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Servo, stepper or variable frequency drive: Upgrades to packagers and cartoners

Smaller workforce pushed upgrades to do more with less

By Rick Rice

With the economy starting to show signs of life here in North America, the specter that is COVID-19 is starting to feel like it is loosening its grip on our lives. While life outside of the work environment is re-awakening, life inside the work environment didn't miss a beat. If anything, our ragged group of automation junkies has never been busier.

A more than casual side benefit of working for a company that provides an essential service is that demand for what we produce increased dramatically over the past 16 months. Complicating this greatly has been a large dip in the pool of staff to run the lines and, now, a negative impact in the guise of lack of supplies to make product. All of this makes sense as a global pandemic put the immediate brakes on much of the manufacturing sector and a rapid ramping up as life re-opens has caused a lapse between demand and supply. A nice benefit of this momentary gap is we get a chance to catch our breath before the next onslaught.

It is during this gap that my colleagues and I have had an opportunity to take yet another look at how we are doing our equipment controls upgrades. Gathering around the proverbial napkin, we had a chance to really dive into the impact that fewer resources, aka people, has meant to our team and our prospective output. Purely incidental, while our general workforce has dwindled over the past year, quite a few of our key people have arrived at retirement. With what seems like every single business now trying to hire or rehire people, we are faced with the very real problem of just not being able to pull in skilled people to replace these long-time employees who have finally reached the golden years. Faced with the same expectations as far as new production lines and vintage equipment replacement/rebuilds, we have had to re-evaluate how we go about things from a design standpoint, with the emphasis on re-engineering the solution to use a smaller workforce to get the same or more work done.

From an automation standpoint, we have finally decided to jump in with both feet and embrace distributed I/O on our machines. Now this might seem like a strange admission in 2021, but, for our needs, distributed I/O never really came up in conversations. We are pulling controls off 60-year-old packaging machinery, and, while using modern components, we have just wired them up the same old way.

It suited our needs, and it was familiar to the people who, in some cases, have been operating and maintaining these machines for 40 or more years. As the collective age of our workforce has increased and is now stepping off into post-work life, we have a new generation coming in that isn't tied down by years of doing the same thing.

In the spirit of this new direction, an opportunity came up that made us rethink the driving force of our packaging machinery. Traditionally, our rebuilds of horizontal packagers—pouch makers—and horizontal and vertical cartoners involve simply modernizing the VFD-driven versions of yesteryear. However, we recently took it upon ourselves to rewrite the software for a previously converted horizontal packager that we had an outside company do for us.

That machine used servo drives and broke out the three main machine functions into individual servo axes that cammed up to follow the main cycle shaft. Our rewrite simplified the OEM code and we've had rave reviews from our work mates on the form and function of the newly revised control system.

Following this success, in a meeting called by our ownership group to evaluate how we can get more production with a limited workforce, one of the key observations was the impact that automated pouch placers and collaborative robots to palletize production have had on our bottom line. To paraphrase the commercial for a hot sauce product, it is our intent to put that "stuff" everywhere.

The challenge then is how does one put new machine technology on 60-year-old, or even 30-year-old, machines. Well, in some cases, you really can't.

In a bold proposition, I suggested that I might be able to take one of the kits that were purchased to be a horizontal packager upgrade, with the servo drive previously mentioned, and make it a horizontal cartoner upgrade instead.

We really don't need the sophistication of a servo to drive a horizontal cartoner; we are not splitting off any functions to multiple axes. But the distinct advantage would be that we would use the same control components and either produce a cartoner or a packager as needed. Had we really just come up with a truly modular control design?

Let's take a look at what went into our VFD-driven cartoner design. We would need a variable frequency drive, an inverter duty motor and a means of feedback to trigger operations such as bar code scanning, carton coding or flap gluing.

If we were to use a servo instead of a stand motor with VFD solution, we would still need a drive and motor, but the feedback would automatically be included because a servo is a closed-loop control system.

One of the drawbacks we had with our VFD solution is we also had to add a pseudo-jam detection system to detect carton/product jams so that we didn't suddenly stop and load up the chains moving the product through the machine.

The shock relay we employed was designed to detect load on a chain and comes from the chain manufacturer, but it really wasn't designed to be used as we use it. It basically provides a means of setting a maximum current draw over an adjustable duration and use that to drop out a relay that is in series with the VFD output.

The major setback to this attempt at having torque feedback is there is a very fine line between the current required to get the cartoner in motion and the current rise that will happen when the main drive is locked up on a product or component jam.

The challenge is amplified by the gearbox between the motor and the driven device as that multiplies the torque output but does little to the current required to drive the machine. Suffice to say that this hasn't worked as well as we had hoped.

Summing up all this, the cost of a VFD, motor, encoder, shock relay and all associated wiring brings the investment very close to the cost of a servo drive and motor. The servo utilizes feedback and also provides true torque feedback with a means to cut out and alarm on torque overload, which is a much shorter response time than the shock relay of the VFD solution.

All in all, this solution seems so simple that we find it hard to imagine why we didn't pursue it years ago. In our defense, it is human nature to keep doing what you have been successful with, and it is inevitable that we only depart on a new path when the one in

> A smaller pool of people to do the work became the roadblock that sent us off on a new path.

front of us becomes blocked. A smaller pool of people to do the work became the roadblock that sent us off on a new path.

One great sidebar to all this is my team has come up with a way to build the same control system for multiple applications, and that means the code is very similar, as well. Broken down into modules, it takes far less time to put the whole thing together than we previously experienced.

