The Power of Air

How pneumatics, a 360-year-old technology, is accelerating growth in large-scale solar
Many industries from manufacturing to transportation and healthcare depend on the ability to convert power into productive use. Three technologies are commonly used: electrical power, hydraulics and pneumatics. This paper will explain why pneumatics, used extensively since the 19th century, has become a multi-billion-dollar industry itself and a disruptive force that can be readily applied to new technologies, like single-axis trackers for large-scale solar energy systems.

Pneumatic systems have several advantages when compared with electrical power and hydraulics. Both in terms of installation and operation, pneumatic systems enjoy the benefits of simple design. Pneumatic actuators provide a quick path to motion and they provide significant force in a small space, as noted by industry expert Chip McDaniel in the August 2017 edition of Industrial Equipment News. Powered by compressed air, pneumatics has an unlimited supply that can be pulled straight from the atmosphere, easily stored, and released back into the atmosphere when the work is done.

Pneumatics also delivers a unique combination of power, reliability, durability and size. Though compressed air can begin to transmit power at low force, pneumatic systems can also generate an exceptionally high force. For example, the Firestone Airstroke actuator, used in gas pumping systems, corn planters and other use cases, can reach a force of 100,000 lbs. Speed is subject to few limitations. Pneumatic systems can easily regulate air pressure and volume. Reliability of pneumatics systems is excellent. Systems operate safely in wet or corrosive environments. Maintenance costs are low. And because the market is mature, many core products have been available for a long time and from numerous vendors.

### Power Systems Comparison

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⭐ Best Option  ⚫ Better Option  ┇ Good Option
What Pneumatic Systems Do

Pneumatics works on the principle that pressure equals force divided by area. When you compress air, you reduce volume and increase pressure. Many pneumatics systems use an air compressor to pull air from the atmosphere, store it in a high-pressure tank called a receiver, and maintain pressure systemwide. Through a network of pipes, tubes and valves, the system supplies compressed air to an actuator that uses compressed air to generate force and cause a machine to move.

Pneumatic systems have three essential functions. They supply compressed air, distribute air and consume air to perform an action. Systems can perform many types of actions: activating the brakes to slow down a truck or a high-speed train, lifting or tilting heavy objects in an industrial manufacturing or processing plant, and repositioning an array of hundreds or thousands of solar modules to generate energy at a low cost.

The supply system has several functions. It filters air. Systems can condition air, regulating moisture, temperature and contaminants, at three different stages: at intake, in storage, and through inline filters. It converts mechanical energy from a motor to potential energy in the form of compressed air. It regulates air flow. The high-pressure tank that stores compressed air, known as a receiver, plays an important role here. The tank must be large enough to hold all the air from the compressor, and air pressure in the tank must exceed air pressure in the rest of the system. If part of the system experiences air loss, the receiver can increase flow to maintain pressure in the system. And it monitors and regulates air pressure using control valves.

The distribution system delivers compressed air from the supply system to a group of pneumatic actuators that are used to bring machines to life. In the Sunfolding system, air tubing connects the supply system to a group of controllers that can keep hundreds of actuators moving in concert and maintain precision. Additional tubing connects the controller to the actuators in series.

The end point of the system converts potential energy from compressed air into motion. Several types of actuators can be used to animate different types of machines. Sunfolding’s unique air actuator consists of flexible bladders sandwiched between two metal end plates with a bladder to the east and one to the west. When the bladders are pressurized to different levels, one side expands, tilting the solar module structure above to the opposite direction. The control of the air pressure in the bladder works to track the structure towards the sun.

Imagine a seesaw in which each side has an air spring underneath. The higher-pressure spring pushes up on the seesaw, tilting the structure in the opposite direction. If the pressure is exactly the same on both sides, the structure is balanced, facing up to the sky.
Durability, longevity and little need for maintenance are chief advantages of air actuators. They can complete 6 million cycles before replacement. A long cycle life helps these actuators withstand the rigors of many industrial applications. They also work in conveyors as gates or stops, in paper mills to provide calendar tension, in lift tables for manufacturing and material handling, and in transportation to lift truck axles and apply tension to rubber tracks on construction and agriculture vehicles. Sunfolding projects have an expected system life of 35 years. At one cycle per day, the actuator will complete 12,775 cycles overall.

