

## MOTION SOLUTION FOR ELECTRIC EXPANSION VALVES

### Stepper motors deliver performance for Electric Expansion Valves

Expansion valves are flow-restricting devices present in any refrigeration system. The valve needle remains open during steady-state of operation. The size of the opening, or position of the needle, is related to the pressure and temperature of the evaporator. When set and controlled properly, an expansion valve will keep the evaporator active throughout its operation.

There are different types of expansion valve technologies popular in the market place, such as:

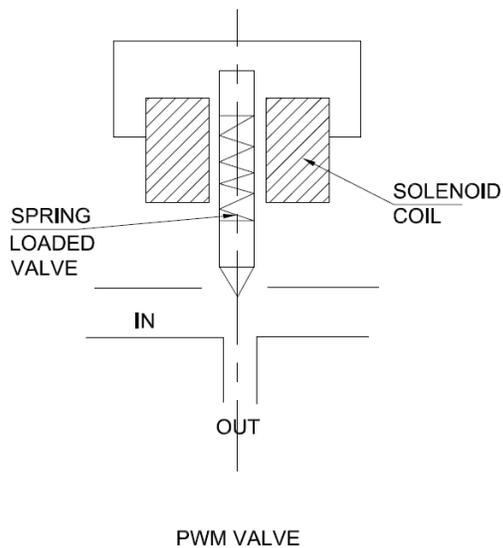
- Non-motorized solution using temperature sensing bulb
  
- Motorized solution using:
  - Simple solenoid driven in Pulse Width Modulation (PWM)
  - Motor and lead screw combination, with motor being a stepper in most cases

### ***Pulse width modulated expansion valves (PWM)***

Pulse width modulated expansion valves use a simple solenoid valve circuit to control the refrigerant flow. These valves can open or close completely for a set period of time, upon receiving a signal from the controller. As an example, a PWM expansion valve remains open for first five seconds and then shuts down for next five seconds to achieve 50% flow within ten seconds.

Such valves are used in multi-circuit evaporators due to their ability to adapt to changing loads, moving from a fully closed to a fully open position and vice versa, in a span of a few milliseconds.

A major drawback of pulse width modulation valves is power consumption. Though such a valve pulses only when changes are required, it uses up solenoid holding power for the entire open portion of the cycle. They may also create excessive pulsation during start-up if used in single circuit, low-tonnage systems.

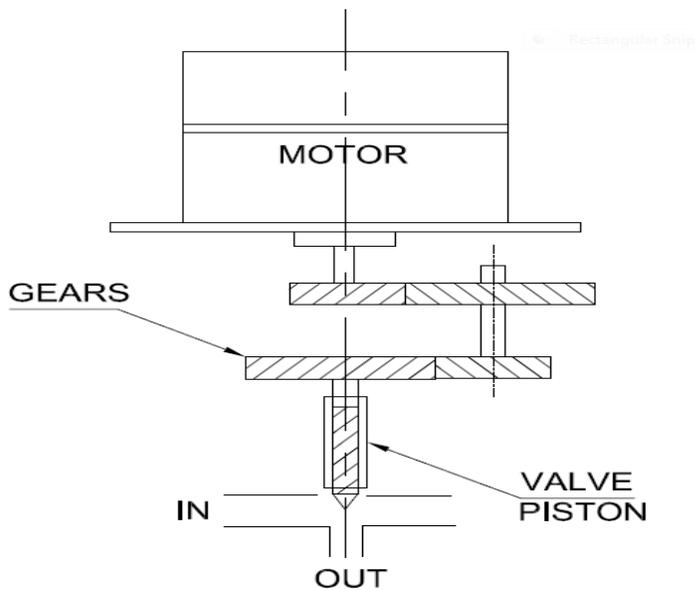


### ***Stepper motor driven expansion valves***

As opposed to PMDC motors that rotate as long as power is supplied, a stepper motor rotates in discrete steps using magnetic fields to move in fixed increments. Depending on the step size of the motor and the step pattern of the controller, stepper motors can achieve extremely accurate positioning.

### ***Selecting the right stepper motor***

A conventional stepper motor provides rotational movement in small steps, which can be used in several industrial and medical applications. However, in case of electronic expansion valves, not only is linear motion needed, but also a significant linear force is required to close the valve port against high system pressure.



STEPPER MOTOR BASED EEV

Several factors affect the choice of a stepper motor for valve applications, such as

- Output Torque/ Force
- Speed
- Step Resolution
- Drive system

### **Output Torque/ Force**

The output torque or force from a stepper motor is a function of motor size, duty cycle, motor winding, and the type of driver used. In a manufacturer's data sheet, the pull-in and pull-out torque are specified as functions of the stepping rate for various types of motor and driver combinations.

The pull-in torque curve shows the maximum load torque that a motor can start with, at different stepping rates, without losing any steps. The pull-out curve shows the total available torque when a motor runs at constant speed at a given stepping rate.

Understanding the exact force requirement can be a challenge, as the valve operates against significant back-pressure and under varying load conditions. Many designers prefer to keep at least a 50% safety factor above application torque at any given speed.

## Motor Selection Example

Any rotary stepper motor datasheet has Pull-out and Pull-In Torque vs speed curves. Depending on the loading pattern in the application, we need to choose either of the torques for calculation. If the motor has to accelerate and is loaded from start, the Pull-In torque has to be considered, which is typically the case for expansion valves.

The following example can be considered to select a motor for a given valve force and speed.