One can't help but wonder what the OEMs of the original equipment would think if they knew that a horizontal packager and a vertical cartoner were practically the same machine from a control standpoint.

We've even made the HMI applications virtually identical since we like to keep the main control buttons—stop/start/reset—physical. Our final benefit is that if we prebuild the main power and control panels, as well as the three on-machine point I/O stations, we can execute a complete controls rebuild in just three weeks. Considering that we have a team of three doing most of this work, this is quite an achievement.

While many are still in the grips of a pandemic, it is important to remember that most technological advancements happened because there was a need. Our need was to do the same things we normally do with a significantly reduced workforce.

All is possible if we just put in the effort to color outside the lines of what we normally do. Wherever you are, I hope you are able to rise above the challenges, and someday soon we can collectively take in a breath of fresh air.

What's driving your decision?

Take a fresh look at VFDs

By Rick Rice, contributing editor

Twenty four years ago, in my native country of Canada, I worked for an original equipment manufacturer (OEM) that made conveyors, palletizers and depalletizers for the food and beverage industry. Having graduated from college in 1988, I was still in the early years of my career, and this was my first job where my primary focus was programming and commissioning packaging equipment

My first project with this OEM was to re-write the software application for a two-car shuttle-car palletizer that unitized bags of dog food. If that wasn't daunting, the president of our company, upon meeting me a week after I was hired, casually mentioned that the last time a rewrite was attempted, it just about broke the company.

My only previous experience authoring a PLC program was on a product once offered by Allen-Bradley called a modular automation controller (MAC). It was basically a printed circuit board with spaces on the circuit board where one could plug in input and output modules.

The project was a conveying line that brought field product in, washed it and conveyed it through various processes with the result being a bottle of pickled onions. To go from this to rewriting the controls algorithm for a major packaging machinery manufacturer was nothing short of terrifying for a young controls engineer.

Perseverance is essential in a controls engineer, and, as you might have guessed, I did manage to rewrite that program, the company did not go broke, and I have made a career out of this fascinating line of work.

The controls in packaging equipment of that vintage came in the form of an Allen-Bradley PLC-5 with 1336 variable frequency drives. For those who may not remember, the PLC-5 was a huge boat anchor of a processor utilizing the 1771 I/O system.

The 1332/3/5/6 drives were equally large by today's standards and were often mounted on the outside of the control cabinet because they generated so much heat that mounting them inside the enclosure would cause issues for the other components in the panel. Commands and status for the variable frequency drive were entirely digital, via terminals on the control board of the VFD.

As one can imagine, being restricted to digital signals to and from the variable frequency drive limited the capabilities of the control system. Hardware providers of the day expanded the capabilities of the VFD by adding analog input to the drive command structure; and, since parameters in the drive had to be entered manually prior to operation, they added terminals to give more options to the control of the drive.

Typical selections via the terminal interface included multiple speed selections by using binary coded input and a second set of accel/decel commands that could be engaged while the drive was in motion.

The flexibility of variable frequency drives was greatly enhanced by the introduction of machine-level network protocols. With the advent of Modbus, Profibus, ControlNet, DeviceNet, SYSMAC and others, the wiring of drives was simplified to just the enable/disable input, and the rest of the control could be accomplished via the network connection.

These early connections basically duplicated the digital interface in a memory block transfer format. PLC programming in those days was memory-based, unlike the tag-based programming of today. A typical drive interface would have four integers, two for input and two for output. The input would be in the form of a status register and feedback register, while the output would be a command register and an output frequency.

Remembering back to my first big programming project, we really did a lot with a system that would be considered archaic by today's standards. Our primary mover on a multiple car palletizer was a shuttle car that moved back and forth to stop in multiple positions underneath a stationary palletizing tower.

All major motions were accomplished by a variable frequency drive and creative use of flags and proximity sensors to tell the control system where the various axes of motion were. To move shuttle car positions, we would ramp up to a running speed, sense the presence of a flag on the shuttle at the desired stop position, ramp down to a slower speed and stop when the stop sensor on the shuttle was triggered by a stop flag at the desired stop position.

This use of a variable frequency drive really hasn't changed all that much in the ensuing years. I was pleased to meet up with my former colleagues, who like to say you can't spend your whole career with the same company, when my current employer bought a shuttle car palletizer from that same company that I worked for so many years ago.

There is an expression: If it isn't broke, don't fix it. That same control approach from 24 years ago, as it turns out, is still a great way to control a shuttle car today.

As many readers know, I like to take a look at where we came from in order to have a better understanding of how the technology of today has evolved. While the first half of this piece seems to suggest that the use of a variable frequency drive hasn't

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changed much in the past 25 years, nothing could be further from the truth.

The transition to machine-level networks was really just the start of the journey. Since then, hardware manufacturers enhanced the PLC to VFD interface by including additional blocks of memory into the data exchange. The advent of tag-based PLCs has opened up the potential interface to seemingly limitless possibilities.

Now one might ask why we need an expanded interface. While the control of the variable frequency drive might seem unchanged for many years, there is much more going on in the background.

A VFD, even in those earlier days of automation, has many parameters that can be manipulated to more finely tune the performance of a drive-motor combination. Motor technology has continued to advance over the years and the driving technology has matched pace with it.

Today's VFD might have 400 or more parameters that can be manipulated. With the ability to access parameters via the machine network, today's VFDs are usually configured using that network interface, using the programming software application itself in many cases.

As with all other sectors of automation, more performance in a smaller package, combined with the constant progress of technology, has moved servo and stepper motors into the forefront of automation projects. One of the primary motivations for moving in the direction of servos was the open-looped nature of VFD and stepper control.

