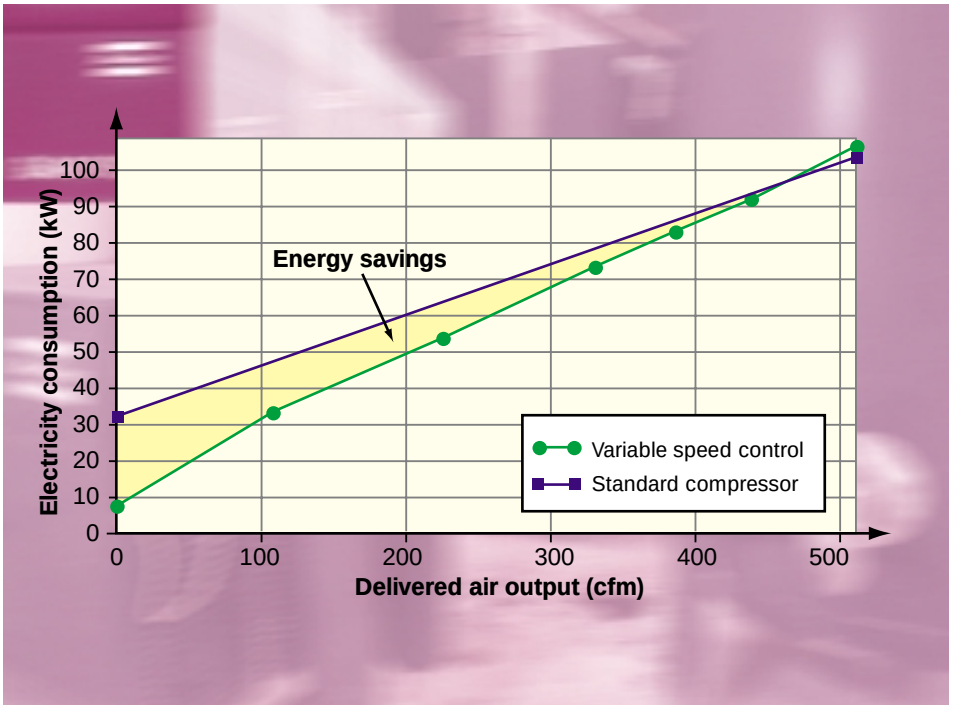
Air compressors with integral variable speed control



- **Air compressors with integral variable speed control are now available**
- **Variable speed control offers large energy savings at part-load**
- **Energy savings of 9% found in recent study**

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INTRODUCTION

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Many air compressors spend a large proportion of their operating time at part-load. This is an inefficient use of energy when using conventional controls.

However, a new generation of air compressors with variable speed controls has become available that provide an energy efficient solution to part-load operation. These compressors have a variable speed drive (VSD) built into the air compressor as an integral part of the machine.

This Leaflet gives an introduction to variable speed control of air compressors, and details the results of a recent study to investigate the energy saving benefits of using an air compressor with integral variable speed control.

VARIABLE SPEED CONTROL OF AIR COMPRESSORS - THE BENEFITS

Variable speed control is unique because the air volume output is varied by varying the speed of the motor driving the air compressor. The motor is controlled by an electronic system referred to as an inverter, frequency controller or variable speed drive. This is unlike conventional control techniques that work by throttling the air flow into the compressor. Thus, variable speed control is inherently more efficient.

Several other factors also contribute to the efficiency of variable speed controlled air compressors when operating at part-load:

- As the speed of the motor is variable there is no need for a gearbox or belt drive (see Fig 1) and its associated mechanical energy losses.
- There is tighter pressure control, allowing the mean generation pressure to be lower. In a single compressor installation, or where a variable speed machine is continuously running as a 'top-up' machine, delivery pressure can be kept within a band of 0.2 bar. This saves 2% of power consumption compared to a typical conventional on/off machine, where the pressure band is 0.5 bar.
- Lower mean pressure reduces leakage and lowers air consumption by air-powered equipment — typically resulting in a 2% reduction in air consumption at a mean pressure of 7.0 bar(g).

Variable speed is ideal for controlling single compressors with variable loads, and compressors used to provide 'top-up' capacity. They should not be used for supplying base load capacity as they are less efficient than comparable machines with standard controls when at full-load. This arises as some of the power is dissipated from the variable speed control electronics.

