Is variable speed drive the panacea we're looking for?

What does a compressed air system have in common with a symphony orchestra? Best performance is not achieved by outstanding soloists, but by optimum interplay. Experienced manufacturers of compressors are now in the position of offering system solutions to industry that can meet this requirement in every respect **(fig. 1)**. Together with correct system design and sizing, both the master and the internal controller play a very important role.

Fig. 1
An efficient compressed air supply requires optimal interplay of all components. Which is why custom-made solutions such as this car manufacturer's compressed air supply system are in high demand.

Five types of internal control modes can be considered as suitable for compressors: Dual, Quadro, Vario, and Proportional Control, using inlet valve regulation, and Variable Speed Control of the drive motor **(Fig. 1a)**. Of these five modes, Dual, Quadro and Variable Speed have proved themselves the most efficient in practise.

Fig. 1a:
Kaeser's DSD 141 SFC variable speed drive compressor is designed for maximum efficiency and a 100 percent duty cycle.

Dual and Quadro Control - efficient and good value for money

One of the most efficient and economic modes is Dual Control (full load - idling - stopped). If the air demand fluctuates heavily, a mode of control (Quadro) is recommended that can automatically select between full load, or idling or can stop the machine completely according to air demand or, alternatively directly from full load to stop. This intelligent variant is only slightly more expensive and reduces the power consumption of the compressor during 50 percent loading to less than 60 percent compared with full load.

Variable speed drive - a wide range form of control

In certain areas of application the use of variable speed drive can be advantageous. This type of control, which Kaeser calls Sigma Frequency Control (SFC), functions as follows: when a preset minimum pressure limit in the air system is reached, the compressor starts, runs up and settles down to a final speed that is related to the air consumption. If demand begins to fall resulting in a rise in system pressure, the compressor will begin to slow down in response. If pressure continues to rise to the cutout point, despite slowing down the drive motor to minimum speed, the compressor is vented and goes into idle mode for approximately one minute. If pressure has not dropped to the cut-in point by the end of this period, indicating a return of demand, the compressor shuts down completely. Theoretically, the number of starts per hour of the drive motor is unlimited because it is stopped from idling speed and soft-started. But even a variable speed drive compressor needs a run up and run-on period of approximately one minute, which limits the number of possible starts to not more than 60 per hour.

Whereas the definition of performance in Dual and Quadro Control is relatively simple, several factors have an important influence on variable speed compressors. Because a characteristic curve is followed over a certain speed range the performance of the compressor should always be represented such that the specific power requirement is shown related to the free air delivery (speed). Only this kind of interpretation shows the actual performance of a variable speed compressor. Graphs that merely show the power related to the air delivery interpret the performance of the machine on a linear basis only. This means that they provide no visual insight into the actual costs of a certain mode of control and can lead to misinterpretation. The efficiency of the drive motor, the frequency converter and the compressor airend related to speed determine the specific performance of the compressor at the corresponding air delivery, related to the overall power consumption. It is projected as a U-shaped curve **(Fig. 2)**.

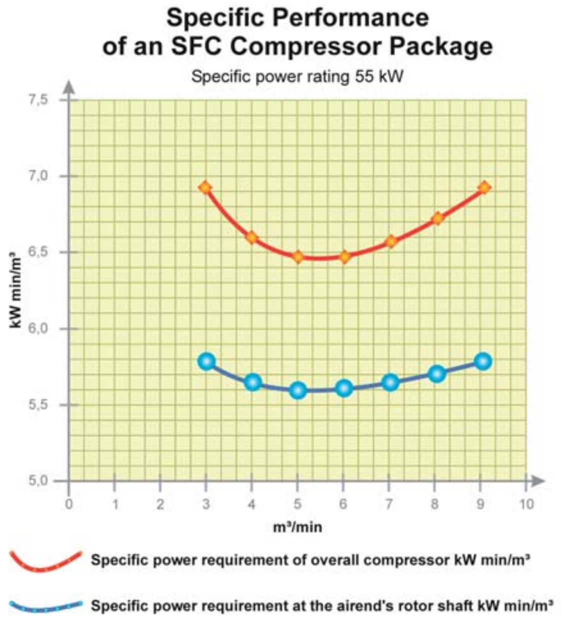


Fig. 2:
The influence of power losses on the performance of a rotary screw compressor in relation to speed

15 compressor models can be fitted with SFC variable speed drive, allowing the user to choose those to suit his particular application. This has proved itself especially favourable if individual compressors are directly allocated to a specific air consumer, as is the case when generating inert gases. In systems consisting of several compressors in which an SFC machine is used to cover peak loads, fine-tuning is also possible.

