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Control

Controls in compressor systems are used for both compressed air production and compressed air treatment. This fact sheet deals with the controls which match compressed air production to consumption (see Fig. 1).

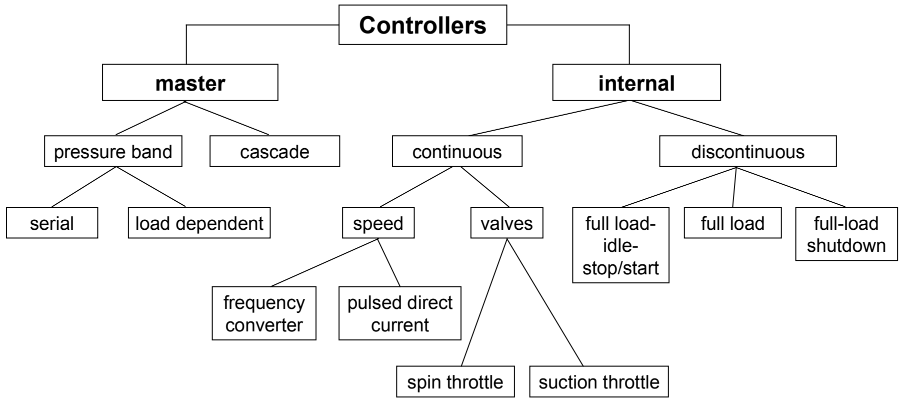

Fig. 1: Control of compressed air systems

Internal and master controllers

Within compressor systems, a distinction is made between internal and master control of the compressors. Internal controls are responsible for adjusting the respective compressor component to the air consumption required and to prevent overloading by an optimal coordination of the internal control processes. Since modern compressor systems are usually made up of several individual compressors, the task of the master controller is to operate the individual systems to capacity and to coordinate and monitor their use according to the actual air consumption.

Types of internal control

For internal types of control, a distinction is made between discontinuous and continuous controls.

Discontinuous control

The full load-idle-stop/start control is currently one of the most common controls in drives without variable speed control. If the operating pressure reaches the set lower pressure limit p_{min}, then the compressor is switched on and delivers compressed air. When p_{max}

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is reached, the compressor is not switched off but into idling mode by venting. If p_{min} is reached during the no-load period, the compressor then returns to full load operation. For low air consumption, the compressor is shutdown after a certain idling period (Fig. 2).

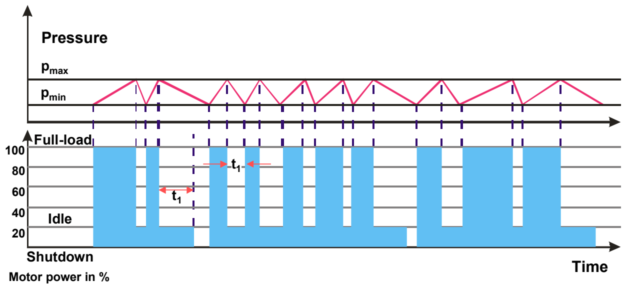

Fig. 2: Range of application peak load compressor

Note:

- Fast reaction
- High switching frequency without overloading the motor
- If poor load, high energy consumption during idling.

In no-load control with optimised idling time, the follow-up time is varied depending on the pressure fluctuations over time and the motor size and thus helps to make considerable cost savings in idling mode, especially in base load machines (Fig. 3).

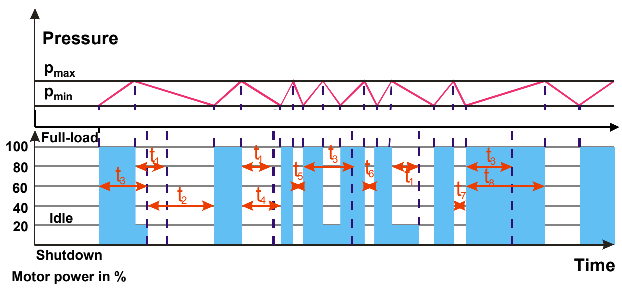

Fig. 3: Range of application base load compressor

Note:

- Lowest possible no-load share
- Good energy efficiency
- Longer reaction time.

Systems with discontinuous control have in common that they are controlled via pressure limits p_{max} and p_{min}.

Measuring transducer

The pressure limits required in mechanical pressure switches are sometimes up to one bar apart, but pressure differences can be reduced to 0.2 bar today using modern pressure sensors.

Note:

- Energy saving through small Δp
- High repeatability
- Low pressure fluctuations
- No universal interchangeability.

