

Comparing traditional and integrated rod-style linear actuators: How to choose the best solution for motion control applications

By Aaron Dietrich, Product Manager
Tolomatic, Inc.

About the Author:



Aaron Dietrich is product manager for Tolomatic's electric product line. He has an extensive background in the motion control industry and has several years of experience working specifically in the drive and controls area as a design and application sales engineer. Aaron has a B.S. in electrical engineering from the University of North Dakota.

Tolomatic is a leading supplier of linear actuators, both electric and pneumatically driven. Tolomatic's expertise includes linear actuators, servo-driven high-thrust actuators, servo and stepper motors, drives, and configured linear systems. Standard products are built to order and shipped in five days or less. Tolomatic also manufactures right-angle gear drives, caliper disc brakes, and clutches.

Introduction

Moving a mass in linear motion can be done using a variety of linear actuator devices employing both rod and rodless technologies. For rod-style actuation requiring lower amounts of force requirements (< 1,000 lb.s), there have traditionally been two possible solutions: pneumatic actuators (typically called cylinders) and electric actuators. Recently, a new electric linear motion trend of integrating the control, drive, motor and other components into the actuator is beginning to change this perception and has given birth to a new category of electric rod-style products called integrated actuators.

For many years, pneumatic rod-style cylinders have been widely used because they are cost effective and simple to apply. However, electric rod-style actuators—both integrated (motion controller, drive or amplifier, motor, coupling, motor mount and actuator in a combined package) and traditional—are gaining momentum in the marketplace for their flexibility and “sustainability,” supporting the growing trend towards energy and environmental compatibility. Despite these advantages, electric rod-style actuators have been perceived as a more expensive and complex solution for linear motion applications.

This paper will explore the advantages and disadvantages of rod-style pneumatic cylinders, electric actuators and integrated electric actuators in motion control applications. It will also compare the effectiveness of each technology in reducing purchasing, operating and installation costs, machine footprints, and number of components—all key issues in motion control and automation today.

Traditional motion control solutions

Traditional solutions include pneumatic motion control systems and electric motion control systems. Each includes a variety of separate costs and components in order for the systems to function.

Pneumatic cylinder solutions —

In a pneumatic motion control system, many ancillary components are required, including an air infrastructure that utilizes:

- An air compressor to generate pressure.
- Condensers (dryers) to regulate humidity of the compressed air.
- An infrastructure of air lines (pipe/tubing) for distribution of compressed air throughout a plant facility.
- Drop lines (access points) to route compressed air from the plant air line infrastructure to the individual point-of-work locations.

Low unit level price points are a major advantage of pneumatic rod-style cylinders and have been a significant barrier to implementing advanced electric technologies.

Each of these access points typically requires an FRL (Filter–Regulator–Lubricator) to filter the air, regulate the air pressure, and lubricate the actuators at the point of work to help prolong actuator performance. An FRL may supply a single pneumatic cylinder or a bank of multiple pneumatic cylinders. Each pneumatic cylinder also requires a solenoid-operated air valve (typically two-position or three-position depending on application) and connecting air lines to the pneumatic cylinder. A logic device (with wiring) to operate the solenoid is also required. The solenoid-operated air valve has different flow paths, depending on the position selected, that directs the compressed air flow to a rod-style pneumatic cylinder, enabling it to extend or retract.

For good reason, pneumatic cylinders have a long history of being popular workhorses in the automation industry. Their simple design makes them a low-cost choice in the rod-style actuator category. Low unit-level price points are a major advantage and have been a significant barrier to implementing advanced electric technologies. Pneumatic cylinders are also easily operated via simple digital I/O signals, that do not require in-depth knowledge of motion control components for their operation. Some pneumatic systems have incorporated distributed solenoid banks that can receive signals over network communications such as Ethernet. Other advantages of pneumatic cylinders include good service life, as units can be rebuilt easily and economically. In addition, there are industry standards for cylinder sizes, mounting, and interface detail that make them easily interchangeable.

Current trends involving sustainable manufacturing—the building of infrastructure and manufacturing processes that are friendly to the environment—have caused users to

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look closer at the poor energy inefficiencies of pneumatic systems. Pneumatic systems, compared to their electric counterparts, are neither environmentally friendly or energy efficient due to the energy losses during the compression process as well as during use. The pneumatic infrastructure these systems need to operate, as described above, also contributes to energy losses as the compressed air is distributed. A key disadvantage of all pneumatic infrastructures is air leakage and the lost energy it represents. Always present, even little leaks can add up to significantly increase the cost of operation, resulting in decreased manufacturing efficiency.

For example, cumulative leaks, which may emanate from a number of sources in the system (e.g., fittings, cylinders, valves, etc.), add up. If this cumulative leakage were to reach a level equivalent to a ¼-inch hole, and the system is operated at \$0.04 per kW-h, it would cost \$6,600 per year in wasted energy in a 24/7 manufacturing environment. This dollar amount can multiply rapidly for very large manufacturing operations.