**Becoming a $5 Billion Industry**

Pioneering work in the history of pneumatics began in the 17th Century with the invention of the air pump. The inventor Otto von Guericke demonstrated how air pressure can exert extraordinary force by placing two copper bowls together to form a hollow sphere, removing the air inside and demonstrating to the Holy Roman Emperor Ferdinand III that two teams of horses, with 15 horses on either side, could not pull the bowls apart.

Compressed air became a “distinct and accepted branch of engineering” at the start of the 19th Century, but development was “slow and spasmodic,” according to the 1919 edition of The Americana: A Universal Reference Library, Comprising the Arts and Sciences, Literature, History, Biography, Geography, Commerce, Etc., of the World. The methods used to compress air started to develop in the 1820s and achieved successful application in the 1860s and ‘70s, improving the tunneling process, first in Western Europe and then in the US. The pneumatic drill debuted at the US project, the Hoosac Tunnel, paving the way for a wide variety of air-powered tools: hammers, presses, lifts, conveyors, holds for jigs, fixtures, and much more.

US shipments of pneumatic products was a $5.3 billion business in 2018.
Air actuators take the weight
Supports loads up to 100,000 pounds

Easily surpasses 1 million cycles
More than 100 times better than electric actuators

Tolerates harsh weather
Handles high heat, extreme cold and moisture

Operates through power losses
Operates solar trackers without battery backup, unlike electric actuators

Runs continuously
Runs without the risk of overheating

Another application for pneumatic systems that has stood the test of time is pneumatic tubes, used to propel cylindrical capsules within buildings and across large areas. Starting in the mid-19th Century, major European cities including Paris, Prague, Vienna and Berlin built extensive postal systems to transport mail through pneumatic tubes. The US Postal Service also used pneumatic tubes to help distribute mail. A pioneer in the US was John Wannamaker, who used pneumatics to transport cash and documents in his department stores, Wannamaker's, then expanded use of the technology after President Benjamin Harrison named him US Postmaster General. Today, world-class hospitals use pneumatic tubes to transport blood, medicine, and tissue specimens across vast networks of chutes. Stanford Hospital sends 7,000 samples through its four miles of pipes every day.

US shipments of pneumatic products was a $5.3 billion business in 2018, according to the National Fluid Power Association. The leading uses for pneumatics are in the production of cars and trucks, semiconductors and medical equipment and food processing.

Using air-driven actuators, manufacturers and other businesses that convert power for productive use can enhance capabilities through various means. They can support loads of up to 100,000 pounds. They can take advantage of design flexibility with range of motion, a compact starting height to fit actuators into small spaces, and the ability to reach a high maximum height. Air actuators are practically maintenance free, with no lubrication needed.
Because air actuators double as springs that isolate vibrations in vehicle suspension systems, and they have gone through millions of miles on roads, manufacturers can point to a deep supply of reliability data. The results show a clear-cut difference when choosing between pneumatics and electricity as a power source. Many pneumatic systems can generally accommodate outdoor temperatures and environmental conditions by design. Those that use electricity can encounter problems from high heat, extreme cold, or moisture. Electric actuators need fail-safe options, such as battery backup, in the event of a loss of power. Pneumatic systems can continue operating through loss of power. With a reservoir for air storage and valves that can limit air flow to any part of the system that has a drop in air pressure, pneumatic systems can also operate through loss of air. Pneumatic systems can achieve higher utilization rates, running continuously without rest. Electric systems that run continuously face risk of overheating. Lastly, the cycle life of a pneumatic actuator exceeds the cycle life of an electric actuator by roughly two orders of magnitude. While an electric actuator might complete 10,000 cycles, a pneumatic actuator can easily surpass 1 million cycles. The cycle life of some pneumatic actuators continues up to 6 million cycles.

Recent improvements in manufacturing processes and advanced materials have made air-driven actuators more durable and reliable than ever before. Sunfolding’s air actuator is made from polymers selected in cooperation with Dupont that have proven successful in marine tethers, cushioning used in railroad transportation, and protective material in the auto industry used for the joints that connect vehicle transmission to the wheels. The tubing and connectors that link controllers and actuators come from the air brakes and fuel lines used in commercial motor vehicles, both subject to auto industry standards. Using more durable, long-lasting materials that do not need replacement during the service life of the system can make pneumatic actuators more cost competitive than ever.

