24-volt drive technology in continuous conveyor systems

Abstract

Today's continuous conveyor systems can be used in many different sectors and industries. In recent years , in addition to the standard 400 V drive technology, 24V DC technology has become increasingly popular.

Energy demand, costs, system performance and flexibility are key factors in the choice of the optimum system. A direct comparison of the two techniques in many cases shows the 24V DC as the most efficient and attractive alternative.

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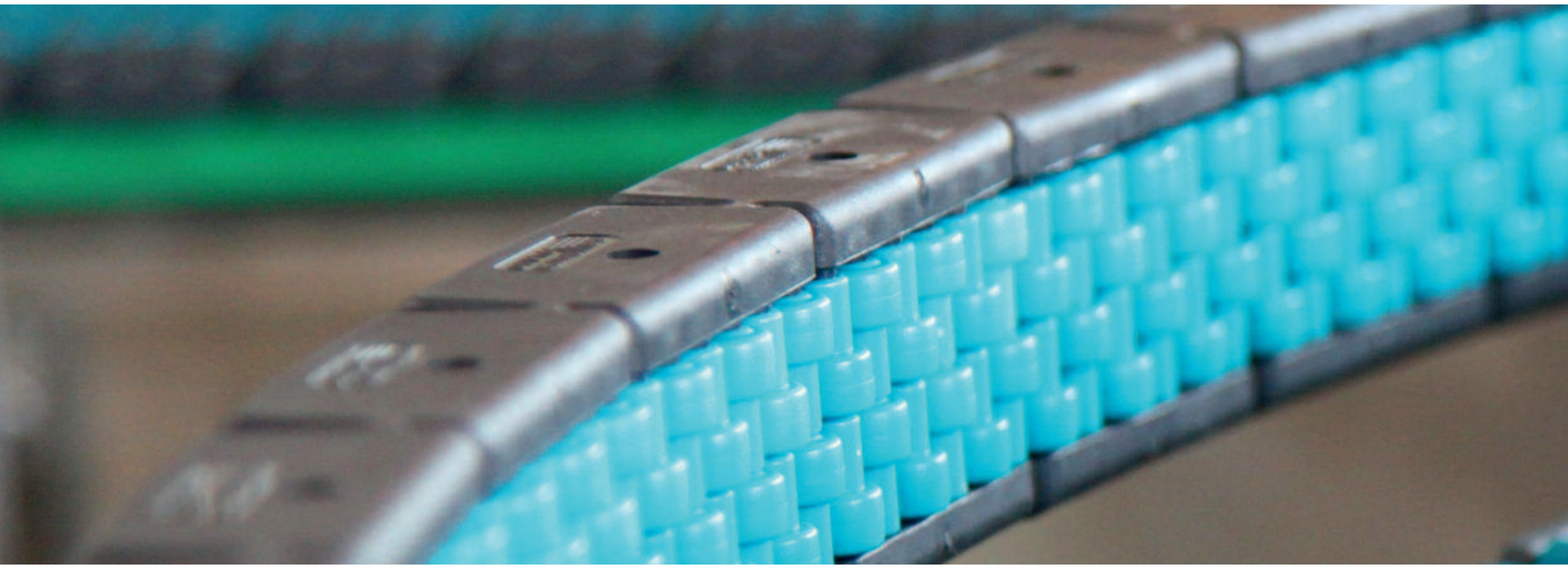
M. Braun, P. Linsel and K. Furmans: 24-volt drive technology in continuous conveyor systems



Today's continuous conveyor systems can be used in many different sectors and branches of industry. As well as classic 400-volt drive technology, 24-volt drive technology has increasingly been used over the past few years. Since 24-volt and 400-volt drive technology share some common distinguishing features, the two drive technologies will be compared with each other in this paper. Possible distinguishing features include the operating mode, drive-train design and conveyer task.