Besides air leakage, it is widely known and accepted that compressed air systems operate at about 10% efficiency vs. their electric counterparts, which operate at 50–70% total system efficiency. Equating this to energy consumption, a pneumatic cylinder uses much more energy (electricity) vs. an electric actuator each year to operate. Also, the higher the duty cycle of the application, the wider the gap between electric and pneumatic solutions becomes.

Calculating the cost of an air leak.

Cost of leak = (CFM) x (Minutes / year) x
(Electricity to compress air) x (Electricity cost)
where:
CFM* (Cubic Feet per Minute) \approx (Area of hole)
x (PSI) x (12 in/ft)²
where:
Area of hole = $\pi \times \text{radius}^2$

*Due to variances in air pressure, temperature, and humidity, this calculation is an approximation.

Constants, assumptions:

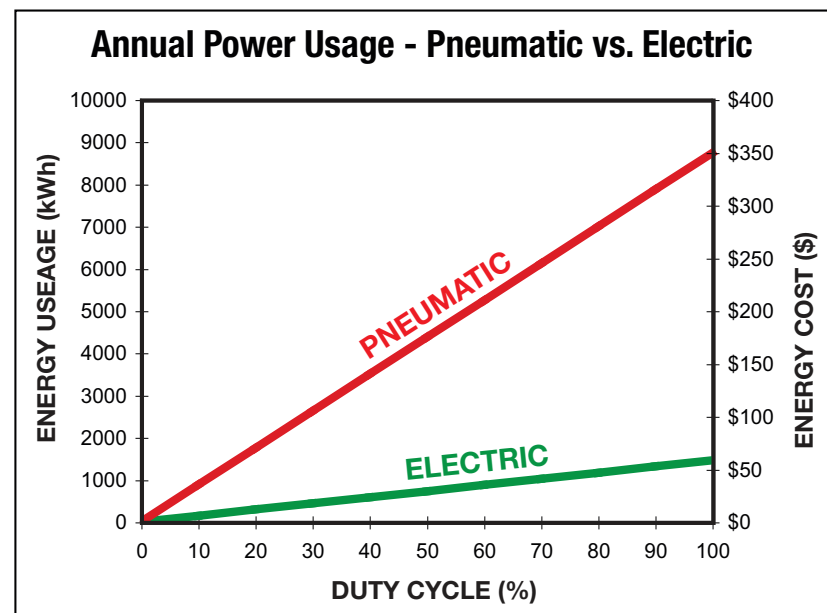
Electricity to compress air: 3–4 kW-hr / 1000 ft³
Electricity cost: \$0.03 to \$0.09 / kW-hr
Minutes / year = 525,600
PSI = 80 lbs / in²

Calculating the power costs of an application:

Cost of application = (Power-In) x (Hours / year)
x (Electricity cost)
where:
Power-In (kW) = Power-Out (kW) / efficiency (%)
where:
Power-Out (kW) = Velocity (meters/sec) x Force
(Newtons) / 1,000 (convert to kN)

Constants & assumptions:

Pneumatic efficiency = 10%
Electric efficiency = 60%
Application = 0.100kW Power-Out
Hours per year = 24x365



Since most electricity is still produced by burning fossil fuels (primarily coal), efficiency has a direct correlation to the amount of CO₂ emissions from a manufacturing operation. Given the context of recent international agreements (such as the Kyoto protocol), the reduction of CO₂ emissions has become a priority of public policy. Reducing the energy consumption in a manufacturing plant, supports the drive toward global reductions in CO₂ emissions and will ultimately improve the environment for all of us.

Applications that require precise position control, velocity control, or multiple positioning, tend to favor electric actuators.

Another major disadvantage of the pneumatic cylinder is its limited flexibility in performance and capability. For example, it is very difficult to regulate velocity, do mid-stroke positioning, or program multiple positions with a pneumatic cylinder. The complexity of the pneumatic system would need to increase exponentially to meet all these challenges. For this reason, applications that require precise position control, velocity control, or multiple positioning, tend to favor electric actuators. In addition, pneumatic cylinders are noisy due to the compression and release of air on each stroke.

Electric solutions typically operate with in the 50-70% total system efficiency, cost less to operate than pneumatic systems, and are more environmentally friendly.

Traditional electric actuator solutions —

In a traditional electric actuator solution, the actuator also requires many components to operate but does not require as complex an infrastructure as do systems with pneumatic cylinders. While the power source is simply line voltage, the traditional electric actuator solution requires many other components: digital drive, motor, coupler, motor mount, actuator, cables, and an enclosure or electrical cabinet. Some electric actuator solutions may also require a motion controller or PLC in the system.

The major disadvantage of a traditional electric actuator solution (actuator, motor mount, coupler, motor and drive) is that it requires a higher initial investment. However, the total lifetime cost of an electric solution can be less than a pneumatic actuator solution.

Traditional electric actuators have been around for many years and are becoming more popular as the automation industry looks for more precise and complex motion with more efficient components. Electric actuator solutions are typically fully programmable and provide maximum application flexibility. With this flexibility comes the ability to tightly coordinate the motion of multiple actuators for more complex applications. As stated earlier, electric solutions typically operate with in the 50–70% total system efficiency, cost less to operate than pneumatic systems, and are more “green” or environmentally friendly.

