



装有变速执行器的DN 1900、PN16蝶形阀，
用于控制炼钢厂锅炉内的供气
DN 1800, PN 16 butterfly valves with
variable speed actuator for control of air
feed in a steel plant furnace

变速传动

装置削减成本

变速传动装置的运转
调节降低了能耗

Variable speed drives cut costs

Running adjustments by variable speed drives reduces energy consumption

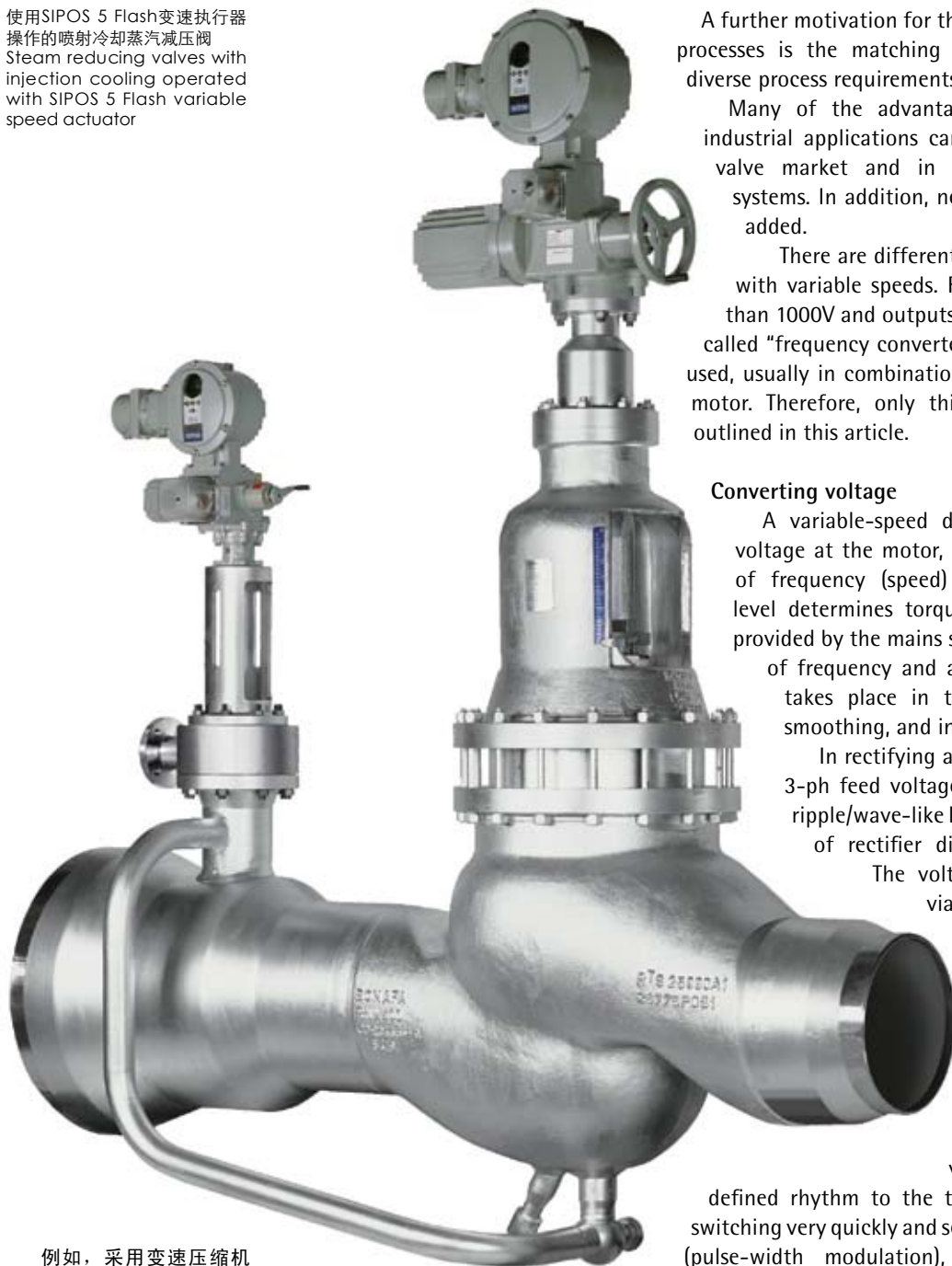
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近几年来，变速传动装置（VSD）在工业设备工程、甚至消费行业都日益得到广泛使用。其中一个主要的原因是该装置能够节能。

Variable-speed drives (VSD) have increasingly become established in industrial plant engineering and even the consumer sector in recent years. One of the main reasons for their selection is their potential to save energy.