As the control method described earlier suggests, much can be done with just sensors and some control over speed and acceleration, but, without feedback, open-loop control can only do so much. With the presence of the VFD on the machine-level network, the ability to use a linear or rotary encoder to provide positional feedback has added a way to partially close the loop. While not quite the same thing as true closed-loop control, being able to use an encoder instead of digital sensors makes for a more finite way to use a VFD to accurately provide motion control.

In the past couple of years, a new method of control has been introduced for a variable frequency drive. Some manufacturers have closed the gap between a VFD and a servo drive by producing a variable frequency drive that accepts encoder feedback directly into the drive. Now, motion is controlled at the drive level, instead of using the PLC algorithm to approximate closed-loop control.

These drives are less costly than a servo drive solution but are actually controlled using the same commands as a servo. Not to be outdone, some manufacturers of servo drives offer the option to additionally control a VFD from that same servo drive.

The benefit of these latest developments is purely in the hands of the designer and programmer: accurate control of motor-driven components for less money and with a complete tool chest of parameters to clearly define the behavior of the motor application.

Further sweetening the pot, today's VFDs also make use of integrated safety features that provide a safe torque off (STO) function. With STO, the drive is prevented from producing any torque-generating energy.

When this feature—a physically wired, dual-channel connection—is used in conjunction with a safety relay, there is a means by which to guarantee that a motor is disabled when a safety device is tripped.

Finally, with all things related to automation technology, today's VFD is a much smaller package that its ancestor. A 10-hp drive in that older technology would occupy a space that was 10 inches wide by 18 inches tall by 9 inches deep. The equivalent version today would be 5 inches wide by 10 inches high by 8 inches deep. One half the footprint and generating far less temperature during operation means the same control system can be in a much smaller electrical enclosure.

The great part of these advances in technology is the designer doesn't necessarily have to invest in a servo drive to get servo-like behavior. For the maintenance team, the new machine doesn't need someone with servo knowledge to troubleshoot a machine failure. Even if, ultimately, a servo is not needed, the ease with which today's VFD can be commissioned and operational makes it an excellent choice for control of a motor. What's driving your decision?


Learn
more!

Pneumatic vs. hydraulic vs. electric linear

The application will determine how to define the best actuator type and standards

By Anna Townshend, managing editor

A Control Design reader writes: Our production operation is part of a multinational portfolio that includes many manufacturing companies serving a variety of market segments. Yet our parent company's procurement organization is determined to standardize as much equipment as possible. While we primarily use pneumatic actuators for pick-and-place applications, an increasing number of customers are requesting electric linear actuators. And one of our sister companies prefers hydraulics because of the heavy lifting and harsh environments where they operate. How do I emphasize the importance of keeping all three options to procurement? I fear we'll lose key accounts if we're unable to give customers what they want. And how do we decide between pneumatic and electric if the choice is left to us?

ANSWERS

ACTUATOR ADVANTAGES AND DISADVANTAGES

Pneumatic, hydraulic and electric technologies bring their own unique features and benefits when being considered for an application. Questions that need to be asked pertain to what advantages are the most necessary in contrast to the disadvantages that can be tolerated.

Pneumatic systems are by far the least expensive of the three technologies and lightweight in comparison but are severely limited on their load capability and low accuracy due to the fact; compressed air can be very spongy and highly unrepeatable. Greater speeds can be achieved while being environmentally friendly; however, constant feedback can be complicated and cumbersome.

Hydraulic systems boast the largest load capability; they are very repeatable with extremely accurate feedback to boot. A hydraulic system's ability to apply constant force and torque regardless of speed changes is definitely a game changer. The drawbacks really need to be considered since the overall system is extremely expensive, including an array of additional components such as power units, filters, pumps and motors. Also, they are less environmentally friendly with the possibility of oil leaks. They also operate at extremely slow speeds and require complex sizing.

Electric actuators give the highest precision positioning, while reprogramming is quick and easy. They allow for immediate feedback for diagnostics/maintenance while being very quiet in comparison to hydraulics and pneumatics. They are, however, far more expensive than other actuators. Due to their construction, which consists of motors, encoders and sensors, among other more delicate components, electric actuators are less well-suited for hazardous locations. When their internal components fail, the likelihood for repair is relatively low. Their bulky size installation can also be an issue. Pick your battles when choosing which technology to use in your application. Ask yourself what is necessary and what can I live with to get the most out of my actuators.

STEVE HORVATH

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MULTIPLE TECHNOLOGIES ACROSS MULTIPLE APPLICATIONS

Different market segments have different needs and potentially standards or regulations. If addressing diverse market segments is the company strategy, then it is unlikely rigid standardization to one technology is possible. However, identifying a core group of actuators from within these technologies is still achievable.

To be successful, it is critical to listen to customers. By listening to what they want, you as the experts in your business can help them to see what best suits their needs. One technology rarely is the best solution for every application or project.

The point of separation for hydraulic actuators from pneumatic or electric is perhaps the easiest to define. The strength of hydraulics is high force and slower speeds. Typically, large, heavy equipment with exposure to outdoor elements is where hydraulic solutions are best-suited and most common. Neither pneumatic nor electric actuators are practical for these types of applications.