Thanks to optimised design of airends and drives, it is now possible to supply the industry with compressors of outstanding efficiency. For example, the Kaeser DSD 141 rotary screw compressor achieves a free air delivery of almost 15 m^3/min at 7.5 bar, running at only 1800 rpm - with a 100 percent duty cycle. In this case, the manufacturer has chosen frequency converters from Siemens.

Custom-made compressed air system concepts

During design of a customised compressed air system, the low pressure swing of only ± 0.1 bar that can be achieved is put to good use. This can only be achieved, however, with sufficient buffer volume. Fluctuations in air consumption that do not exceed the control range of the variable speed compressors are also conditions that are indispensable to attain minimal pressure swing.

a) Conventional splitting solutions
Solutions that split the air supply between one compressor and a standby machine or two equally sized machines to meet the demand of a facility are no longer in keeping with latest developments in technology, nor are they the most attractive investment when the cost of the standby machine is taken into account. Power and idling costs, controllability and the flexibility of this configuration must be regarded as falling short of current standards or even inadequate for the task **(Fig. 3)**.
Often, a configuration is offered by which the air demand is satisfied by a base load compressor, a standby compressor and a variable speed load regulating compressor, all of the same capacity. But often the fact that a variable speed machine cannot regulate down to zero is forgotten so that so-called control gaps appear. High power costs and, sometimes, high investment costs are the result. Increased idling costs, not from the peak load but the subordinate machine, bad controllability and restricted flexibility also enter the equation. According to the modern state of the art of compressed air systems, such configurations could be regarded as bad design.

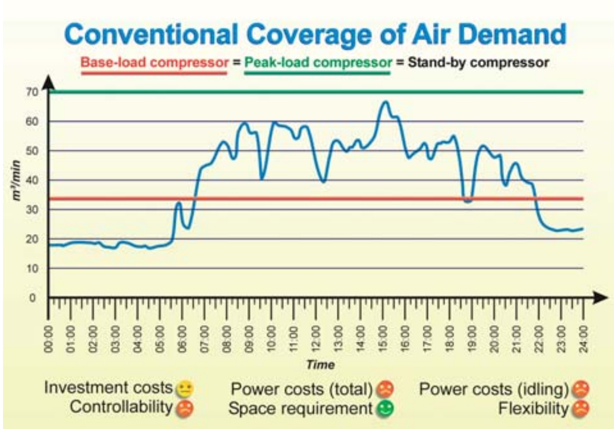
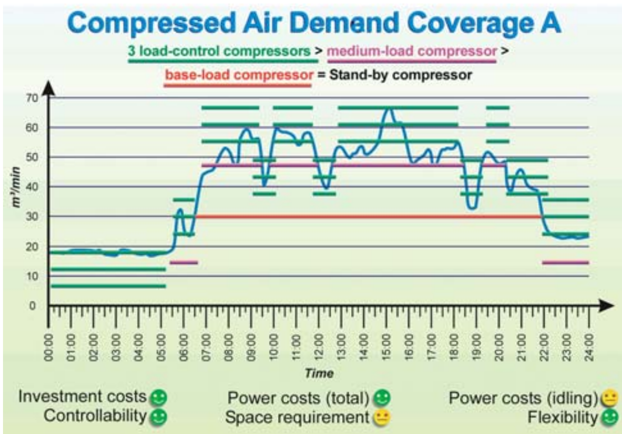


Fig. 3:
Conventional coverage of air demand using equally sized compressors - assessment of efficiency:
red circle = in need of improvement
yellow circle = acceptable
green circle = optimal

b) Optimised splitting solution - up to 30 % energy savings
An efficient method of splitting is that favoured by the Kaeser Company in which two or three small Dual-controlled peak load compressors of similar size are combined with larger medium load and peak load compressors, whereby the total capacity of the peak load compressors should be slightly larger than the subordinate compressor. This configuration allows the power consumption during idling to be reduced to 1 to 2 percent of the

Fig. 4:
System concept with three small load-controlling compressors (peak-load splitting)



overall power consumption of the system. Compared with conventional solutions, up to 30 percent power savings can be achieved. In addition, the use of smaller compressors and therefore smaller standby compressors brings considerable savings in investment costs. Also, the optimised controllability of these systems allows flexible matching of the compressors to heavily fluctuating air consumption **(Fig. 4)**. The only disadvantage, which is not too serious in view of the advantages listed above, is the somewhat larger space requirement.