It is, for example, cheaper for a variable-speed compressor to supply the flow of air required, instead of running a compressor at a fixed speed for maximum demand and generating the actual demand by means of throttles – thus wasting energy.

使用SIPOS 5 Flash变速执行器
操作的喷射冷却蒸汽减压阀
Steam reducing valves with
injection cooling operated
with SIPOS 5 Flash variable
speed actuator



例如，采用变速压缩机
供应所需空气流比采用固定速度
的压缩机更加便宜，因为后者针对满足最大的
需求并使用节流阀控制产生实际需求，因此造成了能量的浪费。

而推动VSD更加广泛地应用于工业进程的因素是执行结构元件与
多种工艺要求之间的匹配。

VSD在工业应用中的许多优势也可以在阀门市场和电力执行机构
传动系统中得以实现。此外，还增添了许多新特性。

A further motivation for the use of VSDs in industrial
processes is the matching of actuator elements to
diverse process requirements.

Many of the advantages offered by VSDs in
industrial applications can also be realised on the
valve market and in electrical actuator drive
systems. In addition, new benefits are also being
added.

There are different ways of running a motor
with variable speeds. For mains voltages of less
than 1000V and outputs of several 100kW, the so-
called "frequency converter with DC voltage link"
is used, usually in combination with a robust induction
motor. Therefore, only this version will be briefly
outlined in this article.

Converting voltage

A variable-speed drive (VSD) requires 3-ph
voltage at the motor, changeable both in terms
of frequency (speed) and amplitude (voltage
level determines torque). However, the voltage
provided by the mains supply is constant in terms
of frequency and amplitude. The conversion
takes place in two steps, rectifying and
smoothing, and inversion.

In rectifying and smoothing the 1-ph or
3-ph feed voltage is first converted into a
ripple/wave-like DC voltage using a network
of rectifier diodes ("bridge rectifiers").

The voltage is further smoothed
via thick capacitors that are
used as a buffer for the
energy.

In inversion, the
second part of a
frequency converter
consists of six fast
"electronic" switches
connecting the DC
voltage in a precisely
defined rhythm to the three motor terminals. By
switching very quickly and selecting the proper voltage
(pulse-width modulation), a three-phase voltage
system is established. The large amount of DC voltage
"slices" are filtered by the motor windings, only the "basic
oscillation" of the voltages generates a rotary field with the
desired frequency and voltage amplitude.

The "trick" is to extrapolate the voltage patterns and to
rapidly implement the switching states. In modern VSDs this
task is performed by high-speed processors (micro-processors

变速电动机有多种运行方式。对于干线电压低于1000V并且输出功率约为100kW左右的电动机，采用了所谓的“直流电压传输变频器”，并且通常与强健感应马达结合使用。因此，在本文中只简要介绍这种类型。

变换电压

变速传动装置（VSD）在电动机处需要三相电，并且频率（速度）和振幅（电压水平决定力矩）都应可调。但是，干线供电所提供电压的频率和振幅都是恒定的。变换包括两个步骤：整流和滤波，以及转换。

在整流和滤波阶段，单相或三相馈电电压首先被转换为一种波纹/波状交流电压，用于整流二极管网络（“桥式整流器”）。接着电压使用厚电容器进行滤波，这些电容器用作能量的缓冲器。

在转化阶段，变频器的第二部分包括六个快速“电子”开关，这些开关将具有精确定义脉动的直流电压连接至三个电动机终端。通过快速切换开关并选择适当的电压（脉冲宽度调制），就可以建立一个三相电压系统。大量的直流电压“削波”都被电动机绕组过滤，只有电压的“基本振荡”生成一个具有所需频率和电压幅度的旋转磁场。

“窍门”在于外推电压起伏，并快速执行开关状态。在现代VSD中，该任务由高速处理器（微处理器或微控制器）执行。

开关命令由电子元件执行，自二十世纪九十年代初期以来，电子元件就开始形成系列零件，确实达到了“理想开关”的要求，也就是达到了快速开关而没有损耗的程度：“IGBT”（绝缘栅双极晶体管）。

以下对这些部件的容量进行介绍：在正常条件下，逆变器6个IGBT中的每一个都能以每秒6000到10000次的频率接通和断开约540V的电压（三相连接电压，整流400V）。

在阀门应用中使用变速执行器的优点包括缓慢但稳定的启动。发电厂或水处理厂的阀门有时候必须承受很大的压差。当阀门在整个操作过程中快速工作时，就会产生湍流和涡流。

这样，部件材料就受到应力作用，而这会危害到阀门、管路和连接零件。有害或破坏性的副作用（例如穴蚀和“水锤”）可能会扩散至整个设备，而这可以通过流量限制器良好“受控的”工作速度来防止。

当阀门首次缓慢打开时，可能会出现压力补偿；当达到预定的阀门位置时，执行器可能会以更高的速度工作。

or micro-controllers).

