The 'Internet of Things,' or when drives start thinking for themselves

This paper shows how advances in technology likely will force manufacturers to properly size drives and surrender their 'comfort zone' cushions to maxmize the capacities of their processes.

By González Villar and Juan Carlos González Villar

Analyses of existing production machines show that most drives are not run at their rated operating point, but instead are run mostly at partial loads. In Europe, the average utilization of motors is no higher than 60% of the rated load. This is particularly true for applications with high variance, for example constant output drives (load torque curve -> f(n)=1/n, e.g. winding machines, turning machines, saws, etc.) or constant torque drives (load torque curve -> f(n)=n, e.g. extruders, belt haul-offs, haul-off capstans, etc.) The potential for future improvement of individual components (drives, motors, gear units, converters) is relatively small because they already exhibit a very high level of refinement and efficiency (0.98% at rated operating point). For this reason, the future of drive technology may belong to small servo actuators that are linked in real time and have an intelligent energy efficiency interconnection. This would be a base technology fully in keeping with the notion of the "Internet of Things (IoT)."

Whether revolutionary or evolutionary, the initial steps and ideas behind the IoT have brought the world of industry to the cusp of a new leap forward in development. But what do we see when we take a more detailed look at this leap forward? What can the various branches of industry expect as we move into the future? And what kind of (monetary) benefits/advantages will the IoT bring your own company? In order to satisfactorily answer these questions, it is advisable to take an early look at this extremely broad topic and examine the developments, technologies, and trends that are already in play. For example, the energy efficiency of electrical drives is currently in Europe a major factor in such developments. The definition of efficiency classes in IEC 60034-30 has been a contributor in this area. This may be a step in the right direction, but it is far from an all-encompassing answer. When one looks at typical applications for electric drives, in many situations they are run predominantly under partial load. This is true, for example, for constant-torque drives used with conveyance systems and extruders as well as for constant-output drives used with unwinding and winding equipment. This article examines a specific example from the cable industry, whereby an intelligent drive system (see Fig. 1) can save the user significant quantities of power and reduce energy costs accordingly.

Fig. 1. Patent/intelligent drive system.

Internet of Things – A definition

The term Internet of Things represents the fourth Industrial Revolution (see Fig. 2) and a new way to organize and control the entire value-creation chain throughout the product lifecycle. This cycle is oriented on increasingly individualized customer expectations and covers everything from the initial product idea, through contracts for development and production, to delivery of a product to the final customer, and even recycling, including associated services. It is founded upon the real-time availability of relevant information through networking of every link in the value-creation chain as well as the ability to derive from the data the optimal flow of value creation at any given point in time. By bringing together people, objects, and systems, it is possible to create dynamic, real-time-optimized, and self-organizing value-creation networks across multiple organizations and to optimize these networks according to various criteria such as costs, availability, and resource consumption.

What's noteworthy in this paper

WJI: What's the most important news in your presentation?

Villar: Winding and unwinding drives, traversing drives, and drives used in the pushing, pulling and drawing equipment of a system may use only one motor size/motor type. The described drive system maximizes generator power, minimizes motor power and standardizes the entire drive system. It provides significantly higher overall efficiency and allows installation of smaller-output motors with lower operating costs.

For designers, this offers lower development costs, economical production with unit-price degression, several series of identical design, and consistent and straightforward assembly processes. For users, exchangeable modules make repairs fast and economical. Compatibility and use of shared parts reduce the need to hold spare parts to a minimum. Consistent modularity greatly expands the benefits for both the manufacturer (sales, assembly, spare parts service) and users (purchasing, operation, repairs).

WJI: Were you surprised that European motors are often used for less than 60% of rated load capacity?

Villar: I consider this figure, which figure comes from an EU-sponsored study, to be too optimistic for the wire and cable industry. Compare the net power requirement to the installed power and you'll see. I am intrigued how some companies use the term "energy efficiency." I see this as marketing without substance.

WJI: Will development engineers ever give up their "safety cushion"?