Variable speed - the alternative to splitting

Variable speed compressors such as the Kaeser SFC series are another good way of matching the performance of a compressed air system precisely to the user's air demand. Indeed, the investment costs for this solution are a little higher, but in return, system power costs, idling costs, controllability and flexibility can be optimised **(fig. 5)**. However, with all peak load concepts it must be considered that the conventional base load and peak load functions no longer apply. This means that the peak load, or better, the load controlling compressors run the longest, sometimes as much as 8760 hours annually because they are the first to start and the last to stop. However, it would be wrong to think that variable speed compressors can save the installation of an air management system because, as in all multi-compressor systems the interplay of individual machines must be precisely coordinated. For such purposes, intelligent master controllers such as Sigma Air Manager (SAM) or Vesis can be used **(Fig. 6)**.

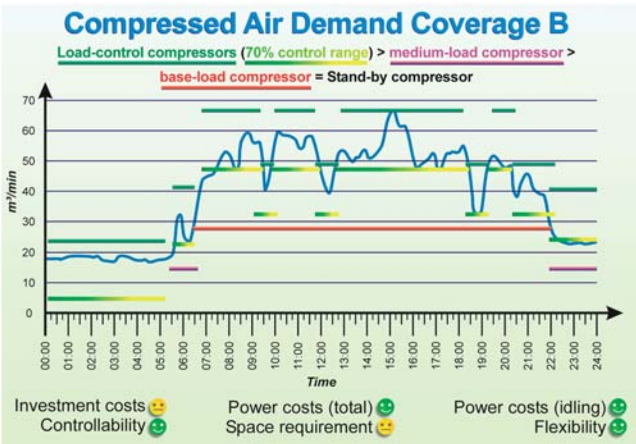


Fig. 5:
System concept using variable speed drive load-controlling compressors

A guide to optimised efficiency - computer-aided air demand analysis and system assessment

The capacity of compressors used in an air system is of great importance in the assessment of the efficiency of various configurations. Depending on size, the cost-effectiveness of compressors differs under full load or partial load operation. However, this fact does not obviate the need for detailed calculation when actually designing an air system. With the help of a detailed analysis of air demand and special assessment software such as

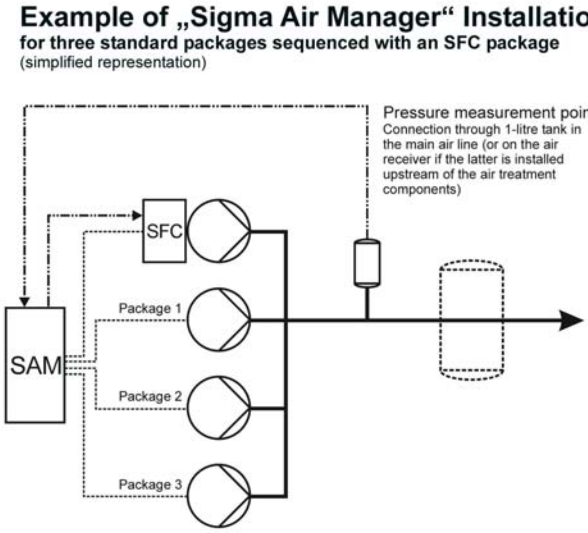


Fig. 6:
Compressor sequencing using a Profibus with a network-compatible air management system (SAM) or Vesis, and an integrated SFC load controlling compressor package.

that developed by Kaeser called Air Demand Analysis (ADA) and the Energy Saving System (KESS), this is possible without too much time-consuming effort.

Individual assessment

The configurations recommended by this detailed analysis represent the optimised version in each case. Obviously, changes can be made to give the customer a concept perfectly tailored to any special needs. It is imperative, however, that such changes take into account control criteria such as defined control ranges or compressor size to avoid the appearance of a control gap.

Further criteria to be taken into account during system design are the influences of air receiver capacity and the extent and frequency of fluctuations in demand. In this respect, Kaeser has available a broad palette of equipment; three air management systems, five programmed control modes in Sigma Control, the internal compressor controller, 15 compressor models that can be fitted with SFC variable speed control, 29 variously sized rotary screw compressor models with airends of the most efficient speed and size for each case, all allowing an optimal package configuration to be found for every application.
Because of the multiplicity of equipment available an analysis of compressed air demand and a system assessment, such as can be carried out by KESS, should always precede the design of a new air supply system or the modernisation of an existing system. This eases selection of the right configuration, helps to avoid design errors and saves considerable cost. To think that a certain type of compressor such as a variable speed machine as being a kind of cure-all would, however, be wrong.

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