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Demand-Side-Management by flexible generation of compressed air

Ralf Boehm[a,*], Joerg Franke[a]

[a]*Institute for Factory Automation and Production Systems, Friedrich-Alexander-Universität Erlangen-Nürnberg, Fürther Strasse 246b, 90429 Nuremberg, Germany*

[*] Corresponding author. Tel.: +49-911-5302-96254; fax: +49-911-5302-96250. *E-mail address:* ralf.boehm@faps.fau.de

Abstract

Industrial compressed air systems embrace significant potential for saving both energy and cost due to their share of approximately 7 % of the total industrial electricity consumption in Germany. As in electric energy systems based on renewable generation plants supply and demand often do not occur in the same period of time, volatile prices occur and demand side management is gaining importance. Decentralized automation offers opportunities in industrial environments for control of the equipment according to availability of electrical energy. Product-service systems on industrial plants supply manufacturing equipment with compressed air, nitrogen and other technical gases, which partly can be obtained from air by deposition processes. Those systems consist of air compressors, gas separators, reservoirs and lines. With suitable dimensioning and by equipping with automation technology those product-service systems can be used for demand side management purpose. In addition to basic operating parameters like current air pressure and status, those systems can process further information and create, for example, profiles on compressed air consumption over time. By enriching those profiles with data on pressure, volumes, system restrictions and current production requirements, the system control can identify the available potential for demand side management. Evaluation of operational strategies has to optimize conflicting objectives within the triangular relationship of storage design, control of the production according to price prospects and influencing or predicting the use of compressed air.

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Keywords: Industrial compressed air systems; Energy flexibility;

1. Introduction

Compressed air systems (CAS) of industrial companies account for 7 % of industrial electricity consumption (Fig. 1) and show significant potential for using energy more efficient. The german Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) assumes that industrial energy consumption can be reduced by 20 % up to 40 % in an economically reasonable manner by the year 2020. In particular electric drives cause two thirds of electric energy consumption, whereof 15 % can be saved using rotational speed control. [1] For CAS a decrease in annual electrical energy consumption by 4.7 TWh in Germany and of 13 TWh for the whole European Union are assumed . [2] [3].

In a survey on efficiency of compressed air systems [3][4] the number of air compressors installed in countries of the european union was estimated. According to the data depicted in Tab. 1 the electrical power rating of air compressors can be assumed in a range between 10 and 50 GW in the european union and between 2 and 10 GW in germany. The power consumption of all air compressors installed is equivalent to the maximum power output of several large power plants, such as

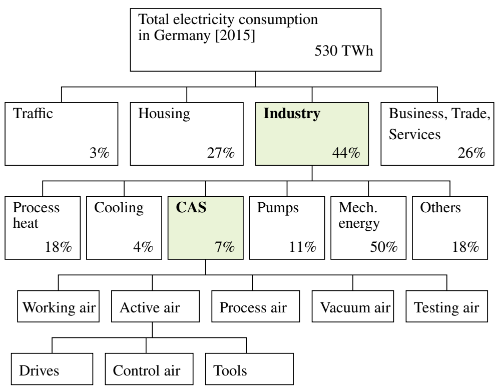

Fig. 1. Electricity consumption by sector and systematization of compressed air applications.

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Table 1. Number of air compressors in the European Union per country and performance class. [3] [11] [4]

Country	10 – 110 [kW]	110 – 300 [kW]	∑ Country
France	28.885	14.880	43.765
Germany	43.400	18.600	62.000
Italy	30.660	13.140	43.800
Great Britain	46.750	8.250	55.000
Other EU countries	81.700	35.000	116.700
∑	**231.395**	**89.870**	**321.265**

nuclear power plants or several thousand wind power plants. Thus it becomes evident, that intelligent control of CAS embraces significant potential for load management. In the recent past some investigations concerning compressed air energy storage (CAES) have been carried out focussing on conversion of electrical energy into compressed air and reconversion into electricity. [5] [6] [7] The approach presented in the present article concerns flexibilization of operation of industrial compressed air systems. Previous investigations concerning flexibilisation using storage [8] and control strategy [9] [10] are to be enhanced by establishing a connection to production planning and control as well as to energy management.