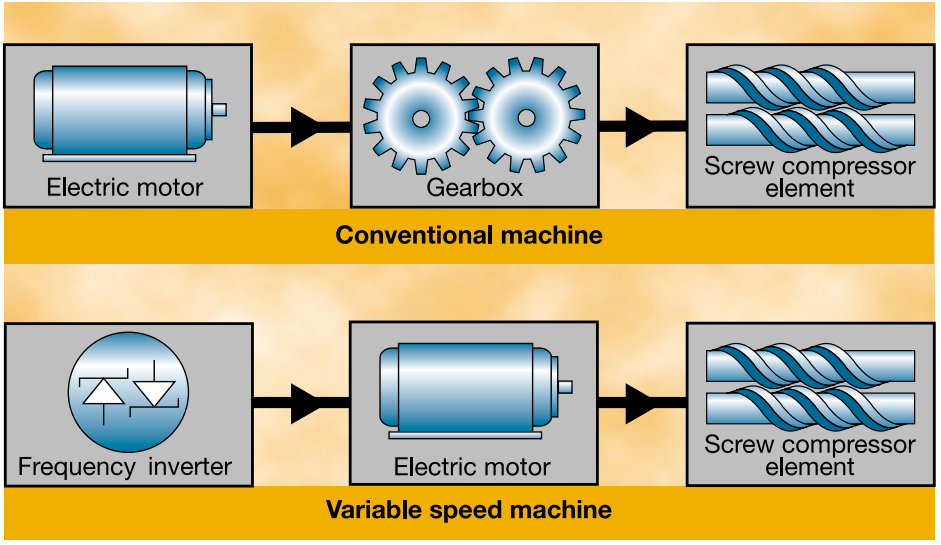

Fig 1 Drive systems of conventional and variable speed screw compressors

OTHER BENEFITS OF VARIABLE SPEED CONTROL

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Tighter pressure control not only saves energy but can also improve product quality and reduce waste.

Variable speed control machines benefit from reduced starting and stopping stress due to the soft-start facility within the inverter allowing almost unlimited motor starts per hour. This compares to conventional machines which are limited to typically four starts per hour to prevent damage to the motor. In some circumstances, this can allow the compressor to be completely switched off more frequently, saving energy through a reduction in idling (no-load) time. However, if the variable speed machine is working under optimum control as a 'top-up' machine, this should not be necessary.

VARIABLE SPEED CONTROLS

Variable speed control of induction motors of the sizes found in screw compressors is performed by an inverter. Inverters work by rectifying the incoming AC mains to a steady DC voltage and then digitally 'chopping' it at high frequency to produce a variable frequency, variable voltage output waveform. This variable frequency waveform allows the speed of the motor to be varied efficiently to match the air demand, and the microprocessor controls allow fast and accurate pressure control.

Special 'switched reluctance drives' are used with switched reluctance motors, but while the technology is different, both approaches use variable speed control and share the same core benefits.

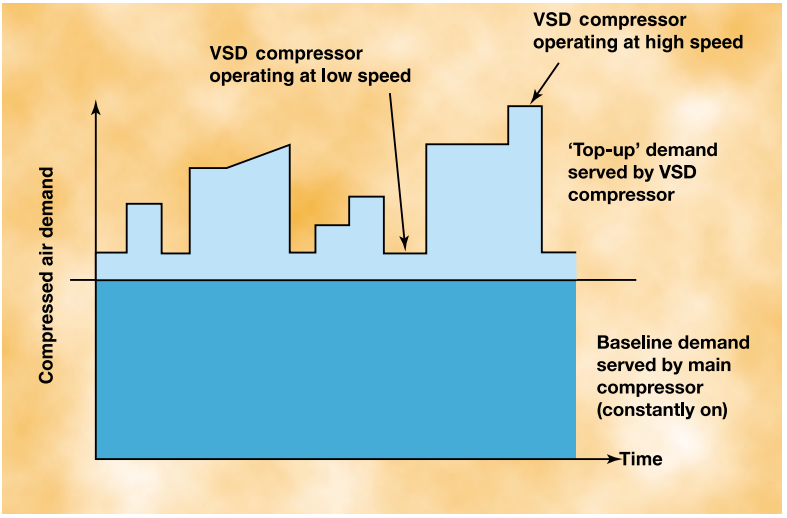

Fig 2 Example of application of variable speed compressor providing 'top-up' demand above a base demand provided by a main compressor (no switching control strategy required)