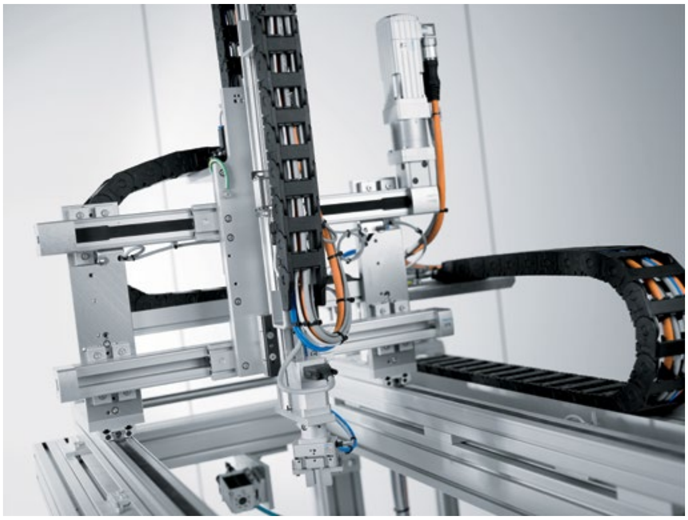

Figure 1: This gantry robot has flexible-motion electric axis and high-force pneumatically powered gripper.

Figure 2: This pick-and-place gantry has flexible motion profile electric slides and pneumatically powered vacuum gripper.

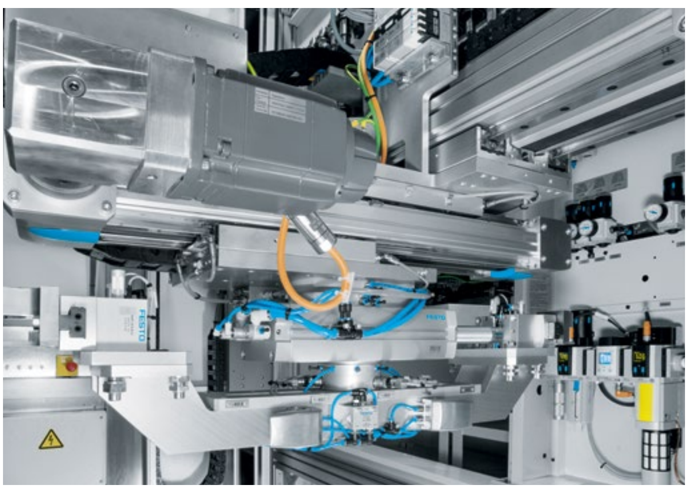

Figure 3: This high-force, easy-setup pneumatic cylinder offers simple, two-position motion.

Figure 4: This electric light assembly features a combination of electrically powered slides featuring precise motion and pneumatically powered vacuum grippers for assured damage-free grip.

The application is the key to answering the question of whether to use pneumatic or electric. There are many situations where the best solution is a combination of both. The first consideration however is infrastructure. Does the facility currently have a compressed air system? Today many facilities do, as compressed air is used for many industrial applications over and above an automated handling system. If not, an electric solution may be a more suitable starting point.

For now, assume both compressed air and electricity are available options. Some key application questions can help to guide your direction.

- Does the function require long strokes/travel at high speed and short cycle time?

	Pneumatic	Electric
Strengths	• easy installation and setup • low maintenance, durable, reliable, robust • high degree of protection especially in harsh environments • high force density, less required space • overload is possible	• flexible motion profile • easy adjustment of the drive system • high stiffness • high dynamic movements • load-dependent use of energy
Weaknesses	• energy losses with leakage • noise emission • drift in vertical position • low stiffness	• relative complex system design • decentralized heat generation • limited overload capability • higher required space

TECHNICAL CONSIDERATIONS

Table 1: Pneumatic and electric actuators have their own strengths and weaknesses to guide your choice for the application.

- Is free and flexible positioning needed (three or more positions)?
- Is smooth motion critical?
- Is the actuator task more than clamping or holding?

If you answer no to all these questions, then a pneumatic actuator is the most suitable starting point (Figures 1-4). If your answer is yes to any or all these questions you should explore electric.

Table 1 explores the strengths and weaknesses of using pneumatic and electric actuators.

Costs are also important factors in the decision process. There are several different cost elements that sum to total cost of ownership and should be considered. They include:

- acquisition costs
- energy costs/efficiency
- installation costs
- implementation efforts costs (time, knowhow)
- maintenance costs.

In the study of many applications, acquisition costs typically favor pneumatics, but total cost of ownership depending on the application can favor electric actuator solutions over the life of the machine. In general, the rule of thumb as it relates to preference for economical/efficiency factors is as follows:

- Long strokes in combination with high cycle counts favor electrical solutions.
- Short strokes and/or long holding durations are perfect for pneumatics.

Many projects require both of these scenarios, so it becomes clearer that a combination of pneumatic and electric actuators is the best solution for many design projects.

DARREN O'DRISCOLL

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THE CASE FOR STANDARDIZING TO ELECTRIC

This is a really great question and a relatively common one for machine builders who are encountering changing customer requirements with regard to technology. Ultimately, the decision should come down to a combination of your machine and customer design requirements. There are advantages to pneumatic (cost/availability), electrical (performance/precision) and hydraulic (capacity/reliability) actuators. When selecting an actuator that meets your design requirements, you must weigh the advantages and disadvantages of both. As a design engineer your analysis will typically focus on specific design requirements such as performance, accuracy, function, environment. I encourage you to consider factors that are relevant to other departments such as procurement. Factors such as cost, availability and maintenance requirements for your customers are all considerations that procurement attempts to take into account when making decisions about where to source components. By presenting your selection in terms that procurement can understand, you can strengthen your argument to select a specific actuator type. I think maintaining flexibility with regard to machine design is extremely beneficial from a design standpoint, and, by considering deciding factors outside your department, you can better make this case to procurement and upper management.

