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Assessing the contribution of energy saving technologies: the case study of variable speed drive air compressors

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TARGETS

The role of bottom-up methodologies of energy savings:

use of variable speed drives for air compressors, compared to fixed speed motors, with a load-unload technique

A simplified procedure for evaluating and monitoring the effects of such technological replacement;

potentials and drawbacks of a simplified assessment procedure in a case study,

projections of potential savings in the Italian industry.

KEY POINTS

* Introduction
* The bottom-up methodology

*Comparing schemes and installations of air compressing units

* Proposal of a simplified methodology- the monitoring stage and the energy savings assessment

* The case study. Application of the procedure to a mechanical company

* Remarks on the methodology

INTRODUCTION 1/3

- The monitoring and validation activities on energy savings >>

- **EU funded projects aiming at delivering general procedures for the evaluation of energy savings** (i.e. the EMEEES project), Standardization Bodies (CEN/Cenelec and ISO) setting up technical forum and groups of experts

- Still, the effectiveness of using top-down versus bottom-up approach is a hot topic for the experts.

INTRODUCTION 2/3

In Italy, project savings are evaluated by means of several bottom up procedures that must be approved by the Regulatory Authority for electricity and gas, AEEG.

A simplified procedure for evaluating and monitoring the effects of the technological replacement (VSD air compressors vs. load/un load controlled) is reported.

The whole procedure is made up of the a priori and of the M&V procedure.

INTRODUCTION 3 / 3

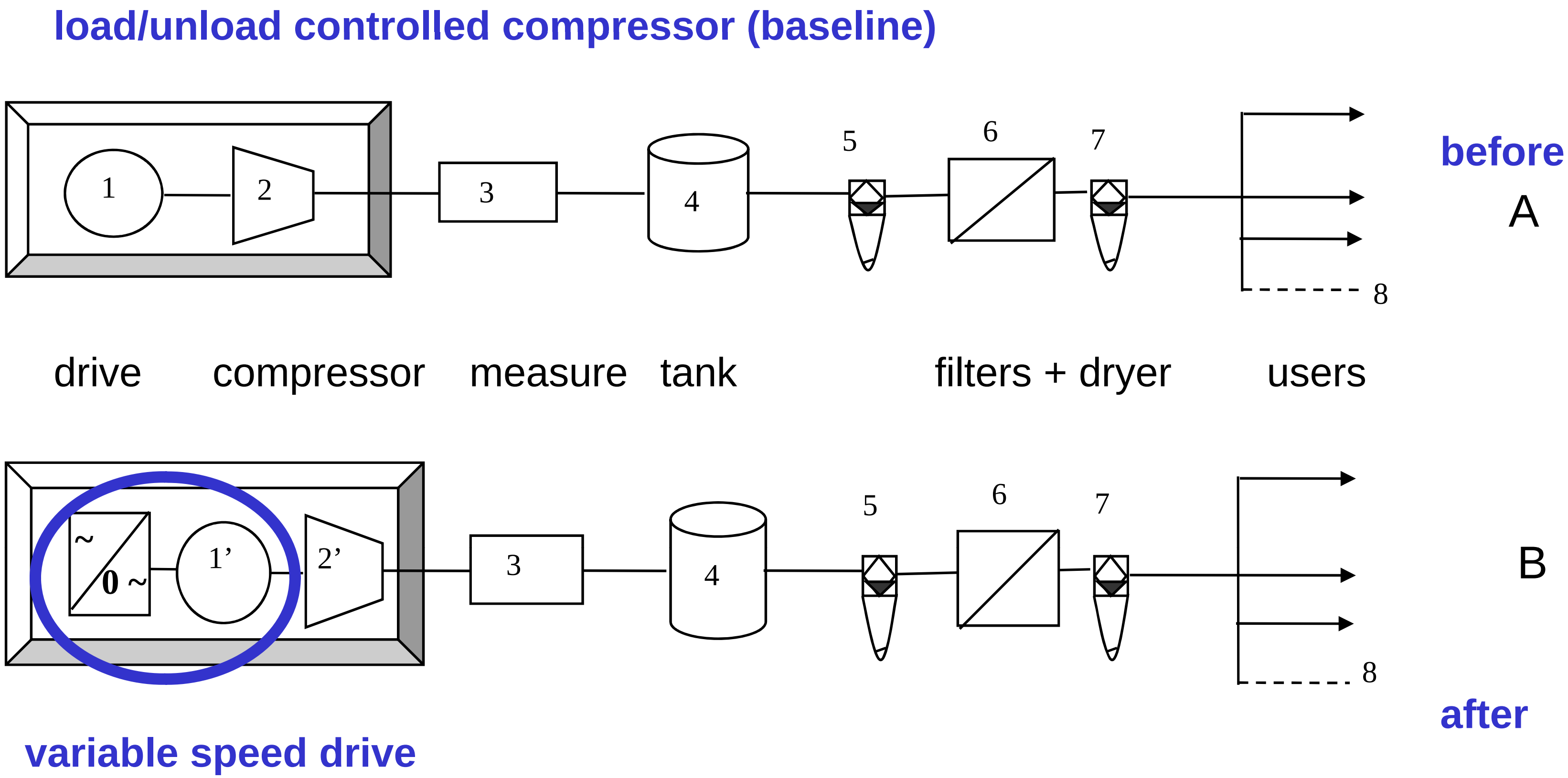
In Italy, in 2007 the mechanical sector consumed roughly 3,6 TWh/y (less than 10% of the national electricity consumption).

