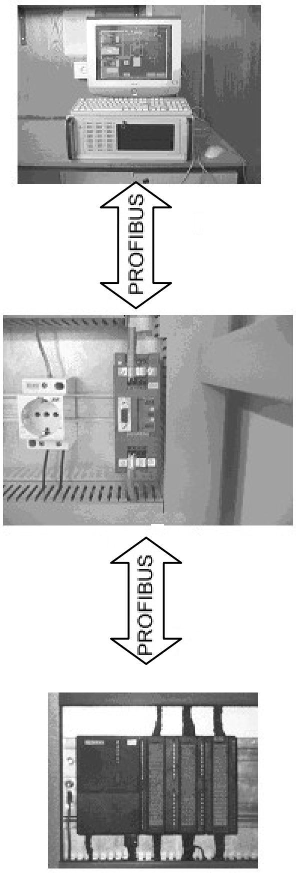


Fig.4: Communication between controller and industrial computer [6]

Fig.5 shows the FIX application (basic picture) available to users for displaying the values of the current state of components in the compressor unit and for the entry into next applications. For remote control of the compressor unit the application with active switches for setting the desired values of parameters has been made as shown in Fig.6.

The monitoring system ensures also the time representation of current and filed data. Important data include the compressed air pressure and temperature [7] and the actual focal point. Those data define the property of the compressed air. Fig.7 shows an example of computer graphic application of the mentioned data.