The switching commands are implemented by electronic components which have been available as serial parts since the beginning of the 1990s and virtually meet the requirements of an "ideal switch", i.e. switching rapidly and without loss: "IGBTs" (isolated gate bipolar transistors).

Just to give an idea of the capacity of these components: under normal conditions, each of the 6 IGBTs of an inverter typically switches voltages of about 540V (three-phase link voltage for rectifying 400 V) on and off at a frequency of approximately 6,000 to 10,000 times per second.

The advantages of using variable-speed actuators in valve applications include starting up slowly but consistently. Valves in power plants or water treatment plants sometimes have to resist major differential pressure. When operating the valve quickly over the entire travel, turbulences and vortices are created.

As a consequence, stress is put on the material and this can represent a hazard for valve, pipe work and connection parts. Undesired or damaging side-effects such as cavitation and "water hammer" which spread within the entire plant can be prevented by a well-"controlled" operation speed of the flow restrictor.

When first opening the valve slowly, pressure compensation may take place; on reaching a defined valve position, the actuator may be operated at increased speed.

For variable-speed motors, the motor frequency is adapted by means of a so-called "ramp function generator" with defined acceleration and jolt limitation ("ramp").

If the actuator moves the valve at full speed into the valve seat, the function "close tightly" is fulfilled, but at the price of a high dynamic load torque for both valve and actuator. During the delay time between detection of the torque and switching-off, the motor continues its operation at full speed.

Even after the motor has been switched off electrically, the stored kinetic energy continues to increase the excessive

VSD在工业应用中的许多优势也可以在阀门市场和电力执行机构传动系统中得以实现。此外，也增添了许多新特性
Many of the advantages offered by VSDs in industrial applications can also be realised on the valve market and in electrical actuator drive systems, and new benefits are also being added

对于变速电动机，使用所谓的“斜坡函数发生器”以及定义的加速和摇动限制（“斜坡”）来调节电动机频率。

如果执行器能够全速移动阀门进入阀座，就会执行“关紧”功能，但同时也提高了阀门和执行器的动态负载扭矩。在扭矩检测和关闭之间的延迟时间内，电动机继续以全速工作。

即使在电动机电动关闭后，储存的动能仍继续提高已经过大的扭矩。阀门和执行器的尺寸设计都必须能够适应这些过大的扭矩——这与常规操作相比真是一种浪费。

在电动机上安装另外的制动器，可以制约这种影响，但这会产生额外的成本并增加制动器的磨损。而装有VSD的执行器能够在达到终点位置前控制输出速度并减速，从而降低动能至较小水平。此外，还可以对电动机电压的设定值进行选择，使所需失速转矩对应于阀门的跳闸扭矩。这样，即使断开检测和实际电动机关闭之间在延迟时间，也没有关系。

控制执行器速度

在使用带阀门的执行器的一个例子中，可以对此进行说明：在强大的扭矩作用下，执行器缓缓地将阀门移出一个阀门终点位置，进入另一个终点位置。整体变频器自动调制终端位置的频率和振幅。因此，执行器以降低了的电动机速度工作，也就是说，执行器以降低了的工作速度进入终点位置区域（该区域的尺寸可以设置为阀门行程的百分之X），并且即使在堵塞情况下也不会产生过大的扭矩。这样阀门、阀座、密封以及其它机械部件都会受到特别的保护。

有时，可能需要在阀门行程的不同部分以不同的速度工作，例如，在工艺内旁通临界位置而不受到共振的作用或者将工艺变动的压力、温度和流量等保持在一个固定水平或者线性化阀门特性。通过接通/切断“固定速度执行器”循环（步进模式）和多个小脉冲（以及许多启动电流尖脉冲）只能达到VSD执行器的标准。在操作期间改变输出速度的方法有很多。

变速执行器可被加以编程，这样阀门在关闭方向的定位速度将不同于开启方向的速度。一种典型的应用是采用SBR程序（定序间歇

torque. Valve and actuator both have to be sized for these excessive torques - a real waste compared to normal operation!