Continuous Control

Motor speed control

The most common ways to regulate speed in modern compressors are either to use a frequency inverter or direct current modulation. In both cases the systems are started at a pressure limit p_{min}. The motors then progress along a characteristic curve to a speed which is specified by the ratio of actual pressure to control pressure.

If the air consumption exceeds the control range of the machine, the system is either shutdown or switched to idling mode depending on the sequencer (Fig. 4).

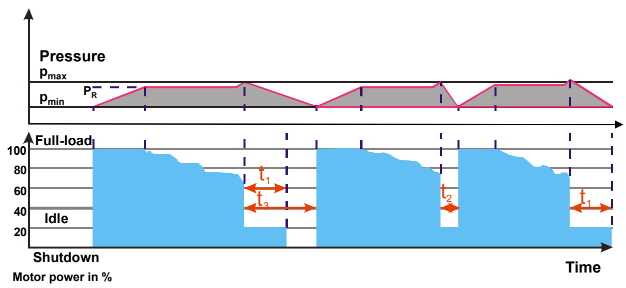

Fig. 4: Range of application peak load compressor

Note:

- Good controllability
- Fast reaction
- Constant pressure +/- 0.1 bar
- Good energy efficiency in the control range between 40 and 80 %
- Low energy efficiency at load > 80 %, < 40 %
- High investment costs
- Back coupling to electric grid

The characteristic curve of the controller, the motor and the air end in the partial load range is decisive for the efficiency of the control mode (Fig. 5).

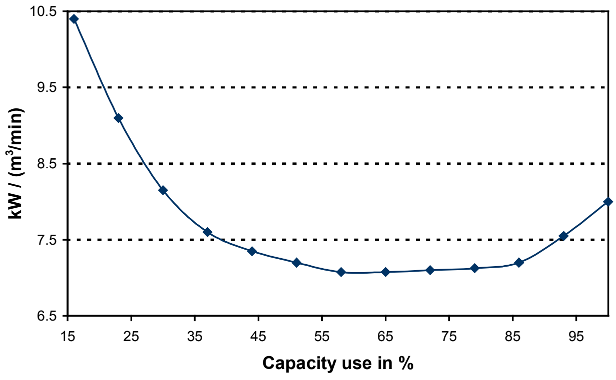

Fig. 5: Specific performance of a speed-controlled compressor

Suction throttle control

Machines with suction throttle control are normally compressors with a full load-idle-stop/start control and an additional control device. This is set to a certain control pressure. If this pressure is reached, the inlet valve of the compressor is either closed or opened depending on the plus-minus deviation from the control pressure. In positive displacement compressors, this actually only involves a reduction of the volume flow rate which only has a negligible influence on the performance of the compressor (Fig. 6).

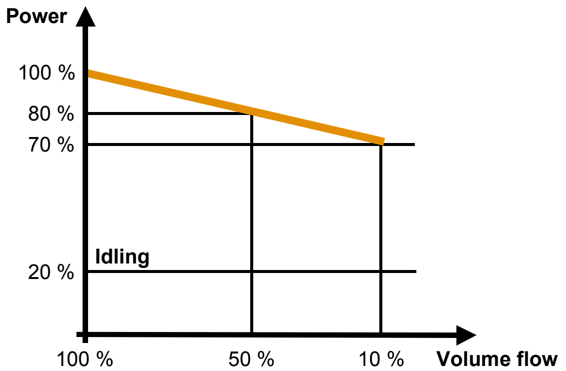

Fig. 6: Control of the volume flow rate using a suction throttle

Note:

- Low costs
- Large control range 100 % to 10 %
- Extremely poor energy efficiency.

Turbine bypass control system

Controls are characterised as turbine bypass controls in which the compressor discharges compressed air into the atmosphere and thus adapts the output to the actual air consumption.

This type of control is used in low pressure systems (e.g. fans) or also in dynamic compressors.

This control is also used in dynamic compressors to influence the performance but this is only possible in a relatively small control range (Fig. 7).

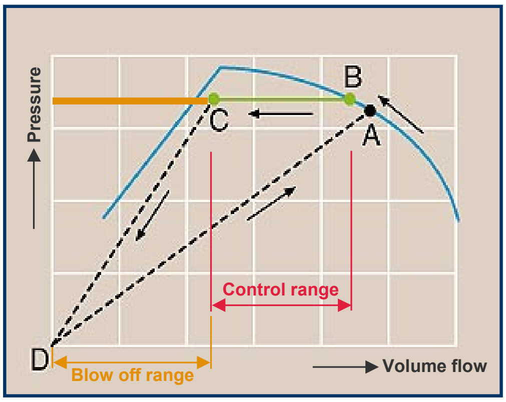

Fig. 7: Turbine bypass control system

Note:

- Linear performance in the control range
- Control range normally approx. 20-30 % without turbine bypass (higher energy loss).