Villar: The so-called "safety cushion" found its way into machines at the beginning of the third industrial revolution in the 1980s and 1990s. Then, every machine had standard switching gearboxes and continuously variable transmissions (CVT), but today there is a large motor sized for the model's maximum required torque and a beefy single-line gearbox sized for the maximum required machine speed. When energy costs are low, no one cares, but when the price is much higher, a rethink is in order.

WJI: Will the "Smart Factory" eventually force manufacturers to better optomize drive capacities?

Villar

Villar: As was evident at this year's Hannover Fair, the Smart Factory, based on cyber physical systems, is still in the developmental phase. It will take years, if not decades, until they have penetrated all areas of industry. Without 100% data security, there will be no Smart Factory. This "security" must be established first. The third industrial revolution cut back on mechanical drive engineering in the machines and inflated reliance on electrical engineering. The fourth industrial revolution—based or not-based on cyber physical systems—will bring back the mechanics and cut down on electrical engineering. At that time, mechatronics will have asserted itself definitively. The era in which machine builders use motors that are 10 times the size they need will finally be in the past.

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Partial loads & elevated energy costs

The extrusion process remains the core discipline within the cable manufacturing process. These manufacturing systems not only place insulation around the conductor, they also impart the essential characteristics that make a cable a high-tech product, such as fire resistance, flame retardancy, permittivity, impedance and other properties. During the cable extrusion process, the endless material (provided in coils or drums) is generally fed to the extruder head by way of an insertion or feeder device and then jacketed by a viscous synthetic material that is worked and conveyed under the application of heat and pressure. After leaving the extruder head, the hot strand is directed through a series of water-cooled guide rollers and drawn or pushed by a conveyor apparatus to the traversing winding device. Extrusion systems commonly use over-

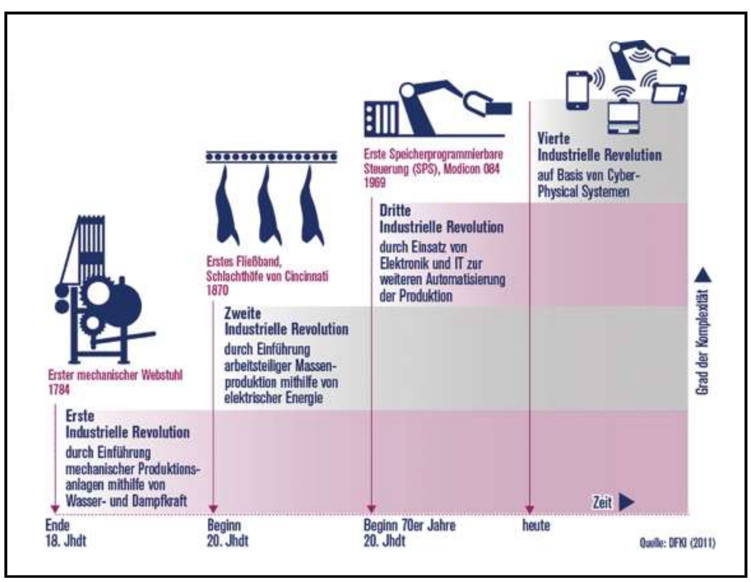

Fig. 2. The four stages of the Industrial Revolution.

sized constant-torque and constant-output drives with high power reserves that are not fully exploited. Does this make sense?

Even today, oversizing a drive system is considered to be good practice in order to ensure stable operation of the machine. If the development engineer cannot be certain of the mechanical loads, the load spectrum, or the environmental conditions, he can stay on the safe side by specifying an oversized drive. In addition, drives with specific loads and speeds must be selected to match the maximum operating conditions. So in many cases the presence of power reserves is fully justified. Consider, for example, an extruder that conveys a viscous compound for the production of a high-value final product, such as LWL cable, high-voltage cable, telephone cable, etc. Overheating and failure of the motor on a hot summer day could have expensive consequences. It is a similar situation with winding and unwinding machines, where the nature of the process requires oversizing. Although winding drives do not need to produce high speeds and high torques simultaneously, the motor must be capable of both. In such cases, the installed power capacity is much greater than the power consumption of the process. As a result, high-output electric motors must be used, but their capabilities are only partially exploited. The use of converters permits operation of motors in the field weakening range and expands the winding drive's speed range. This can justify the additional power costs that result from oversizing of the drive systems. But are there any alternatives?