As a rule of thumb, a share between 5 and 10% of electricity is accounted for the compression of air in the sector (180-360 GWh/y):

a potential underestimated saving of energy between 15-25% for the sector can determine a benefit of 27-90 GWh/y (13.5-45 ktCO2eq/y emissions reduction), that is the equivalent production of a 6 MWe power plant

THE BOTTOM-UP METH.: COMPARING SCHEMES

load/unload controlled compressor (baseline)



The scheme applies to rotating compressors ~ 30 kW upwards

THE BOTTOM-UP METH.: COMPARING SCHEMES

Before. The old plant is monitored and 'a priori' feasibility evaluation study is performed (more details in a previous paper)

After. A monitoring phase is conducted on the new plant once the VSD is operated.

Key issues

•The operating conditions of the compressed air system before (SP1) and after (SP2) the replacement have to be known.

•The new energy saving configuration has to be monitored in its operational parameters and compared to the old one: the terms of such comparison need to be set.

THE SIMPLIFIED METHODOLOGY

The procedure requires two sampling periods: (at least one typical working week each or more)

The time span "SP1", when the load/unload compressor is still operating .

In this case a comparison is carried out to demonstrate that a VSD machine would perform better. If the feasibility is demonstrated, then, once the replacement takes place, the monitoring second phase is scheduled.

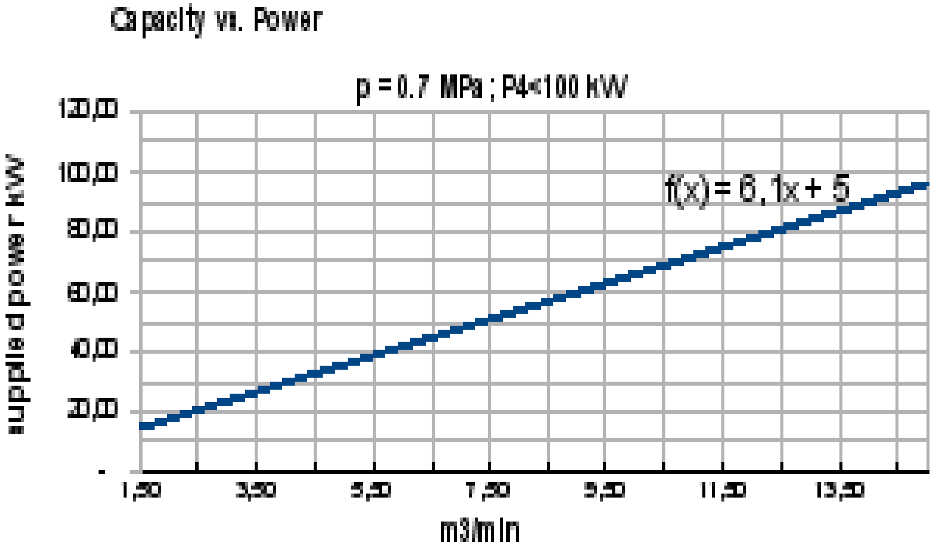
The time span "SP2", when the VSD compressor has been installed

The system is monitored and its performances are compared with the old system data. The M&V phase is illustrated here.

THE SIMPLIFIED METHODOLOGY 1/8

During SP1 the air requirements are monitored (the service delivered by the compressed air system, therefore the consumption).

To evaluate the convenience of a VSD solution it is here proposed to rely on 7 universal curves and equations (2 curves for 3 set pressure levels, plus one, according to the size of the machine: below 100 kW and above) to assess missing data in the comparisons.