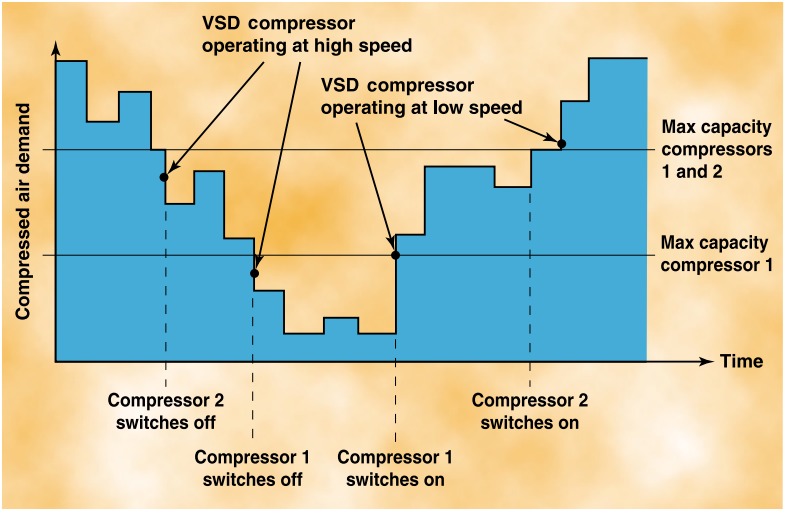

Fig 3 Example of application of variable speed compressor providing 'top-up' capacity throughout the full range of demand (switching control strategy required)

SINGLE AND MULTIPLE COMPRESSORS

SINGLE COMPRESSOR INSTALLATIONS

The simplest use for a variable speed compressor is in a single or stand-alone compressor installation. Good energy savings can be made when the demand is below maximum output for long periods.

MULTIPLE COMPRESSOR CONTROL

In multiple compressors, the set-up of the control sequencing is critical for optimising energy efficiency. The most efficient set-up is to bring conventional machines on- and off-load to meet the bulk of the demand, with a variable speed machine running continuously as a 'top-up' (Fig 4).

If this arrangement is not possible, or undesirable, then the installation can be set up such that the variable speed machine is set in the sequence so as to be the one most often working at part-load. However, the energy savings will not be as great as with a machine which is acting as a true 'top-up', as both its running hours are likely to be less and it could spend excessive periods running inefficiently at full-load.

It is essential that the control requirements for the variable speed compressor are fully discussed at the time of purchase and that the best set-up for an installation is established prior to specifying the compressor.

Unless care is taken over the air compressor installation, the maximum energy savings may not be achieved.

