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A review on compressed-air energy use and energy savings

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ABSTRACT

Compressed-air systems account for about 10% of total industrial-energy use for few selected countries as found in literatures. Compressed air is typically one of the most expensive utilities in an industrial facility. This paper describes a comprehensive literature review about compressed air energy use, savings, and payback period of energy efficient strategies. This paper compiles latest literatures in terms of thesis (MS and PhD), journal articles, conference proceedings, web materials, reports, books, handbooks on compressed air energy use, efficiency, energy savings strategies. Computer tools for compressed air analysis have been reviewed and presented in this paper. Various energy-saving measures, such as use of highly efficient motors, VSD, leak prevention, use of outside intake air, reducing pressure drop, recovering waste heat, use of efficient nozzle, and use of variable displacement compressor to save compressed-air energy have been reviewed. Based on review results, it has been found that for an electric motor used in a compressed-air system, a sizeable amount of electric energy and utility bill can be saved using high efficient motors and applying VSDs in matching speed requirements. Also, significant amounts of energy and emission are reducible through various energy-saving strategies. Payback periods for different energy savings measures have been identified and found to be economically viable in most cases.

Contents

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Nomenclature

AES	annual energy savings
AEU	annual energy usage
ES_{VSD}	energy savings with the application of VSD
H_{avg_usage}	Annual average usage hours
n	number of motors
P	motor power (kW)
S_{SR}	percentage energy savings associated certain percentage of speed reduction
VSD	variable speed drive
hp	motor's rated horsepower
L	load factor (percentage of full load)
hr	annual operating hours
c	average energy cost (US$/kWh)
E_{std}	standard-motor efficiency rating (%)
E_{ee}	energy-efficient motor efficiency rating (%)
0.746	conversion factor from horsepower to kW
AES_{cs_leak}	annual energy savings by preventing leak (MWh)
%ES	% of energy savings by preventing leak
T	on-load time (min)
t	off-load time (min)
V	m^3
P	kPa
T	minutes
W_R	fractional reduction in compressor work
W_I	work of compressor with inside air (kW)
W_O	work of compressor with outside air (kW)
T_I	the average temperature of inside air (°C)
T_O	the annual average outside air temperature (°C)
AES_{ia}	energy savings associated with the usage of outside intake air temperature
AES_{pd}	energy savings due to pressure drop
FR_i	ratio of proposed power consumption to current power consumption
FR	the horsepower reduction factor
P_{dp}	discharge pressure at proposed operating pressure conditions (kPa)
P_{dc}	discharge pressure at current pressure conditions (kPa)
P_i	inlet pressure (atmospheric pressure) (kPa)
k	ratio of specific heat for air (k = 1.4).
HRF	heat recovery factor
ca	air compressor
ANS_i	annualized net dollar savings in i year of air compressor
AS_i	applicable stock in year i of air compressor
CRF	capital recovery factor
d	discount rate (%)
ES_i	energy savings in year i of air compressor
IIC	initial incremental cost for more efficient air compressor
PF	price of fuel
SF	scaling factor
$PV(ANS_i)$	present value of annualized net saving i of air compressor
PEi	percentage of electricity generation in year i of fuel type 1 (%)
Em_{np}	fossil fuel emission for a unit of electricity generation of fuel type 1 (kg)

1. Introduction

Use of compressed air in industry and in service sectors is common as its production and handling are safe and easy. In most industrial facilities, compressed air is necessary to manufacturing. Compressed-air generation is energy intensive, and for most industrial operations, energy cost fraction of compressed air is significant compared with overall energy costs. Yet, there is a vacuum of reliable information on the energy efficiency of a typical compressed-air system [1–6].

As a general rule, compressed air should be used only if safety enhancements, significant productivity gains, or labour reduction, will result as it is very expensive (see Fig. 1). Greenough [7] also reported how to select compressed-air system for an industrial facility.

Annual operating costs of air compressors, dryers, and supporting equipment, can account from 70% [9–11] to 90% [12] of the total electric bill.

Compressed air accounts for as much as 10% of industrial electricity consumption in the European Union [13]. Fig. 2 shows compressed-air energy use in 15 EU countries. Compressed-air systems in China use 9.4% of China's electricity. Compressed air is probably the most expensive form of energy in a plant, because only 19% of its power are usable. In the US, compressed-air systems account for about 10% of total industrial-energy use [14], as in Malaysia [15]. In South Africa, compressed air consumes about 9% of total energy consumption [16,17]. Table 1 shows the industrial application of compressed-air system.

According to the total life cycle costs (LCC), initial investment and maintenance represents only a small portion of the overall cost of

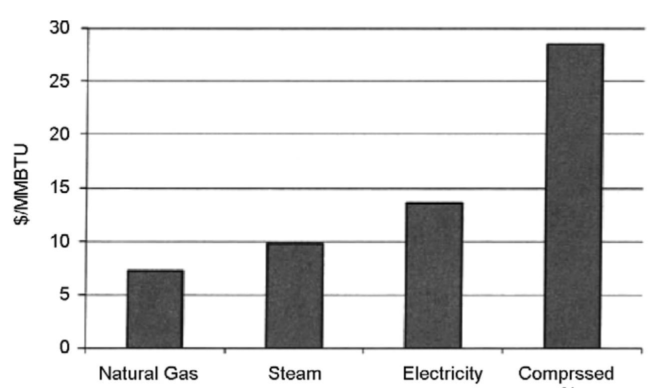

Fig. 1. Cost of energy delivery modes [8].