### Example:

- **Minimum Force to be achieved by the valve:** 150 N
- **Actuation linear speed required:** 0.4 mm/sec
- **Linear resolution of the valve:** 0.002 mm/step
- **Voltage:** 12 VDC

Since the valve needs a fine linear resolution, a motor with large number of steps per revolution is an ideal selection. Portescap offers 42 mm motors with 100 steps/revolution which is suitable for most of the expansion valve applications.

Assume a gearing system with reduction ratio of 12.25: 1 is used with the motor to improve the available torque for linear actuation. A suitable lead screw is selected for linear actuation which can safely operate at higher force and provide better transmission efficiency and desired linear resolution. The lead of the screw in this case will be 2.45 mm.

The datasheet provides the torque vs speed curves. To determine the operating point of the motor, we need to calculate the PPS (input frequency) needed to achieve the desired linear speed.

**Number of steps per revolution of motor** = 100  
**Gear reduction ratio** = 12.25  
**Linear speed of valve (mm/s)** = 0.4  
**Lead of Screw (mm)** = 2.45

$$\text{PPS (full steps/sec) of motor} = \frac{100 * 12.25 * 0.4}{2.45} = 200$$

From the datasheet of Portescap 42M100D2B motor, the available Pull-In torque is 0.024 N-m  
Assume the transmission efficiency of gears is 90% and that of Lead screw is 50%.

**Torque available at Lead screw** =  $0.024 * 12.25 * 0.9 = 0.265 \text{ N-m}$

$$\text{Output force of the Valve (N)} = \frac{0.265 * 2\pi * 0.5}{2.45 * 10^{-3}} = 340$$

From the above example, we can see that the motor has a minimum safety factor of 3, to achieve the desired force at the desired speed.

Most low capacity residential systems can use direct drive linear actuators which comprises a can stack stepper motor with a threaded rotor and an integrated lead screw, which provides direct linear motion in a smaller package. But higher tonnage systems having large force requirements may need an additional specially designed gearing system.

### ***Step resolution***

To precisely control the refrigerant flow during the dynamic load conditions, the stepper motor in the valve is designed to provide linear motion to the valve needle in smaller steps.

The resolution of a stepper motor system is affected by several factors—

- The stepper motor full-step length, i.e. step angle of the motor
- The selected driver mode (full-stepping, half-stepping, or micro stepping)
- The gear reduction ratio
- Lead screw pitch

Thus, there are several different combinations which can be used to get the desired resolution. Stepper motor valves can have hundreds of steps, thus enabling an extremely precise control of refrigerant flow and smooth adaptation. These valves are comparatively more effective than pulse width modulation valves due to their ability to respond accurately to changing load conditions.

### ***Drive system***

There are three commonly used excitation modes for step motors; full stepping, half stepping and micro-stepping.

### ***Full stepping***

In a full step operation, the motor moves through its basic step angle, for example a stepper motor having 7.5 degree step angle would take 48 steps per motor revolution.

## ***Half stepping***

Half step excitation resulting in steps that are half the basic step angle. Due to the smaller step movement, this mode provides twice the resolution and smoother operation. In order to have a smooth motion and a holding torque constant regardless of position, it's important to drive the motor in current source at constant power dissipated by the Joule effect. If the current is X Amp in position One Phase ON, then current in each phase should be  $X/\sqrt{2}$  in position Two Phase ON.

## ***Micro stepping***

For applications that require smoother resolution at lower speeds, the full step operation may not provide the required resolution; this is where the micro-stepping controller is used.

The micro-stepping controller is a driver that sends pulses to the motor in an ideal waveform for smooth rotation. The idea is for the driver to send current in the form of sinewaves. Two sinewaves that are 90 degrees out of phase is the perfect driver for a smooth motor. If two step coils can be made to follow these sinewaves, it results in a perfectly quiet, smooth motor with no detectable "stepping".

Most of the today's electric expansion valves use extremely fine micro stepping to solve noise and resonance problems, and to increase step accuracy and resolution. Looking at the criticality of the system, the drivers are integrated into a sophisticated controller which accepts inputs from temperature and pressure sensors located at the upstream of the evaporator to maintain optimum system balance.

## ***Conclusion***

The primary reasons for using an electronic expansion valve is to improve system efficiency by minimizing superheat (SH), and to respond more quickly to changing capacity requirements. Though both valve technologies are capable of meeting these requirements, stepper motor valves, if designed correctly, can be more effective at low load conditions by holding steady at just a few percent of capacity. A stepper motor design provides some unique advantages such as lower running cost, simplified design and ability to respond quickly to changing load conditions, thus making them the first choice for system designers.

## ***Portescap Capabilities***

Portescap provides geared can stack and direct-drive linear actuator solutions with a custom sub-assembly capability that allows for streamlined integration into the valve body, yielding precision flow control of refrigerants.

Our vast experience with custom valve solutions and our understanding of refrigerant control lets us provide you with cost-effective innovative systems that are environmentally protective and space-efficient.

## **Benefits**

- Cost effective – compact design, low integration cost
- Maintenance free – no brush wear
- Can stack linear technology – optimizes application space
- Multiple lead screw pitch options
- Mechanical component reduction
- Technical expertise providing multiple solutions

## **Customization Options**

- Coil optimizations – adjust resistance and inductance for a specific voltage
- Special cables – lead length, insulation, connectors, shrink tubing
- Lead screw lengths
- Custom shafts – flats, knurling, length
- Geared options to increase linear force
- Special mounting flanges
- Magnets – to yield higher torque or reduced detent torque level

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