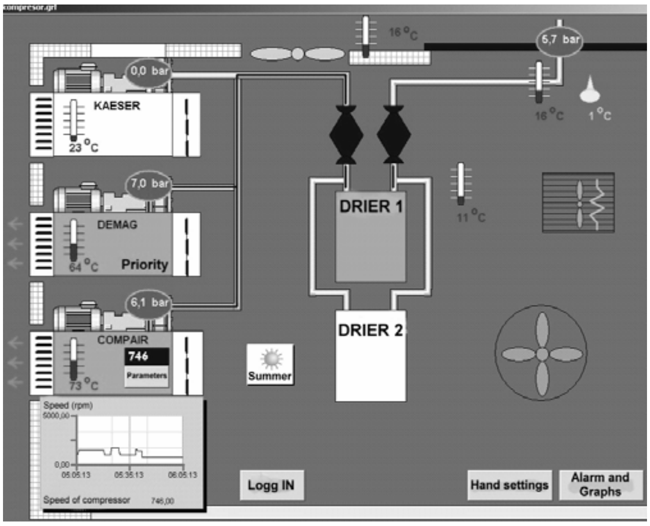


Fig.5: Basic picture in FIX application

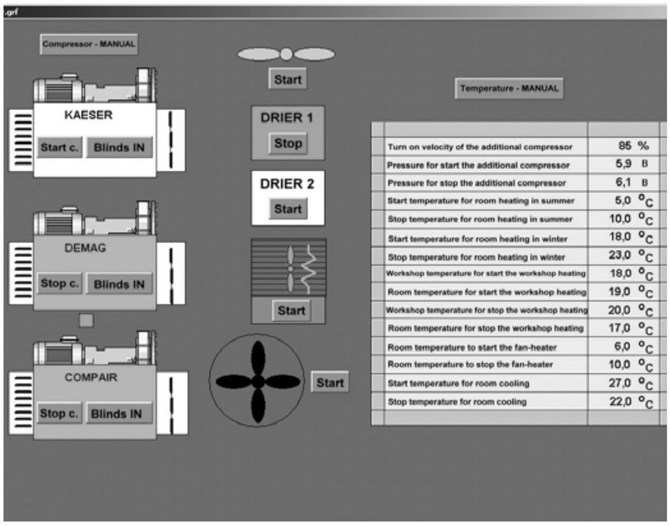


Fig.6: Application for remote operation

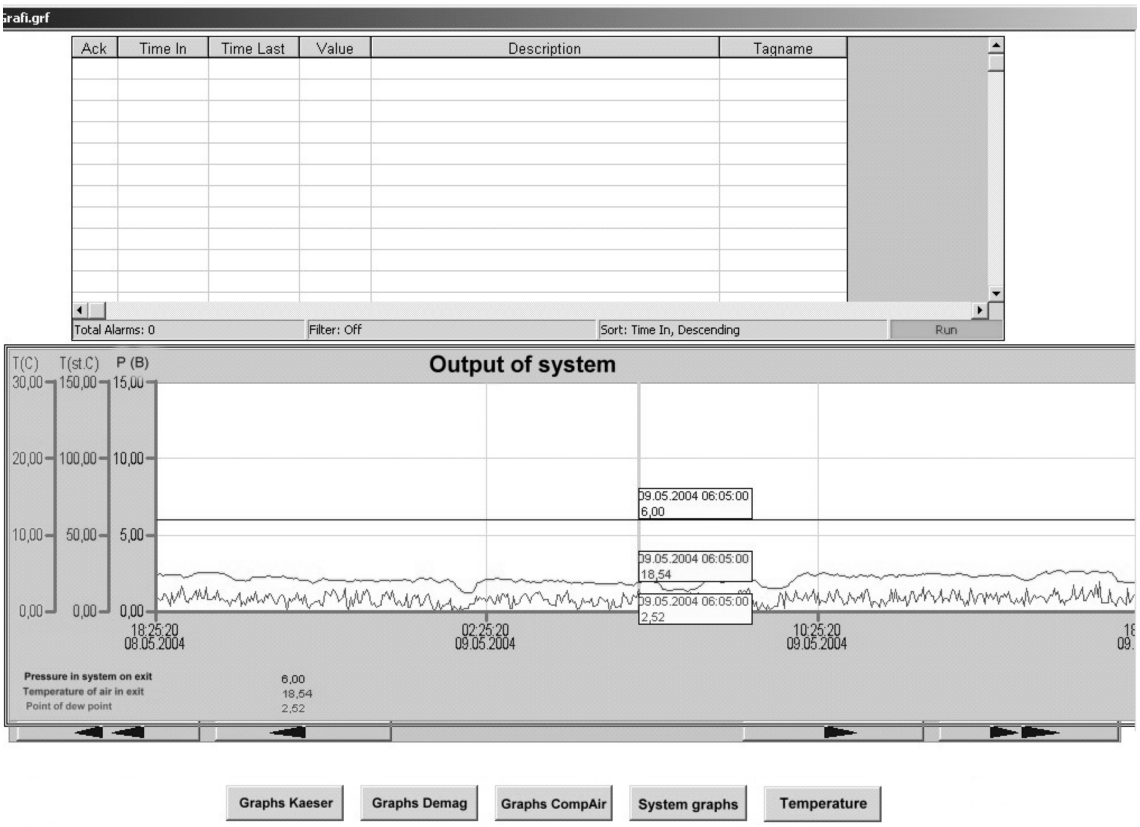


Fig.7: Properties of compressed air

4 Conclusions

With the modernization project and introducing of automation into the control and monitoring process of the compressor unit an out-of-data industrial energy system has been transformed into a modern system justifying the investment into modernization and giving positive results. The acquisitions are lower costs of energy consumed and lower costs due to removal of stoppages in production occurring originally because of non-uniform supply of compressed air.

Analysis of the modernized pneumatic supply system in one year operation revealed the following direct acquisitions:

- the introduction of compressor with continuous control of the driving motor rotating speed for covering the peak loadings of the pneumatic system has reduced the cost of idle run of the compressor system for about 5000 €.
- reduction of leakage by thorough renovation of the pneumatic distribution network from original 5.16 $m^3 min^{-1}$ (38.2%) to 2.83 $m^3 min^{-1}$ (21%) has brought an annual saving of 3770 € for energy.
- the control of compressors with pressure regulation in the system ensures trouble-free provision of the compressed air. Thus, the frequent 15-30 minute production stoppage, which amounted to 12 hours/year before rebuilding according to the analysis data have been eliminated. Financially, the fact that there are no production interruptions has not been evaluated.
- owing to pressure control in the system the original pressure fluctuation between 5.8 and 6.5 bar has been reduced to between 5.9-6.1 bar. Reduction of the hysteresis of the pressure fluctuation to 0.2 bar favourably influences the uniform running of actuators. Reduction of pressure level for 0.4 bar brings a considerable energy saving. According to literature the pressure level reduction for 1 bar implies 15 % energy saving.
- the acquisition of the certificate ISO 14001, putting the emphasis on the environment protection, has imposed the solutions of the monitoring system in the modernization, which assures the 4th quality class of compressed air according to standard ISO/DIS 85731. Let us mention only the installation of the separator of oil from water from the condensate OWAMAT 6. The average quantity of condensate amounts to 120 l/day.
- a very important acquisition of modernization in terms of energy saving is the temperature control in the compressor unit. In generation of compressor air 75% of energy consumed are transformed into heat. Thus it is appropriate to use purposefully the longest possible portion of that thermal energy with regulation for heating the industrial workshop (in winter months), whereas a part of that thermal energy is used for supplying the energy to driers.

The regulation system for heating the sanitary water is in the stage of preparation; in their way the problem of utilization of the generated thermal energy in the summer months would be solved to a considerable extent. In addition to the mentioned acquisitions there are still varieties of acquisitions which are less interesting from the point of view of energy saving and are not mentioned in this paper. The calculation show that the means inverted in modernization of the compressor unit will pay within about 3 years, which undoubtedly justifier the execution of the project.

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