And how do we decide between pneumatic and electric if the choice is left to us?

In general, there are advantages to both. Pneumatic actuators are widely available and are a relatively low-cost solution for linear actuators, but maintenance and operating costs tend to be higher. Electrical actuators on the other hand offer some advantages with regard to precision and control but have a higher cost point. I think there is definitely an argument to be made about standardizing your machine design on a single solution (electrical) that meets your customers' requirements. Doing so eliminates the need for your customer to train individuals who are able to maintain/service pneumatic systems and cuts down on the costs of doing so. The general trend in machine design is that cost for electrical actuators are continuing to go down as volume for manufacturers increases. While pneumatic actuators have a much lower price point from your perspective, total cost of ownership (TCO) for customers—maintenance and upkeep—is one reason why it would be beneficial to standardize. Again, when making a decision regarding actuator type, I recommend preforming a 360º evaluation of actuator types. Consider your requirements and budget at the same time you consider the cost and performance requirements of your customer. This will allow you to make an educated decision when selecting actuator design types.

DAN ZACHACKI

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CONSIDER PRECISION

There are two main reasons to select electric actuators over pneumatic or hydraulic actuators. The first one is precision. Electric actuators generally have better point-of-interest accuracy and repeatability than an equivalent pneumatic or hydraulic actuator.

The other advantage of electric actuators is operating cost. With pneumatic actuators, supplying compressed air is expensive and inefficient. Limitations and irregularities in the compressors, air lines and valves can result in fluctuations of performance. Electric actuators are more efficient and consume less energy. In higher-force requirements, hydraulic actuators are often the first choice. However, they tend to be large and bulky and can also be messy.

Often, procurement departments look at the initial acquisition cost. Pneumatic and hydraulic actuators have a lower initial acquisition cost. However, valves, fittings and additional components needed for those actuators, as well as the cost for fluids or compressed air, needs to be taken into consideration when evaluating the overall cost.

Therefore, if precision, space and cleanliness are a priority, then an electric actuator is the right choice. If precision and operating costs are not a concern, a pneumatic or hydraulic actuator can be used.

ISABELLE DURSO

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OPERATING COST AND EFFICIENCY CONSIDERATIONS

This is an age-old question, and, unfortunately, the answer may be less than satisfying. It really comes down to the best system for the job; there is no one-size-fits -all solution. In order to meet productivity and energy efficiency goals, it is always important to suit the technology to the requirements. Each of the systems you mention has its place.

Pneumatic systems are often picked on because of the relatively high energy cost incurred during operation: hence the more frequent requests for electric linear actuators. It's no secret that the typical industrial pneumatic system has an efficiency rating down in the teens, often well below 20%. Even though the total cost of ownership gap between pneumatics and other technologies is decreasing, it's still true that the low upfront-cost, long service life, low replacement cost and exceptional durability, even in difficult environments, will generally outweigh the high energy cost. This is especially true for pick-and-place

The point of separation for hydraulic actuators from pneumatic or electric is perhaps the easiest to define.

and other set-it-and-forget-it applications where there is no need for the elaborate and expensive control systems that are required for multi-position stops or precise on-the-fly adjustment of acceleration, deceleration or transfer speed.

Hydraulic systems are often more complex and require a larger initial investment than pneumatic systems, but their compact nature and controllability, the result of a nearly noncompressible fluid as a means of power transmission, make them an attractive choice in many applications.

From the standpoint of operating cost, a properly designed hydraulic system can be far more efficient than an equivalent pneumatic system. Generally, the choice to go hydraulic is often made when loads and speeds exceed the limits reasonably met by pneumatic or electric systems.

When it comes to operating cost and efficiency, the electric linear actuator is the clear winner. In years past, the initial cost and the complex control necessary for their operation often removed them from consideration unless some of their other attributes were required. As that technology matures, however, the price gap has narrowed to the point that the nice-to-have benefits in controllability—acceleration, deceleration, multi-position stops—have become far more attractive. It still comes down to a cost/benefit analysis of the actual needs of the application.

Procurement teams are fond of standardization as a way of controlling cost. As a counter to this request, you might point out that the unique nature of each application lends itself to a best-technology solution; and you can read “best” as the one that provides the lowest total cost of ownership to your clients. Rather than limiting yourself to one or two of the viable technologies available, it would be better practice to standardize by selecting a vendor in each category that can serve as a one-stop-shop for your needs.

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industry projects manager / SMC of America / www.smusa.com

What you need to know about motor selection

Answer some questions about the application before specifying a motor

By Dave Perkon, technical editor

When it comes to motors in your automation, what do you specify? For a custom machine builder or OEM, it is usually a good practice to consider the cost; however, the application, operation and environment are the big players in motor selection. It's not just about voltage, torque and rpm. The application places specific requirements on motor performance beyond these basic specifications.

So, what type of motor is appropriate for an application? The first thought may be to contact a local electrical distributor or automation vendor. While these distributors, vendors and industrial manufacturers are happy to help with knowledgeable sales personnel and detailed websites, they are going to ask some questions, which will be about the application requirements.

The motor suppliers and manufacturers will have much to say about the type of motor, as well as the innovation and performance of their products, whether they are ac or dc, synchronous or inductive, servo or stepper motors. Yet, resist the urge to select a type of motor until each application's load, speed and operating characteristics are defined.

Obviously, a motor is selected to meet the demands of the application, so the demands should be defined. A big part of these demands are based on the type of load the motor output drives. What is the motor moving? The motor load includes a variable or constant torque and a variable or constant horsepower. The motor may also require positional control or torque control.