Additional brakes at the motor can be used to counter this effect. This creates additional costs and wear on the brakes. An actuator with VSD can control the output speed and slow down before reaching the end position, so reducing the kinetic energy to a minor fraction. Furthermore, the setpoint of the motor voltage can be selected so that the desired stall torque corresponds to the tripping torque of the valve. Thus, even the delay time between detection of the cut-off and the actual motor OFF is irrelevant.

Controlling actuator speed

In an example using an actuator combined with a valve, this can be illustrated: with powerful torque, the actuator gently moves the valve out of one valve end position and into the other end position. The integral frequency converter automatically modulates both frequency and amplitude in the end positions. Consequently, the actuator is operated at reduced motor speed, i.e. the actuator is operated at reduced speed into the end position areas (which can be set in size at x per cent of the valve travel) - without excessive torque, even in the case of blockage. Thus valve, valve seat, sealings, and other mechanical components are treated with special care.

Sometimes, it may be reasonable to operate the actuator at different speeds in different sections of the valve stroke, e.g. to by-pass critical positions within the process without stimulation by resonances or to keep the process variables pressure, temperature, flow etc. at a fixed level or to linearise the valve characteristics. What can only be achieved via switching on/ off cycles (stepping mode) for "fixed-speed

对于低频条件，电压振幅可以实现电动机扭矩的微调。

由于低频存在足够的电压储备，

可以选择启动的转矩，这样即使阀门翘曲它也能启动

For low frequencies, the voltage amplitude enables fine adjustment of the motor torque. Since in particular sufficient voltage reserve for low frequencies exist, the starting torque can be selected so that starting is possible even if the valve is warped

启动柔性...



...性能优良

SIPOS 5 FLASH – 变频智能型电动执行机构

把软启动技术同精确控制和电力技术完美地结合在一起，SIPOS 5 Flash 电动执行机构可以有效地驱动阀门进入或离开末端位置，是保护阀门和延长其使用寿命的最佳方案。

用户得到的好处是：降低了维护成本和运行成本。

SIPOS 5 Flash – 可提供长期完美的解决方案。

智能驱动的领导

- 关断时不会过力矩。
- 通过记录力矩对阀门进行监控。
- 避免了“水锤效应 / 气蚀现象”。
- 控制精确，重复精度高。





一个区域供热泵站的SIPOS 5 阀门
SIPOS 5 Flash in a district heating pumping station

反应器) 的污水处理厂内使用的“滗析器”。滗析臂低速降低伸入媒介内，防止活性淤泥盆内产生涡动。废水排出后，滗析臂以较高的速度从污水表面提起并返回至初始位置，使得淤泥盆能够快速填注以用于下一循环工作。

actuators" and with many small impulses (and many start-up current spikes), is the standard for the VSD actuator. There are different options for changing the output speed during operation:

The variable-speed actuator can be programmed so that the positioning speed of the valve in direction CLOSE differs from the speed in direction OPEN. A typical application is a "decanter" used in sewage treatment plants with SBR procedure (Sequencing Batch Reactor). The decant arm is lowered into the medium at low speed to avoid swirls in the activated sludge basin. After the water has run off, the decant arm lifts at higher speed from the wastewater surface and returns to the initial position to allow fast filling of the basin for the next batch process.

There can be different output speeds for normal operation and emergency situations. Control engineers know this dilemma: when having to select the optimum sizing of a closedloop control for both reference value and variable disturbance. It would be desirable if the "motor operated valve" (MOV) was positioned precisely during modulating duty at low output speed, but moved at maximum speed to a predefined position in case of an emergency situation, such as load shedding in a power plant.

When using variable-speed actuators, this can easily be resolved. How both the position and the behaviour can be pre-defined only depends on the so-called "intelligence" of the programme. The function in case of an EMERGENCY input signal (ESD – emergency shut-down) can be as follows: For VSD actuators, different speeds (e.g. faster ones) can be set for both directions via the emergency input. If the emergency signal is present, the actuator is operated at the set speed into the predefined emergency position (CLOSED, OPEN, or any intermediate position). In addition, different software versions based on the customer requirements are available.