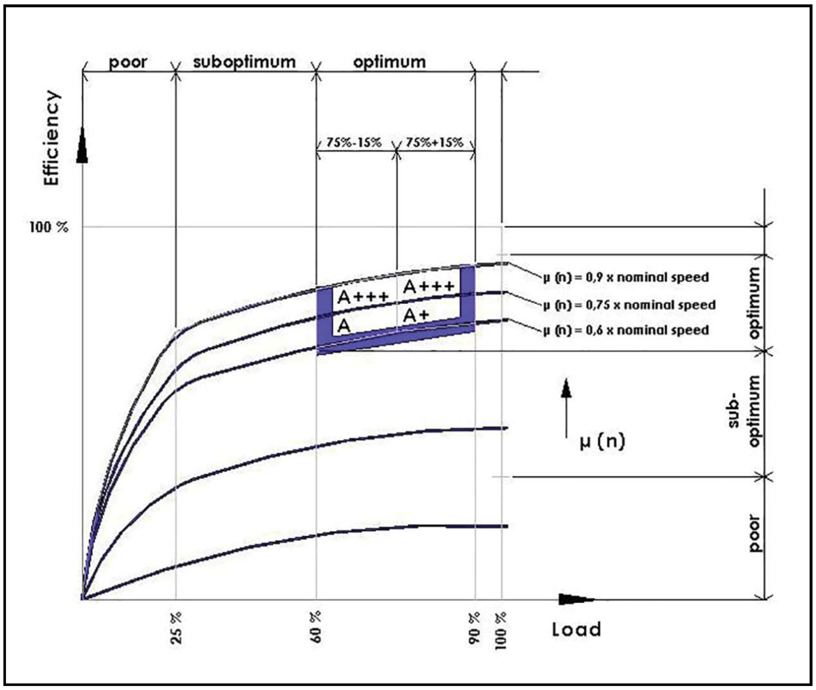

Fig. 3. Efficiency of a standardized motor.

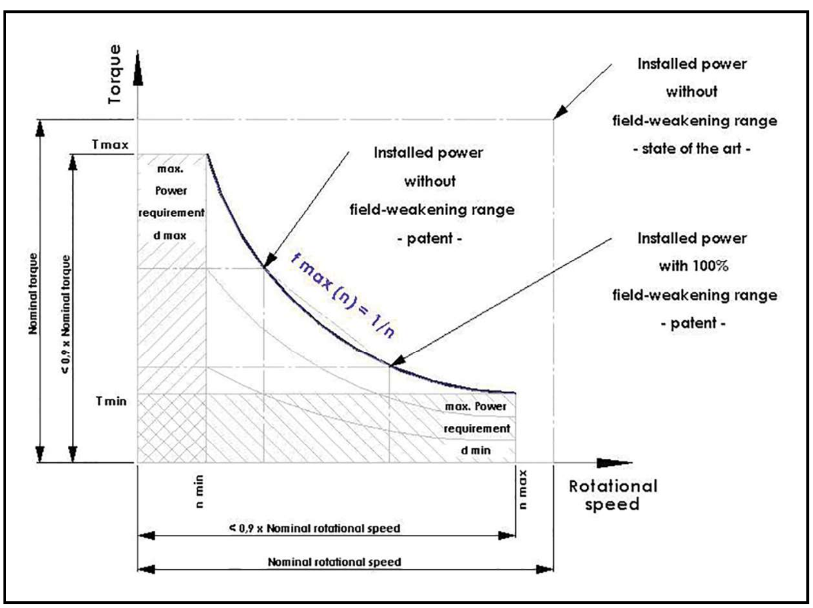

Fig. 4. Constant output curve and 2 alternatives.