Some loads are constant torque—the load doesn't change. For example, the lever arm or roll diameter remains constant. In some constant-torque applications, the horsepower may vary—more work needs to be done or more force is needed to do the work. Basic examples of these constant-torque and variable-horsepower applications include compressors, cranes, conveyors and some pumps—gear-type or positive displacement. Compressing at a higher air pressure, lifting different weight loads with the crane or adding a loaded pallet to the conveyor varies the motor horsepower needed to move the load. Define the work. A wide variety of ac and dc motors work well in these applications.

There are also constant-horsepower and variable-torque applications. A simple example of this is an unwind or rewind application. The material speed remains constant while the roll diameter decreases or increases. The constant material speed ensures a constant horsepower while the roll diameter—lever arm—changes, varying the torque. This application commonly used dc motors many decades ago. More recently, servo motors or ac motors with closed-loop control are popular choices. With these heavy loads, don't forget about regenerative braking as a means to control the regenerative power when stopping.

There are also variable horsepower and torque applications such as mixers/agitators, fans and centrifugal pumps. These are the type of applications where energy efficiency is often discussed. Small changes in the speed of these motors results in large reductions in energy usage. Motor speed plays a large role in these applications. Can you run the mixer, fan or pump slower at times? When the motor speed increase, the load increases, which requires more horsepower and more torque.

The speed of a motor is always part of the motor selection discussion, as is an application's need for frequent or fast starts and stops. Will the motor need to start and stop or reverse direction often? Does it need to do so quickly? Will the motor run at constant speed, or does it need to be variable? The answers, in addition to determining the type of motor needed, such as an inverter-duty ac motor, helps to determine if across-the-line starters or variable frequency drives (VFDs) are needed.

More advanced motor applications require accurate and repeatable positional control, torque control and speed control. These applications include single- and multiple-axis gantries, pick-and-places and web-handling machines. While a stepper motor running open loop may satisfy the requirements of these applications, closed-loop control using servo motors is often required.

Do you really need a servo motor? An ac or dc motor with encoder feedback can also be used in many high-performance applications, providing good speed regulation and reasonable positioning capability. For example, an ac motor specifically designed for inverter or vector duty works well in variable-speed applications and can provide constant-torque capability to zero speed.

In what environment will the motor be installed? The motor selected for industrial applications must be robust and capable of handling the environmental conditions. Don't make the mistake of specifying a single-phase ac induction motor, often used on a small appliance such as a washer or dryer, to control small loads on a machine. There are significant differences between a continuously running industrial machine and a washing machine cleaning six or eight loads of laundry a week. The appliance motor may work great, but there is more than just dust present in industrial applications. Motors need to survive extreme environ-

Resist the urge to select a type of motor until each application's load, speed and operating characteristics are defined.

mental conditions, including high and low temperatures, varying electrical demands and contaminants. A properly selected motor will provide optimal performance and a long service life in harsh environments. Washdown-duty, stainless-steel and severe-duty are just a few requirements to consider depending on the industrial environment.

With the motor application understood and well defined, it's likely the solutions available are many. Although a machine with five different motor applications may require five different types of motors, keep the overall system in mind; using like or similar motors can reduce design complexity, startup time and spare-part needs.

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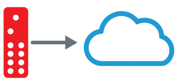

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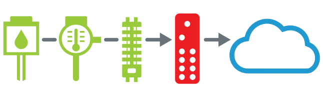

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COMPETENCE IN COMMUNICATION

A clean adjustable speed drive installation

Follow some basic rules when selecting, designing and installing a VFD for cost effective and efficient control of 3-phase AC motors

By Dave Perkon, technical editor

There are many options to vary the speed of motors in automated machines. Depending on the application, servo-motor drive and dc drive can be used, but the star of the show is the variable frequency drive (VFD). When the cost, reliability and ease of operation and use are considered, it's hard to beat the VFD when there is a need to vary the speed of motors controlling conveyors, belts, pumps, blowers and fans.

Sometimes constant speed just isn't enough. Many of you mechanical types are happy to change the diameter of the pulley or sprockets driving the rotating motion, but electronics is much more flexible for adjustable motor speed control. There are some basics to keep in mind when specifying, designing a control circuit and integrating a VFD.

To start, if there are requirements to control the speed of a three-phase ac motor, there are many options available. Gather your requirements and talk to your favorite industrial parts supplier or manufacturer and consider using the popular VFD.

While VFD input voltage can be as low as 115 Vac single phase, 208/230/460 Vac single- or three-phase supply is more common. This supply voltage is connected to the VFD through a short circuit, branch circuit protective device such as a fuse or circuit breaker. The drive's output and the motor it's controlling is always three-phase.

For the most part, a VFD can handle electromagnetic interference (EMI) noise often found in industrial facility's supply voltage, but it never hurts to install some type of line-side filter upstream of the VFD, or at least include spare back panel space to add a drive isolation transformer, filters or reactors in the future. Plan ahead.

On the load side, the inductive motors and the VFD controlling it can create EMI noise and adversely affect nearby sensitive equipment. Just like it's best-practice design to add surge and lighting protection at the main disconnect of most control panels, it's at least good practice to add drive load side reactors or isolation transformers to protect against harmonics, reflected waves and electrical disturbances. Carefully understand installation requirements and talk with the manufacturer, as random "noise" problems can be difficult to find—don't add to the possible problems.