通过接通/切断“固定速度执行器”循环（步进模式）和多个小脉冲（以及许多启动电流尖脉冲）只能达到VSD执行器的标准

What can only be achieved via switching on/ off cycles

(stepping mode) for “fixed-speed actuators”

and with many small impulses (and many start-up current spikes),

is the standard for the VSD actuator

正常工作和紧急局势下的输出速度可以不同。控制工程师了解这种两难局面：必须选择闭合回路控制的最优尺寸，以同时满足参考值和变动扰动要求。“电动阀（MOV）”最好能在以低输出速度调制负载期间进行准确定位，但在紧急情况下以最大速度移动至预定的位置，例如发电厂的甩负荷。

当使用变速执行器时，这个问题就能够很容易地解决。预定位置和动作的方法只取决于程序所谓的“智能”。当出现紧急输入信号（ESD——紧急切断）时，其功能如下：对于VSD执行器，可以通过紧急输入为两个方向设置不同的速度（例如，较快的方向）。如果出现紧急信号，执行器以设定速度操作进入预定的紧急位置（关闭、开启或其它中间位置）。另外，也可以根据客户的需要提供不同的软件版本。

对于VSD执行器而言，执行器的输出速度或定位速度也可以在整个行程内设置成不同值。阀门的整个行程可以分为10个不同速度的行程段。通过这种功能，就可以达到行程与流量的平衡。

变速执行器通过改变输出速度并在开启状态与关闭状态来回切换实现这个目标。紧急功能不会受到影响。它也能够用于辨别执行器是否遵循这种特性，它通过内插点确定，用于本地控制、远程控制或两种控制。

这种功能（例如）正被应用于瑞典多种区域供暖设备内（斯德哥尔摩Birka区的供暖、Upplands Väsby-Akalla的Fortum区的供暖）。执行器以120°C/60°C水分配操作阀门。执行器高速通过行程的第一个部分，直至达到阀门另一侧的压降，然后执行器以降低的速度运动至终点位置关闭。

相反方向的工作也同样如此。这个程序成功地避免了管路内的水锤。对于通过变频器控制的执行器，也可以使用一个0/4-20mA的模拟信号为速度曲线设定一个工艺定向的速度设定值。通过“模拟速度设定值”功能，执行器能够以不同的速度工作，而无需在工作期间重新进行编程。

对于异步三相交流电动机，输出速度变化与接通的电动机电压的平方约成正比。在70%的标称电压条件下，常规控制的执行器只能提供50%的扭矩，这也能通过其它途径获取。即使标准干线内的电压波动没有那么剧烈，当邻近的大型用电器（泵、压缩机、大型电动机）启动时，最强大工业主线内的本地电压也会暴跌。

For VSD actuators, the output speed or positioning speed of the actuator can also be set differently across the travel. The entire travel of the valve can be divided into up to ten different travel sections with different speeds. By means of this function, a proportionality of travel and flow rate can be reached.

The variable-speed actuator achieves this by changing the output speed while running from OPEN to CLOSED and vice versa. The EMERGENCY function is not affected. It can also be distinguished whether the actuator is to follow this characteristic, which has been defined via interpolation points, for local control, remote control, or both.

This function, for example, is used in a variety of district heating plants in Sweden (Birka district heating, Stockholm; Fortum district heating, Upplands Väsby-Akalla). The actuator operates the valves at the 120°C/ 60°C water distribution. The actuator passes the first section of the travel at high speed, until the pressure drop on the other side of the valve is achieved; the actuator is then operated at reduced speed to end position CLOSED.

The same happens for the opposite direction. This procedure successfully avoids water hammer within the pipework. For actuators controlled via frequency converters, a process-oriented speed setpoint by means of an analog 0/4-20 mA signal for the speed curve is also possible. Via the "analog speed setpoint" function, the actuator can operate at different speeds without reprogramming during operation.

For an asynchronous 3-ph AC motor, the output speed changes almost proportionally to the square of the connected motor voltage. At 70 per cent of the nominal voltage, the conventionally controlled actuator provides only about 50 per cent of the torque which would be otherwise available. Even if the voltage fluctuations in the standard mains are not that significant, the local voltage in the most powerful industrial

在阀门应用中使用变速执行器的优点包括缓慢但稳定的启动。

发电厂或水处理厂的阀门有时候必须承受很大的压差

The advantages of the use of variable-speed actuators in valve applications include starting up slowly but consistently.