IDS: installed capacity should not be too big or too small

For a standardized asynchronous motor (see Fig. 3), maximum efficiency, i.e., the ratio between yielded mechanical output and absorbed electrical power, is usually in the range of 60% to 100% of the rated load. Below 25% of the rated load, efficiency drops quickly. If one consider only efficiency, it appears wise to operate motors within the load range where they exhibit maximum efficiency. But if one is also concerned about service life, choosing a somewhat oversized motor is advisable. This results in a higher purchase price, but the motor will have power reserves and will not heat up so quickly. With this in mind, the solution is to develop an energy-efficient drive system that is not only economical, modular and maintenance-free, but one that also exhibits exceptional precision, dynamics and reliability within the optimal efficiency range of the motor and the entire mechanical drivetrain. Smooth operation of the drive system and the mechanical power train must be ensured even with high product, parameter and process variability. The optimal efficiency range of the motor is at 0.75 ± 0.15 x rated speed and 0.75 ± 0.15 x rated torque. An invention (patent applied) by Kabel.Consult.Ing fulfills these requirements. A major advantage of the new drive system is that rated losses and no-load losses of the drive motor are several times lower than the current state-of-the-art. Another advantage is the fact that all of the mechanical power trains involved in the drive can be operated continuously within the optimal efficiency range. The no-load torque of the mechanical drive or the individual power trains is likewise reduced by several times compared to the state-of-the-art. Fig. 4 shows that when several small drives are used properly, one can obtain a situation where the installed output for an application with a constant output curve is not significantly greater than the process power consumption. Nevertheless, there is still an adequate level of safety, e.g. against external thermal influences or a long-lasting overload situation that was not considered during the planning phase. As a result, the drive system will have a very high level of overall efficiency, an optimized energy balance, and therefore low energy costs. And since the motor and the power transmission components constantly run in their optimal efficiency range, most of the drive output is utilized efficiently in the process itself. The new energy-efficient drive system is SIGNO-funded and has been registered for patent protection. It is also part of a funding initiative by Germany's Ministry of Economic Affairs and Energy. n

Comparison of technologies using a winding machine for high-voltage cables as an example.

Coil dimensions

Flange diameter: max. 3150 mm
Core diameter: min. 630 mm
Winding width: max. 2200 mm
Winding factor: 5
Weight: max. 20,000 kg

Technical data of the system

Cable diameter: min. 20 ; max. 100 mm
Winding speed: min. 3 ; max. 30 m/min
Winding tension of product web: 2000 N (max. 4000 N)
Winding torque - Coil: 3000 Nm (max. 6000 Nm)

The following calculation is an example that illustrates the benefits of the new drive (installed in a complex extrusion system from the cable industry) over the existing state of the art:

Technical data of motor	State of the art	New technology
Motor types used:	Asynchronous servo	Synchronous servo
Rated output:	7.5 kW	2 x 0.85 kW
Rated torque:	30 Nm	2 x 3.5 Nm
Rated speed:	2300 rpm	2 x 3000 rpm
Rated current:	17 A	2 x 2.9 A
Rated voltage:	400 V	2 x 400 V
Magnetizing current:	8.2 A	N/A
Weight:	40 kg	2 x 5.5 kg
Moment of inertia:	0.017 kgm²	2 x 0.0005 kgm²
Additional power train:	N/A	14 kg

Power costs (€0.14 € / kWh)

Annual power costs (7500 h):	€3150	€450
Power costs, 8 years (60,000 h):	€25,200	€3600

Villar

Juan Carlos Gonzalez Villar is proprietor of Kabel.Consult.Ing, Mönchengladbach, Germany, a provider of consulting, development, and modernization services for the wire and cable industry. He has 25 years of professional experience in the wire- and cable-making industry, and has worked with numerous manufacturers of wire and cable and stranding machines. Following his graduation from studies in mechanical engineering at Niederrhein University in Krefeld, he joined cable-making machine manufacturers FRISCH Kabel- and Verseilmaschinenbau GmbH as a mechanical engineer. He previously completed vocational training and worked for five years as a machine technician at a cable-manufacturing company in Monchengladbach. He also took a postgraduate course in industrial engineering at Niederrhein University in Mönchengladbach, with specialization in marketing. González Villar This paper was presented at Interwire 2015, Atlanta, Georgia, USA, April 2015.