Worth noting is the reflected wave disturbance's effect on the cable connecting the drive to the motor. These waves can double the voltage at the motor, so limit cable length and be sure to specify inverter-duty motors which have higher insulation ratings, especially on 460 Vac and higher-supply voltage applications. If the cable distance is much more than 100 feet, consider installing the drive closer to the motor.

Once the proper supply voltage and related hardware are connected, it's time to get down to what the VFD's purpose is—adjusting the speed of a three-phase ac inductive motor. But it does more than that. It also provides overload protection required by the National Electric Code so an overload relay on the load side is typically not required.

The drive also starts, stops and controls the direction, and acceleration and deceleration of the motor. In the past, start and stop signals were commonly discrete inputs, often in the form of relay contact closures. Other control modes include keypad control, as well as two- and three-wire control. A speed reference signal is also adjustable via a keypad or internal drive parameter. Analog speed references are also available via 4–20 mA and 0-10 V signals. A more modern approach is to use network communications for drive control and speed reference signals.

There are many communication options for drives, such as RS-232/485 Modbus and industrial Ethernet protocols such as EtherNet/IP, to perform the starting, stopping and speed-changing functions. This communication also returns a variety of drive status information, such as running, and alarm codes, such as overvoltage and overcurrent faults, among many others.

With all the access to the data and parameters that digital drive communication provides, all but the simplest PLC drive control

A more modern approach is to use network communications for drive control and speed reference signals.

applications should include it as opposed to simple discrete signals. Ladder diagram, add-on instructions or similar in the PLC provides significant VFD control and data capabilities compared to what were available in the past.

The ability to change speed to optimize the process or reduce the speed of variable torque loads such as pump, fan and blower applications can greatly improve efficiency. Check out the Affinity Laws. Even constant torque loads such as conveyors, compressors and mixers may benefit from motor speed changes and reduced acceleration when starting and stopping can reduce overloads, wear and forces on the equipment.

While there are many other things to consider when integrating a VFD into an automated system, configuring a drive properly is a must. While minimal drive configuration is necessary—even though there may be more than 50 parameters—some is almost always required. Carefully record the motor nameplate data. Use that data to program the drive parameters such as rated voltage, full load current and speed—at a minimum. Spend the time to review the user's manual to get it right.

The future of linear-motion technology

Market drivers and challenges that will shape design trends

By Anna Townshend, managing editor

Linear-motion technology is the basis for many critical components used in industrial machinery. Learn more about product innovations from Hiwin (www.hiwin.com), Aerotech (www.aerotech.com), Nexen Group (www.nexengroup.com), Nippon Pulse (www.nipponpulse.com), Ewellix (www.ewellix.com) and Bosch Rexroth (www.boschrexroth.com) in www.controldesign.com/linearmotion.

These same manufacturers discussed the overall market for linear-motion technology: what customer desires are driving the market; the biggest challenges facing technological advancement; and the future of linear-motion product design trends in the world of IIoT and Industry 4.0 and beyond.

COMPACT COMPONENTS AND POWER DENSITY

"In general, the precision control market is looking to solve space issues, especially in multi-axis applications where side-by-side motion is required," says Bob White, technical sales manager at Nippon Pulse. The ability to get smaller-diameter motors with higher force capabilities can drive higher density systems, he explains.

"Miniaturization trends are forcing manufacturers to increase the power density of their products or develop new solutions to offer more power in less space," says Will Morris, category manager at Allied Electronics & Automation. "That is required to reduce the machine footprint and optimize the overall layout to get lighter equipment that requires less energy to be utilized."

INTUITIVE TOOLS TO EXPEDITE DESIGN

"Once a design is solidified, the products within should seamlessly transfer to the quote and ordering process with minimal effort on both the customer's and the supplier's side. This speeds up the process and eliminates errors," says Richard Vaughn, automation engineering manager at Bosch Rexroth.

"Designs which offer a complete axis solution bring more value to the marketplace versus individual components," says Justin Hillukka, lead engineer for power transmission and custom products at Nexen Group. "Engineering capacity is limited in many organizations, so offering solutions that make the design cycle more efficient adds value."

END-USER DELIVERY

Speed to deliver automation equipment to the end users is becoming an ever-increasing priority in these markets, says Bosch Rexroth's Vaughn. "Rapidly changing technology in all areas of manufacturing requires that production facilities be able to incorporate new designs or change over to the next generation of products at record pace," he explains.

"A key theme for linear-motion products is ease of use," says Brian Fink, product manager at Aerotech. "With ever-increasing pressure on delivery, both end users and machine builders strive to get their products to market as quickly as possible. It is highly advantageous to select motion stages, controllers and other components that are easy to integrate and operate right out of the box."

REDUCED DOWNTIME AND HIGHER PRECISION

"Developers of motion control and automation systems are being pushed to deliver higher throughput, reduced downtime—higher reliability and reduced maintenance—and better quality, in terms of increased precision, all at the same time," says Art Holzknecht, engineering manager at Hiwin.

"Indeed, the underlying theme of smart products affects linear motion products, as well. In order to reach complete control of the equipment and implement advanced features, such as predictive maintenance or real-time performance optimization, sensors and electronics need to be integrated on linear-motion systems," says Morris of Allied.

LESS MAINTENANCE MEANS INCREASED PRODUCTION

"Maintenance-free operation is also becoming a clear need across many industries, as end users need to reduce the maintenance costs and related downtime to improve their productivity and bottom-line results," says Morris of Allied.

"Innovative motion-system engineers are responding by bringing down the cost of direct-drive linear-motor systems through highly optimized designs, incremental technology improvements and streamlined manufacturing," says Holzknecht of Hiwin.