The major disadvantage of a traditional electric actuator solution (actuator, motor mount, coupler, motor and drive) is that it requires a higher initial investment. The purchase price of the necessary components can be from three to 10 times more than a pneumatic axis of motion (cylinder, solenoid/valve, and air lines), and at least two times more than an integrated electric actuator solution (actuator, power supply). However, the total lifetime cost of an electric solution can be less than a pneumatic actuator solution. In addition, there are assembly and installation costs. Installing a traditional

electric actuator solution also requires cabling and/or wiring to and from the drive(s) in the cabinetry, increasing the overall cost and system footprint. Pneumatic and integrated electric actuator solutions typically do not require this additional cabinet space.

Integrated electric actuator solutions

An integrated electric actuator typically includes the motion controller, drive or amplifier, motor, coupling, motor mount, and actuator in a compact package.

Before the introduction of integrated electric actuator solutions, engineers looking for more functionality than a pneumatic cylinder could provide had one choice: a traditional electric actuator solution. An integrated electric actuator typically includes the motion controller, drive or amplifier, motor, coupling, motor mount and actuator in a compact package. As such, it provides an all-in-one solution with reduced costs and more efficient operation.

Integrated electric actuators are typically less expensive than a traditional electric solution which reduces the cost objections associated with switching from pneumatic to electric technology.

An integrated electric actuator combines the advantages of both pneumatic (simplicity, low cost) and traditional electric actuator solutions (flexibility, energy efficiency). Integrated electric actuators are typically less expensive than a traditional electric solution, which reduces the cost objections associated with switching from pneumatic to electric technology. Integrated actuator solutions typically operate in a stand-alone mode with the addition of a 24–48 VDC power supply. Most motion control systems already have this voltage range available for other logic devices such as sensors, switches, and digital I/O. Depending on the configuration of the integrated actuator and how it is used, the cabling requirements are limited to the power supply, discrete I/O lines, or communications. This significantly reduces the assembly costs associated with running cable throughout the equipment and wire-ways in the cabinet.

While integrated actuators are suitable for a wide range of high duty-cycle industrial applications, they do however have performance limitations with respect to speed and force.

Although integrated actuators are less complicated than the infrastructure needed for traditional electric actuator solutions, a disadvantage of integrated actuators is their dependence on a separate power supply for operation. If existing power supplies do not meet the necessary power requirements, they must be upgraded or additional power supplies must be added to the system. While integrated actuators are suitable for a wide range of high duty-cycle industrial applications, they do, however, have performance limitations with respect to speed and force. This is due to the compact nature of the all-in-one package. The integrated power components contained within the actuator (motor, drive, controller) all produce heat, which limits the maximum speed and force capabilities of the actuator. For higher force and speed applications, traditional electric actuator and pneumatic cylinder solutions will still be required. Today's integrated electric actuator solutions will be suitable for a wide range of low- to mid-force industrial motion control applications that require flexibility, efficiency and a compact footprint.

The integrated electric solution vs. traditional electric solution will save the user purchase costs, installation and assembly costs, and reduce the overall footprint of the machine.

Conclusions

Pneumatic cylinders, traditional electric actuators systems and integrated electric actuator solutions all have their place in today's industrial market. Pneumatic cylinders will continue to be widely used as a result of low component costs and the availability of compressed air in existing facilities. Many engineers are beginning to evaluate the overall inefficiencies and costs of pneumatic systems and have begun the move toward deploying electric motion solutions—including integrated actuators.

The market for traditional electric actuator solutions will continue to grow as motion control applications become more complex and the conversion from air to electric accelerates. The integrated actuator is a newer actuator category that can deliver significant advantages over both pneumatic and traditional electric actuator solutions. The integrated electric solution vs. pneumatic systems will save customers energy and move them closer to sustainable manufacturing. Integrated electric solutions vs. traditional electric solutions will save the user purchase, installation, and assembly costs, while reducing the overall footprint of the machine.

About Tolomatic and the SmartActuator series

Tolomatic has been designing and manufacturing innovative electric linear actuators, pneumatic actuators, and power transmission products for factory automation for over 50 years. Its new SmartActuator series of compact, all-in-one linear actuators (servomotor, drive, controller and actuator integrated into a single unit) is designed to simplify motion control for industrial applications. At half the price of other integrated or traditional full servo linear actuator devices, the SmartActuator series provides 100 percent duty cycle motion control for low- to medium-force industrial applications up to 800 pounds. Available in in-line or reverse-parallel motor/drive configurations, the SmartActuator series devices can be used as a direct replacement for pneumatic and hydraulic cylinders in a wide variety of packaging, material handling, machine tooling and general industrial automation applications. For more information on Tolomatic's SmartActuator series products, including the rod-style ICR Basic and Plus models, visit: www.tolomatic.com or call Tolomatic toll free at 800-328-2174 or 763-478-8000.