2. Fundamentals of industrial CAS

CAS are part of the production infrastructure in industrial companies and belong to cross-sectional technologies that are applied across industries and processes. Energy-related cross-section technologies are compressed air supply, hydraulics, electromechanical drives, air-conditioning and ventilation, process heat, process cooling as well as provision and conditioning of technical gases or other media. A significant share of the total industrial potential for Demand Side Management is accounted for by technologies of the production infrastructure.

2.1. Elements of industrial CAS

Industrial CAS consist of compressors, pressure tanks for storage and piping for supply. Subject to varying requirements regarding compressed air quality, secondary units such as water separators, dryers, oilers, dedusting facilities, valves and pressure regulators are applied. For separation of technical gases obtained from air further components as membrane filters, separate gas tanks and line networks for transport to the point of consumption are provided.

2.2. Advantages of compressed air application

An advantage of compressed air is high working speed concomitted by high possible forces. With regard to precision, the positioning accuracy of pneumatic systems is perfectly adequate for many applications. Production of compressed air can be accomplished apart from production. Hence, space requirements are reduced within the manufacturing area as compressed air tools and applicances often require little space on site. Comparing pneumatic and electric drives and actuators, a further advantage is that no sparks are caused by pneumatic drives. Thus, these can also be operated without risk in fiery environments, such as paint shops. Moreover, electrically driven components are often more expensive in comparison to their pneumatic counterparts. [12] [13]

2.3. Energy efficiency of CAS

Aside from its many advantages, compressed air is considered to be the most expensive form of energy due to high losses of energy conversion. Merely 5 % of the energy used can be converted into useful compressed air energy according to Fig. 2. The major part of the energy supplied is lost as thermal energy in the coolant oil, the heated compressed air itself and in in the drive [14]. It becomes evident why compressed air is regularly classified as the most expensive form of energy. [13] However, there are applications where the use of compressed air is most beneficial compared to other energy forms or no alternative technologies are available. Hence, compressed air application should be reduced to the required minimum.

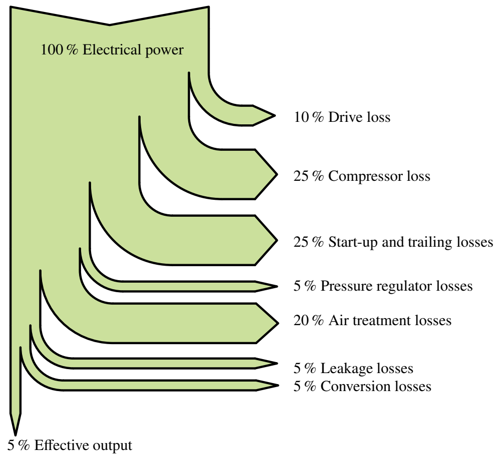

Fig. 2. Energy flow and losses of a typical CAS [13]

Considerations regarding increased efficiency particularly concern minimization of compressed air demand, optimization of compressed air supply and maximization of heat recovery. From a companies point of view it is to ensure that requirements for compressed air systems regarding reliability, cost efficiency and compressed air quality are met at all time. In addition to the known approaches to increase efficiency through appropriate system design and loss prevention, automation technology and industry 4.0 offer auspicious new possibilities in terms of autonomous and self-controlled operation of CAS. For this purpose CAS are extended to cyber-physical systems and hereinafter referred to as cyber-physical compressed air systems (CPCAS). [15]

2.4. Increasing efficiency of CAS between by optimization of production, storage and application

All considerations about increasing efficiency of CAS have to include the three main areas of production, storage and consumption (Fig.3). The aim is to optimize supply of compressed air in a way that required electricity can be purchased at best possible price, lifetime of components of CAS is maximized, required compressed air is generated at lowest possible pressure level and reliable supply is guaranteed all at the same time.