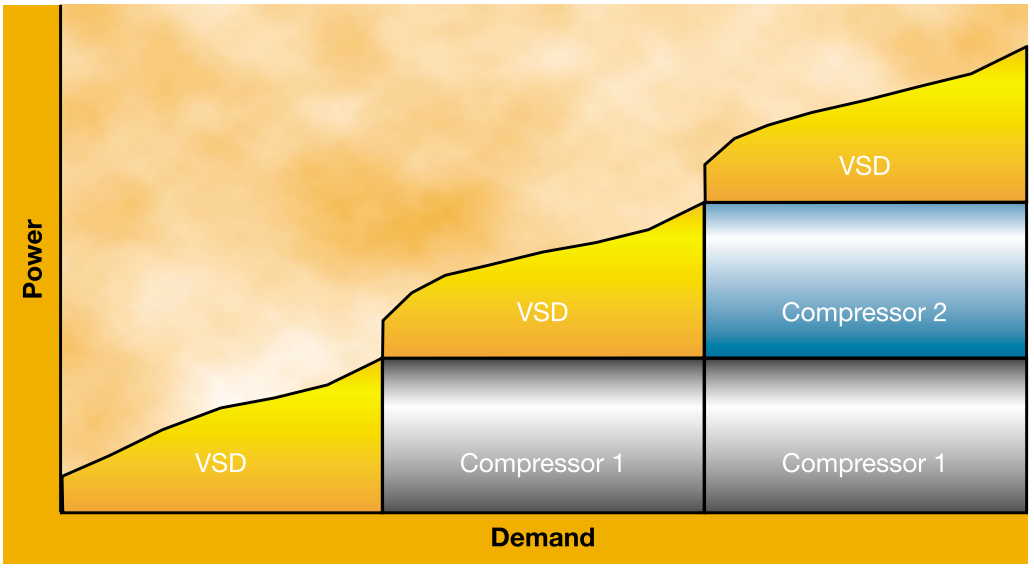

Fig 4 Capacity control with a VSD in a multi-compressor installation

HEADING

TESTS AT NORWEGIAN TALC LTD

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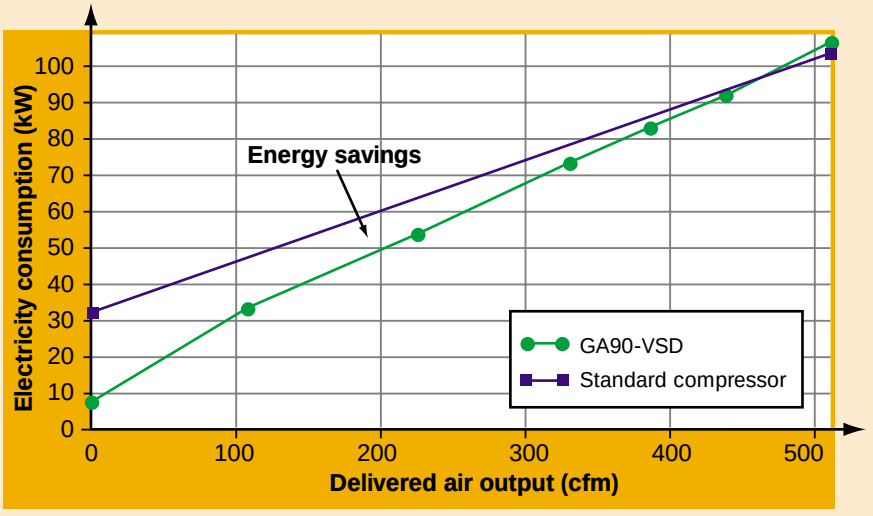
Capacity tests to BS1571 were undertaken on an 18-month old Atlas Copco GA90-VSD screw compressor at Norwegian Talc Ltd, Hartlepool. The results correlated the delivered air output and compressor electrical consumption.

The graph below shows the Atlas Copco compressor's performance compared to the average performance taken from many tests undertaken on similarly sized fixed-speed machines with standard on-line/off-line control. Basing the comparison on average performance compensates for the deterioration in the standard machines' performance that inevitably takes place over time. The results show that the energy savings become greater as the delivered air falls.

The GA90 variable speed drive

Energy savings of 9.4kW (or 9% of full-load power) at 50% of rated delivery are possible, and greater savings are possible if running at even lighter load. However, at full-load the energy consumption will be 4% higher due to the power losses within the inverter. Therefore, the machines should not be used in installations running for long periods at full-load.



Electricity consumption performance of the GA90-VSD compared with standard machines

ECONOMICS AND CONCLUSIONS

ECONOMICS OF USING AN AIR COMPRESSOR WITH INTEGRAL VSD

The energy savings from an air compressor with variable speed control can be sufficient to give a payback of one to two years through energy savings against the price premium of the variable speed machine, as experienced at Norwegian Talc Ltd. However, the exact savings depend on many factors.

Key factors for establishing the economics of purchasing one of the machines include:

- operating hours;
- electricity prices;
- the price premium of the variable speed machine over alternative machines (15% for a GA90-VSD machine compared to an equivalent 90kW rotary screw machine);
- the proportion of time at part-load;
- the proportion of time at full-load.

RETROFITTING VARIABLE SPEED CONTROL

It is also possible to purchase an inverter for retrofitting to standard machines. This can be attractive in some circumstances. However, purchase of an air compressor with integral variable speed control is much more attractive than fitting retrospectively as, when retrofitting, the costs of the now superfluous gearbox and any conventional controls are wasted, and manufacturers will not guarantee adequate lubrication of conventional machines at low speeds. At Norwegian Talc, the price premium for the variable speed machine gave an effective added inverter cost of £45/kW, which is considerably cheaper than when purchasing a separate inverter.

CONCLUSIONS

Energy savings from the use of an air compressor with integral variable speed control can be economically attractive in the many applications where a compressor is running for long periods at part-load.

The key points to consider are:

- For best energy savings on multiple compressor installations, the variable speed compressor should be run as a ‘top-up’ machine.
- Long running hours with a high proportion at mid- to low-load are necessary for the best payback.
- Purchasing a compressor with integral variable speed control is more cost-effective than attempting to retrofit an existing compressor.

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Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R & D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Energy Efficiency in Buildings: helps new energy managers understand the use and costs of heating, lighting etc.