Valves in power plants or water treatment plants sometimes have to resist major differential pressure



污水处理厂内滗析器上的变速执行器系统
Variable speed actuator system on a decanter
in a sewage treatment plant

执行器的设计必须适用于这种低压情况。另一方面，它必须确保出现高压时不会损坏阀门（包括容差内过大的电压）。阀门的尺寸也必须适用于这类操作。

对于VSD执行器，输出电压和转矩用于独立于实际干线电压的主要部分——一个确定尺寸的部分，它可以很轻易地达到因数2。

变速电动机

电动机偶而会要求在停电情况下工作——通过使用一个蓄电池供电的逆变器。采用“标准”三相交流执行器的成本效益低，因为三相逆变器的成本很高——它们不是标准设备。但是，单相逆变器需要单相交流电动机，也就是说，安装了启动电容器的“万用电动机”的问题在于启动扭矩。

变速电动机能够将单相馈电电压转化为电动机的可变三相电压（在制造商设定的输出极限值内），从而提供这种特殊的功能，并且无需额外的补偿或性能损失。

通过使用变频器，电动机不再必须从滑动量=1（输出速度=0）启动、上升至标定滑动量、而产生很高的启动电流：每秒都定义新频率，电动机在电流额定位置持续工作。换句话说：启动电流小于或等于额定电流。

在一个端子上使用多个执行器时，控制箱体积和电缆横断面面积也可以显著减小。

相位连接的顺序对逆变器没有影响（总之电压被整流），这样就始终出现自动相校正。电动机的旋转方向专门由逆变器的规范确定。

对于低频条件，电压振幅可以实现电动机扭矩的微调。由于低频存在足够的电压储备，可以选择启动的转矩，这样即使阀门翘曲它也能被启动。

除了通过传感器持续测量电动机温度外，变频器也控制电动机电流（通过直流线路电压测量）。“烧结电动机”的现象已经成为过去。

自由设定输出速度以及大范围跳闸扭矩的选项，或者较大转变旋转的方向，都大大方便了设备操作期间规划和工艺的优化。

由于VSD执行器的编程功能，发电厂/工业设备内使用的电动机型号以及执行器类型和尺寸都大大减小。而且也不再需要减速装置和输出转速不同的不同电机。这显著减少了库存备件的数量。

mains will collapse if neighbouring large-scale consumers (pumps, compressors, large motors) start up.

The actuator must be designed for this low voltage situation. On the other hand, it must be ensured that the valve is not damaged in presence of maximum voltages (including excessive voltage within the permissible tolerance). The valve must also be sized for this kind of operation.

With a VSD actuator, the output voltage and thus the torque is for a major part independent of the actually present mains voltage—a sizing asset which may easily reach the factor 2.

**对于VSD执行器而言，
执行器的输出速度或
定位速度也可以在
整个行程内设置成不同值。
阀门的整个行程可以分为10个
不同速度的行程段**

**For VSD actuators, the output
speed or positioning speed of the
actuator can also be set differently
across the travel.**

**The entire travel of the valve can
be divided
into up to ten different travel
sections with different speeds**

Variable speed motors

Occasionally there is a requirement that the actuators must be operable in case of power failure - by means of a battery-supplied inverter. The use of a "standard" 3-ph AC actuator is not cost-effective due to the high cost of a three-phase inverter - they are not available as standard devices. Single phase inverters, however, require single phase AC motors, i.e. "universal motors" equipped with starting capacitors whose problem is the starting torque.

The variable-speed motor can convert a single-phase feed voltage into a variable three phase voltage for the motor - within the output limits set by the manufacturer - and therefore provide this special function without any additional efforts or performance losses.

With a frequency converter, the motor no longer has to start from slip = 1 (output speed = 0) up to the nominal slip with a high starting current: a new frequency is defined every second and the motor is continuously operated at the current nominal position. In other words: the starting current is less than or equal to the nominal current.

When using several actuators at one terminal block, the control cabinet volume and the cable cross sections can be considerably reduced.

For the inverter it does not matter in which sequence the phases are connected (the voltage is rectified anyway)- thus an automatic phase correction is always present. The direction of rotation of the motor is exclusively determined by the specification in the inverter.

For low frequencies, the voltage amplitude enables fine adjustment of the motor torque. Since sufficient voltage reserve for low frequencies exist, the starting torque can be selected so that starting is possible even if the valve is warped.

Apart from the continuous measurement of the motor temperature via sensors, the frequency converter also controls the motor current (measured within the DC voltage link). The "burned motor" phenomenon has become obsolete.

The option of freely setting the output speeds and tripping torques within wide limits, or of inverting the direction of rotation considerably, facilitates planning and process optimisation during operation of the plant.

The motor versions and the actuator types and sizes used within a power plant/industrial plant are heavily reduced due to the programming possibilities of the VSD actuators. The reduction gearings which would otherwise be used and different motors for different output speeds are no longer required. This leads to a considerable decrease of the number of spare parts on stock. ■