Master controller

Among master controllers, a distinction is made between cascade and pressure band regulation.

Cascade control

The best known type of coordination is the so-called pressure cascade; in such setups, every compressor is assigned a particular Schaltbereich by the master controller (Fig. 8).

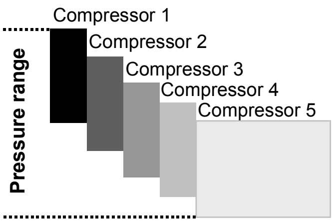

Fig. 8: Cascade control

Note:

- Pressure band, avoidable energy consumption as a result (per bar approx. 6-10 % excess energy consumption)
- No consideration of current air consumption
- Recommended only up to a maximum of 4 compressors.

For compressors of equal size, the compressors are transposed into base, medium and peak load depending on the running time of the compressors or via an interval timer. Sometimes when switching 4 compressors in a pressure cascade using membrane pressure switches or contact manometers, pressure spreads of up to 2 bar are required in order to switch the systems properly. The use of modern pressure sensors makes it possible to reduce the pressure spread to 0.7 bar for 4 compressors.

Pressure band regulation

Modern master controllers use the possibility to control an unlimited number of systems using a pressure band, the smallest control difference is 0.2 bar (Fig. 9). The advantage of this kind of control is a reduction of the maximum pressure in the compressed air system and thus a reduction of the primary energy costs and the losses in the compressed air system.

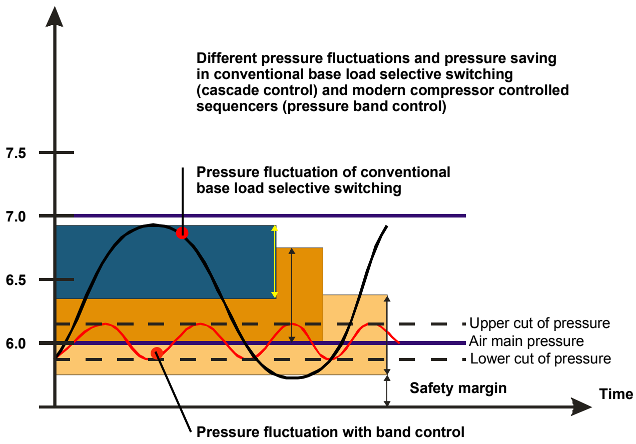

Fig. 9: Pressure band regulation

Extension possibilities with master controllers

Extended pressure band regulation can also select different compressor sizes depending on the load and coordinate these with each other should the demand arise. The correct selection of the compressor size prevents the production of so-called control gaps (Fig. 10). Control gaps can arise at incorrect grading of the compressors and a discrepancy between amount of air required and compressed air produced.

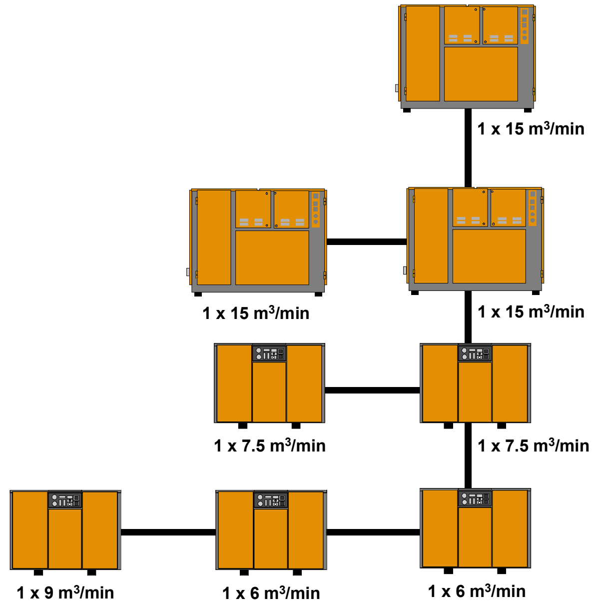

Fig. 10: Ways to split-up compressed air production

In order to improve monitoring and to depict the processes within a compressed air system, these master controllers can record not only the compressor data but also the data of each air treatment and distribution system in a compressed air system and then transmit these data via a suitable control and instrumentation installation software to a centralised control centre (Fig. 11).