The advantages and disadvantages of state-of the-art 24-volt technology will subsequently be determined. A direct comparison of both technologies will then be made using the following criteria: "energy consumption", "costs", "system performance" and "flexibility". To quantify the energy consumption in each case, a distinction will be made between six different scenarios, which will be duly compared.

The three tasks of continuous transportation, intermittent service and accumulating function based on an identical layout in each case will also be examined on a comparative basis. The findings reveal that a 30% energy saving can be made by using a 24- volt roller drive in intermittent service rather than 400-volt technology. As far as the accumulating function is concerned, energy consumption can be reduced by as much as 50%. Not only that, the costs of initial outlay can also be reduced by using 24-volt technology for short conveyor segments.

24-volt drive technology is the perfect complement to modular systems of roller conveyor technology, because the ability to divide non-centrally activated conveyor sections into modules affords greater flexibility for remodeling or modernization projects. The decentralized drive system incorporated within the conveyor roller facilitates compact designs that also provide additional protection from external environmental impacts. This makes 24-volt drive technology suitable for use in many different scenarios or a host of different application areas. For intermittent transportation tasks with piece numbers between 100-1000 unit loads an hour and lightweight units of 30-50 kg, the use of 24-volt drive technology is therefore advisable.

The complete study is available for download at interroll.com

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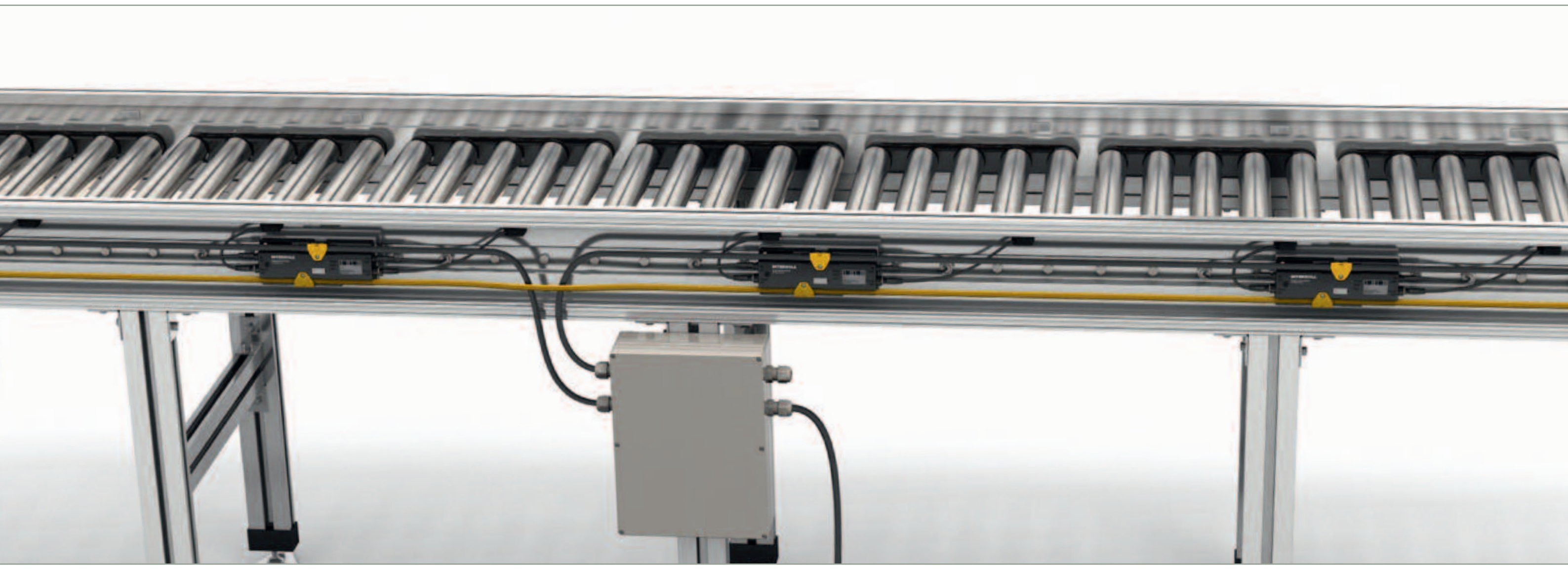
1 Applications areas for 24-volt drive technology