The benefit of taking materials and processes that serve the $5 billion pneumatics industry and applying them to large-scale solar are twofold. First, there is no question about the strength of the supply chain. Components have stood up to the rigors of product testing in the lab and the field. Suppliers have achieved manufacturing at scale and shipped more product than any one consumer segment could ever need. Second, the durability and reliability of the product right off the shelf vastly exceeds the requirements of a device that has to slowly reposition rows of solar trackers during daytime hours. Remember, in industrial applications, pneumatic systems are often called upon to operate nonstop. Large-scale solar projects need actuators in motion for less than 12 hours a day. While other businesses might

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need to manage a load capacity as high as 100,000 lbs., solar modules weigh about 50 lbs each. The load capacity in solar is lower than in other industries. As a result, solar trackers require relatively little force relative to a pneumatic actuator’s capabilities. Lastly, the sun journeys across the sky only once per day, and that’s how often Sunfolding trackers need to cycle. The risk of wearing out pneumatic actuators in a solar project is exceptionally low.

When the founders of Sunfolding set out to design a machine specifically for solar, pneumatic power checked all the boxes. It reduced parts count. Instead of using complex machinery with a huge amount of steel, one unit, the AirDrive X, controls all movement. It reduced costs by being faster to install and easier to operate. If you’re going to use big, heavy motors, you want them turning as many solar modules as possible to keep capital expenses in check. With air-driven actuators instead of motors, you can shorten tracker rows. You can also install solar on complex parcels of land without driving up costs. Lastly, with pneumatic power you can reduce maintenance, as discussed in the operations and maintenance section below.

Installation of the pneumatic system is simple. The Air Actuators Reduce Complexity

AirDrive X™ actuators in the Sunfolding system weigh less than 50 lbs. Two people can lift them and attach them to posts anchored in the ground. The automotive-grade pneumatic harnesses connect quickly and easily with the supply air system. Construction crews unspool the harness and then seat the male and female connectors. There is one supply air system per 5 MW and they come as pre-assembled plug-and-play units that get dropped in place near the inverter. With fewer components, fewer trips to the equipment staging area are needed. You minimize room for error in the field and make it easy to save a lot of time.

Operations and maintenance is also simpler because of the air-power system. Instead of dealing with hundreds of moving parts that are found in electrical power systems, the pneumatic system has far fewer critical points of failure and reduces maintenance locations by up to 95 percent. Pneumatic systems are fundamentally resilient. They help project operators sense the field, using air pressure monitoring to
pinpoint a loss of air. If minimal air loss occurs, the project can continue to operate while a service team performs conditional O&M, monitoring pressure, figuring out what has occurred, and conducting site visits as needed. Though pneumatic system components should operate reliably throughout a project’s service lifetime, a robust vendor ecosystem can assure project owners that spare parts will be accessible far into the future should the need for replacement ever arise.

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A Bridge to the Future of Industry

Though the basic principles of pneumatics have been known for centuries, opportunities to transform industry using the power of compressed air have only recently arrived. The AirDrive X actuator uses advanced polymers supplied by DuPont, one of the largest chemical companies in the world, bringing reliable performance to solar projects as they experience long-term exposure to wind, heat, rain, and snow. Sunfolding also partners with leading auto industry component suppliers to manufacture AirDrive X, delivering the technical ability to achieve production at a global scale and manage quality to the highest standards.

Advances in pneumatics, together with developing capabilities in robotics, smart sensors, and Internet of Things, are helping set the stage for intelligent manufacturing in the context of the Fourth Industrial Revolution, or Industry 4.0. Today, factories use custom-built machines with a huge number and variety of components needed to perform one industrial process at a time. Pneumatic systems and actuators can simplify industrial machines in the same way that Sunfolding has streamlined process in large-scale solar, replacing motors, gearboxes, and many other mechanical parts with a single actuator unit. The future is simple, and it will be powered by air.

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