MARKET CHALLENGES

The desire for smaller, faster and more intuitive and accurate linear-motion products is driving new feature designs and technology innovations. What are some of the challenges facing this product market, and how is industry responding?

- Bringing new technology to a broader customer base: Without specialized knowledge in the system, it's more difficult for new markets to adopt new technology without a lot of education. "Advances in drive technology using advanced servo control algorithms and sophisticated software have taken the complexity out of the customer experience," says Hiwin's Holzknecht. "Setting up a direct drive is easier than ever, with smart tools that guide the user through every step."

- Reaching delivery goals with slow order fulfilment: High demand and low supply have been exacerbated by the pandemic. "Increasing the adoption of more common and standard products by machine designers can allow motion suppliers to streamline and therefore increase their inventories, enabling greater control over product deliveries," says Vaughn of Bosch Rexroth.

- Understanding design tradeoffs: Finding the right system for new customers and doing so on time and on budget means customizing each system by first understanding the system design objectives. "Machine builders and system integrators are often faced with difficult design tradeoffs," says Fink of Aerotech. "It is crucial for motion control and stage suppliers to understand and appreciate these tradeoffs and the implications thereof. Only with this deep understanding is it possible for suppliers to design and manufacture motion control equipment that achieves as many needs of the target buyers as possible."

IIOT IMPLICATIONS

The next industrial revolution is shaping every machine component, including linear-motion products, which are smarter, faster and more open. As with many components, it starts with data collection. "Capturing machine data offers big opportunities to gain knowledge," explains Bosch Rexroth's Vaughn. "These new motion products enable ways to monitor, analyze and in turn improve like never before."

For this data ultimately to be valuable, it needs to communicate quickly and efficiently with the controller. "These devices should work in harmony with the controller to deliver a higher level of functionality to users," says Fink of Aerotech. "Therefore, the design of the controller is at least as important, if not more so, than having a high-performing positioning device."

IIoT and industry 4.0 continue to put pressure on linear shaft designs, especially in the area of feedback devices used to close the servo loops, says Nippon Pulse's White. "These devices integrate with smart controllers that provide a wide array of data on motor health to upstream systems, along with key information about the mechanical elements that make up the machine axes," he says.

Speed is still the name of the end game, whether designing, communicating, upgrading or troubleshooting. "Being able to connect to a motion control or servo drive remotely via an internet connection is key to fast troubleshooting. Expert engineers who are not on-site can respond quickly to machine faults, get diagnostic information and keep a motion control system running before a critical-line-down situation," says Holzknecht of Hiwin.

5 PREDICTIONS FOR THE FUTURE OF LINEAR MOTION

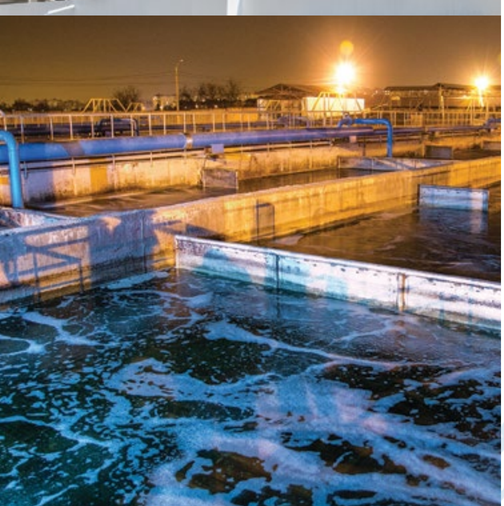
1. "More applications in microelectronics manufacturing, drug discovery/life sciences and precision automation will adopt linear-motion-driven systems to produce their products," says Hiwin's Holzknecht.

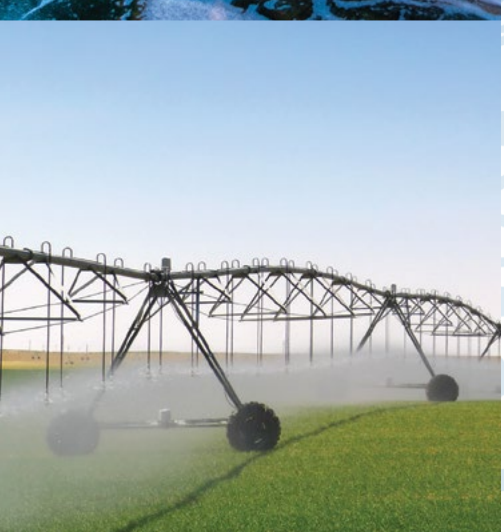
2. "Smart products and fit-for-purpose solutions are key themes that will guide new developments in linear motion. By adding onboard intelligence in the products, we can create new value that can bring innovation in traditional industries and applications, says Morris of Allied Electronics & Automation.

3. "I see a trend toward fully automated and intuitive tools that enable motion-component customers to be completely self-sufficient. This includes online sizing and selection, CAD generation, quoting and ordering all from a website. Additionally, in the future the customer's equipment will be able to program their motion online with a virtual twin of the equipment, well ahead of the physical parts arriving to gain further advantage over short project timelines," says Bosch Rexroth's Vaughn.

4. "I expect that the future will see more of a convergence on mechanical design optimization; but more important than that is the integration of the mechanics with advanced controller features and capabilities," predicts Aerotech's Fink.

5. "Future trends include continued innovation on size reduction, improved magnetics, robust and lower cost feedback elements and a wider array of sealing options for different market requirements," explains White from Nippon Pulse.



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