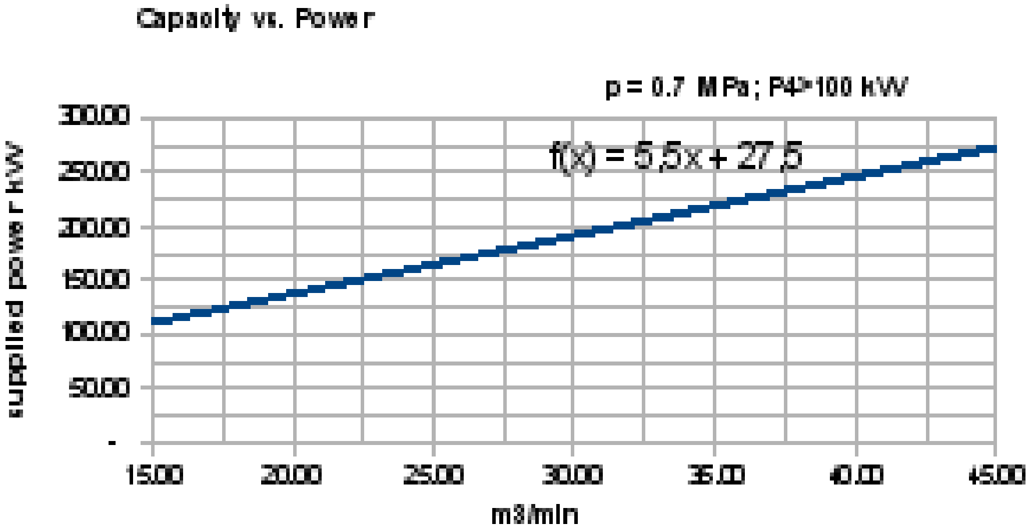


Proposed universal curve, relating capacity and supplied electric power (p_{set}=0.7 MPa, P_4 < 100 kW)

THE SIMPLIFIED METHODOLOGY 2/8

The curves describe the input electric power of the new VSD compressor (P4, full package) as a function of the capacity (q4 free air delivery, m3/min);
they are based on technical data sheets from manufacturers (machines from 30 kW upwards), based on laboratory test results and labels/data sheets, which must be updated and accordingly done to the ISO measurement methodologies.

Proposed universal curve, relating capacity and supplied electric power (p_{set}=0.7 MPa, P_4 > 100 kW)



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THE SIMPLIFIED METHODOLOGY 3/8

Data to be recorded over SP1 and SP2

Recorded or calculated variables on the old configuration, during SP1	Measured	Assessed	From technical data sheets
Supplied load power in the steady state (P_1, kW) - full package	X		
Supplied unload power in the steady state ($P_{2,0}$, kW) and P^1_2 - full package	X	X	X
Hours in the load-mode (A^1_1, h)	X		
Hours in the unload mode (A^1_2, h)	X		
Offline hours (A^1_3, h)		X	
Load/unload cycles (c^1)	X		
Outlet pressure level (p^1_{set} , MPa)	X		
Rated delivered air FAD (q_1, l/min)			X

VSD Recorded variables, during SP2	Measured	Instruments	measuring standards
Cumulative amount of compressed air over SP2 (Q^2)[1]	X	on board reading[2] or from a continuous measurament instrument	According with ISO 1217 (1996) m^3
operating hours on VSD (A^2_4)	X	on board reading	h
outlet pressure (p^2_{set})	X	machine settings or pressure gauge	MPa

THE SIMPLIFIED METHODOLOGY 4/8

The assumptions supporting the comparison :

(i) the SP2 time span needs to be equal to or a multiple of SP1,
(ii) the air, delivered by the two machines must be the same amount, at the same pressure (p2set = p1set)
(iii) A6 = A32 (same off-line hours for the two machines, n off2).

After monitoring during SP2 data will be provided on the actual electricity consumption of the VSD based compressor, to be compared with the consumption of the old load/unload controlled machine, delivering the same service.

On this basis the savings can be assessed.

THE SIMPLIFIED METHODOLOGY 5/8

If both n^2_{tot} and A_4^2 are known then

$n_{off}^2 = A_6 = n_{tot}^2 - A_4^2 = A_3^2$ h [1]

accordingly q_4^2, representing the average capacity delivered by the VSD over A_4^2 to the network, is equal to:

$q_4^2 = Q^2 / (A_4^2 \cdot f_1)$ m^3/min [2]

Given the size of the machine, the average supplied input power P_{42} for the VSD system is obtained by properly referring it to one of the proposed curves.

The consumption of energy over SP2 is thus:

$E_2^2 = P_4^2 \cdot A_4^2$ kWh [3]

THE SIMPLIFIED METHODOLOGY 6/8

It is very unlikely that the same identical operating conditions occur during two subsequent sampling periods. Air demand is a very time dependant variable.

A few adjustments of the previously recorded data over SP1 have been provided to correctly assess the comparison.

New definition of the hours in the load-mode (A_1^2, h):

$$A_1^2 = Q^2 / (q_1 \cdot f_1) \qquad [5]$$

These are the hours the old system would have operated to deliver the same amount of air delivered by the VSD during SP2 .