24-volt drive technology is primarily used in accumulating conveyor systems these days. It can also be incorporated in conveyor modules operated in intermittent mode for throughputs between 100-1000 unit loads per hour. Each module of a longer conveyor is then fitted with a roller drive that is separately powered and with a decentralized control unit that can be directly activated. Each drive has an interface to the external master control system. This means various modules can communicate with each other to facilitate material flows. In each case, the drive is only switched on and ready for action when a unit needs to be moved across that particular module of the conveyor. Once the unit has gone, the conveyor module is immediately switched off again. Long conveyors can thus be divided into segments that automatically switch themselves on and off again.

Such transportation tasks are common in many different sectors. In the packaging industry, the main tasks are dynamic positioning and precise delineation of the distances between transported units. Such tasks can be executed with the aid of 24-volt drive technology. This ensures high availability of the conveyed goods at the unloading points. The challenge in such cases is usually that the loading frequency of the conveyed goods is asynchronous with the unloading frequency.

Similar key tasks are handled by distribution centers or mail order firms with manual picking systems. Roller conveyor systems with 24-volt drive technology are also suitable for use in such instances.

As a general rule, 24-volt drive technology can be used in logistics centers handling throughputs of between 100-1000 unit loads per hour, e.g. in the entry zones of automated high-rack warehousing systems.

Continuous conveyors are basically assembled as modular systems, since the same designs are not necessarily applicable to different settings and purposes. For complex or demanding transportation tasks, standardized functional modules can be combined to form new systems or expand existing plants. Particularly when it comes to capacity or plant extensions, modular systems offer special benefits such as compatibility with existing plants and equipment. 24-volt drive technology forms an ideal component of such modular systems for certain transportation tasks and also constitutes a sensible alternative to 400-volt technology in current usage. [Hom07] [Mar06]

2 Advantages and disadvantages of 24-volt drive technology

Based on the latest technical developments, the following advantages and disadvantages of 24-volt drive technology can be identified.

Fundamentally, 24-volt drive technology can be described as one of the safest options for powering continuous conveyors, since the voltage transformation involved means the high alternating current of the main power supply is converted into low-voltage direct current. This makes the systems easier to maintain and service.

The most commonly used form of propulsion in 24-volt systems is a decentralized drive with a decentralized control unit. This enables longer conveyor sections to be broken up into small, modular, individually designed segments. Depending on the selected transportation task, modules not required at any given time can be switched off to ensure more energy-efficient operation. This means power consumption can be significantly reduced when parts of the system are in idle mode. The energy savings achieved also reduce the operating cost of the system as a whole.

The ability to divide longer conveyor lengths into individual modules with decentralized control units that allow information to be shared with other modules can also increase the flexibility of the system. Any changes as a result of remodeling or extending the system to include extra modules can thus be implemented relatively simply, like “plug and play” solutions.

By using small, compact motor units, it is also possible to incorporate further transmission elements of the drivetrain within the confines of the conveyor roller. This reduces the amount of additional, centrally mounted components required for each transport or accumulation task. As well as the safety aspect of using low-voltage power, the general transportation and handling of the conveyor modules can also be designed in a safer manner.

Integrated roller drives represent a low-maintenance, lownoise option and the advantages of such technology also lie in its compact, space-saving design. The fully enclosed unit protects all transmission elements such as bearings and couplings from external environmental influences such as dust, water, grit, chemicals, fat, oil and the high-pressure steam typically used to clean conveyor systems. [Fis11]

Simple integration of the conveyor rollers with their built-in drive facilitates quick maintenance of each module, and the redundancy of the system allows a fault within the system to be more easily rectified. Since it is possible to simply replace one defective module, the fault no longer has to be fixed within the entire system, as the unit in question can be taken away and checked for identification and repair of any problems. This means the conveyor process or use of the entire intralogistics system is only interrupted for a brief period.