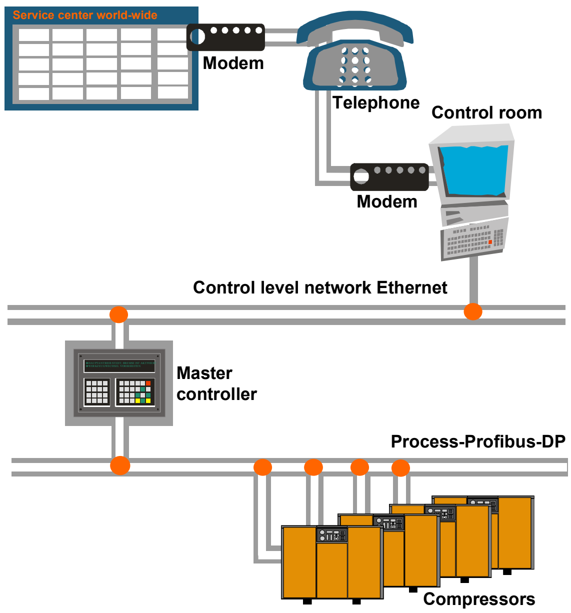

Fig. 11: Use of control technology for compressor control

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Saving potential

According to an EU paper, master controllers can achieve an energy saving potential of 12 % on average by lowering the pressure and better coordination. Optimised internal controls can achieve an energy saving potential of 15 % on average by reducing internal losses.

Storing compressed air

The energy of compressed air is stored in the pipes and receivers. Compressed air users often work very discontinuously. Producing compressed air using compressors has to be reconciled with the discontinuous air consumption. Receivers constitute the backbone/mainstay of the efficiency of a compressed air system. They should be chosen to be larger rather than too small. The influence of the receiver on the efficiency of a system is dependent on the size of the pressure loss between the measurement point of the control and the storage location. Usually this should not be larger than 0.1 bar. Today, a distinction is made between decentralised and centralised buffers in a compressed air system.

Centralised buffers

The main buffer receiver in a compressed air system is primarily there to minimise the switching frequency of compressors. In addition it prevents overlarge pressure fluctuations in the system. It should be selected in accordance with the equation shown, although the efficiency of the compressed air system benefits if a larger receiver is selected than the minimum value calculated in the equation (Fig. 12).

$$V_B = \frac{\dot{V}_1 \cdot (x - x^2)}{z \cdot \Delta p}$$

Compressor power	Usual z-values/h for motor switching:
7.5 kW	30
30 kW	15
110 kW	8
250 kW	4

V_B = Volume of air receiver [m³]
$\dot{V}_1$ = Quantity delivered by switching compressor [m³/h]
$\dot{V}_2$ = Peak consumption minus average consumption [m³/h]
x = $\dot{V}_2 : \dot{V}_1$ = Load factor [m³/h]
z = Permissible switching cycle [1/h]
Δp = Pressure difference ON/OFF [bar]

$z \approx 45$ for screw compressors (full load; idle)
Rule of thumb: $(x - x^2) \approx 0.25$

Fig. 12: Dimensioning of centralised compressed air storage

Decentralised buffer

The decentralised buffer often serves to supply compressed air to users with sudden large and temporary demand and to prevent a pressure drop in the rest of the air mains. It has to be selected corresponding to the running time, the air consumption and the permitted pressure fluctuations of the decentralised user (Fig. 13).

$$V_B = \frac{\dot{V} \cdot t}{\Delta p}$$

Use as:

- Buffer for short but acute withdrawal of compressed air
- as emergency "power generator"

V_B = Volume of air receiver [m³]
$\dot{V}$ = Air consumption [m³/min]
t = Duration of air consumption [min]
Δp = Permissible pressure drop [bar]

Note: Does not replace the compressor over a longer period

Fig. 13: Dimensioning decentralised storage

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VDMA Drucklufttechnik

The campaign "Druckluft effizient" aims to motivate the operators of compressed-air systems to optimise their systems and save substantial costs. It is conducted by the **German Energy Agency** (dena), the **Fraunhofer Institute Systems and Innovation Research** (Fraunhofer ISI; project management), and the **Federation of the Engineering Industries** (VDMA) with support of the Federal Ministry for Economics and Labour (BMWA) and the following industrial enterprises:

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