THE SIMPLIFIED METHODOLOGY 7/8

Similarly A_2^2 is calculated from eq. [4]

$$P_2^2 = P_{2,0} \cdot (A_2^2 - t \cdot c^2) / A_2^2 + P_1 \cdot t \cdot c^2 / A_2^2 \qquad [6]$$

The duty cycle c also has to be adapted (in SP1 was recorded):

$$c^2 = c^1 \cdot Q^1 / Q^2 \qquad [7]$$

$$\mathbf{E_1^2 = P_1 \cdot A_1^2 + P_2^2 \cdot A_2^2 \quad kWh \qquad [8]}$$

THE SIMPLIFIED METHODOLOGY 8/8

The energy savings is thus calculated from eq. [3] and eq. [8]:

$$dE = E_1^2 - E_2^2 \quad \text{kWh} \qquad [9]$$

The assessment of the gross energy saving

$$\mathbf{GES = dE \cdot 0.187 \cdot 10^{-3} \cdot N \quad toe/y} \qquad \mathbf{[10]}$$

THE CASE STUDY 1/3

Validation done on the case of a mechanical company.

One week survey has been carried out on an Atlas Copco GA37 lubricated compressor. The monitored compressor is idling for the most of the time, therefore a convenience in the VSD application is expected. The data have been gathered by means of an Atlas Copco Italy measurement box.

Measured data over SP2 – VSD37 AC	Unit measure	Value
Network pressure level	MPa_r	0.7
n_{tot}^2	h	168
Q^2	m^3/week	16 828
A_4^2	h	160
Other known parameters from the previous monitoring stage SP1 on the old GA37 machine		
C		12,600
q_1(FAD)	m^3/min (l/s)	7 (115)
P_1	kW	47.9
$P_{2,0}$	kW	13.2
Q^1	m^3/week	14 697 (assessed)

THE CASE STUDY 2/3

List of calculated parameters

Variables	Equation number/curve	Unit measure	quantity
n_{off}^2	eq. [1]	h	8
q_4^2	eq. [2]	m^3/min	1.75
P_4^2	from the graph [fig.3]	kW	15.7
E_2^2	eq. [3]	kWh/week	2 511

Comparison with the old machine: Simulating the load/unload controlled compressor functioning: updated values over SP2

Variables	Equation number/curve	Unit measure	quantity
A_1^2	eq. [5]	h	41
A_3^2	eq. [1]	m3/min	8
A_2^2	eq.[4]	kW	119.4
t		s	15
c^2	eq.[7]		12 600
P_2^2	eq.[6]	kW	30.7
E_1^2	eq.[8]		5 608

Once these data are set, then both dE of eq.[9] and GES of eq.[10] can be defined.

THE CASE STUDY 3/3

FINAL RESULTS

			VSD CONFIGURATION			SIMULATION OF THE GA37 COMPRESSOR			
			On line mode	Off line	Total 1	Load mode	Unload mode	Off line	Total 2
hours	(A)	h/w	160,0	8,0	168,0	41	119,4	8,0	168,0
Delivered air (FAD)	(Q)	m3/w	1,75	-	16.828	6,9	-	-	16.828
Supplied input power	(P)	kW	15,7	-		47,9	30,7	-	
Energy consumption	(E)	kWh/w	2.511	-	2.511	1.947	3.661	-	5.608
GES/week						0,5792			

in 2007 the mechanical sector consumed roughly 3,6 TWh/y (less than 10% of the national electricity consumption). As a rule of thumb, a share between 5 and 10% of electricity is accounted for the compression of air in the sector (180-360 GWh/y): a potential underestimated saving of energy between 15-25% for the sector can determine a benefit of 27-90 GWh/y (13.5-45 ktCO2eq/y emissions reduction), that is the equivalent production of a 6 MWe power plant

FINAL REMARKS 1/2

The novelty of the illustrated methodology lies in relying on few and cheap measurable data and references curves: the duty cycle “c” of the load/unload controlled machine, the operating hours and the overall air delivery of the VSD compressor.

The choice of taking into consideration the “on board data” allows to minimize verification costs, thus keeping under control those costs related with measurement tools and personnel.

To prevent any overestimation of savings: the minimum between the two calculated values can be taken into consideration and this position could also satisfy the additionality question.

FINAL REMARKS 2/2

The proposed universal curves have already been elaborated by carefully weighting data from several manufacturers: anyway there is also the possibility in the stage of a M&V procedure for a customer to supply the real technical data measured on the machine.

The proposed curves should be updated every 3-5 years due to new technological solutions with improved performances expected from the market.

The proposed methodology only accounts for the optimization of the single device (the generation of compressed air), leaving aside the whole system optimization, which has to be performed in advance to any change

Thanks for the attention!

…comments and questions can be addressed to

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