The combination in 24-volt drive technology of decentralized roller drive with modern, decentralized control technology offers great potential, for conveyor modules can be strategically switched on and off without having to be centrally administered within the overall control system.

Whenever electrical power is converted to mechanical energy, a certain degree of heat is also generated. The overall system of the conveyor module has to expel that theat. The use of new materials in roller drives lowers the surface temperature of the 24-volt system by generating less friction than comparable, centrally controlled, gear-motor combinations. This means less heat has to be expelled and at the same time the degree of power loss is also significantly reduced. Ultimately this lengthens the service life of the drives and extends the lifespan of the entire system.

Summary of advantages at a glance

- Safe to use
- When de-central drives and control units are used:
  - Options for energy-efficient operation and thus direct cost savings
  - Increased flexibility
  - Compact size
  - Safe transportation of goods
  - Low-maintenance and low-noise technology
  - Simpler to service or repair the entire system
  - Intelligent operating mode
- Less heat generated

Th e task of many distributi on centers is to make products available 24/7 so that goods can be taken from the warehouse and distributed to customers at any time. If high throughput is required at the same time, the entire continuous conveyor system is usua lly ope rated in non-stop mode. For such usage, 400-volt drive technology with central gear-motor combinations is still the recommended option, since these motors have a high power density, long lifespan and, when operate at nominal power, very good efficiency. [Kie07]

Long conveyor lengths are divided up into smaller conveyor modules when 24-volt technology is used. While this means an operating mode appropriate to a particular transportation task can be applied, it also means a large number of different motors is used. Every additional motor-gear combination increases the potential for problems to arise. The overall availability of such an intralogistics system compared to that of an otherwise constant, non-segmented conveyor with a centrally cont rolled 400-volt drivetrain, is therefore lower. As well as the use of other drives, more sensors and control units are also used. The required basic output, due to the increased incidence of stand-by power, thus also increases. [Hom07]

Currently 24-volt drive technology is capable of transporting lightweight goods in the 30-50 kg range. In order to be able to move heavy pallets higher-powered drives are required, at least according to the current state of technology. Both heavy and lightweight goods can be easily transported with the aid of 400-volt drive technology since, depending on the transportation task, the conveyor can be adapted by adding tried and tested versatil e modular products to certain drive elements to improve the energy efficiency and throughput rates.

Summary of disadvantages at a glance:

- Unsuitable for continuous operation
- More motors in use
  - Lower availability
  - Increased stand-by power consumption
- (Currently) limited to conveying lightweight goods

3 Comparison of 24-volt and 400-volt drive technology

A comparison of 24-volt and 400-volt drive technology can be made using various criteria. To be more specific, “energy consumption”, the “costs” of initial outlay, operation and maintenance, the “overall flexibility” and “performance of the system” are the most important criteria. These will now be described in more detail and the appropriate key parameters explained. This will be followed by the findings of this comparison between the two drive technologies.

3.1 Energy

To compare the energy usage of the different drive concepts, the transportation of a unit load weighing 50kg was analyzed. In order to quantify the required energy consumption for other transportation tasks, a simulation model was developed at the Institute for Material Handling and Logistics (IFL), with which the energy consumption of both 400-volt and 24-volt drive technology can be quantified for the different scenarios. This model is not limited to a particular type of conveyed goods or roller conveyor as it is individually adaptable to various tasks.

The model of the roller conveyor (see Figure 1) is basically designed to suit the relevant drivetrain. The stand-by consumption of such elements as current converters, frequency inverters and control units is included in the calculations.

The roller conveyor model allows the performance record to be presented during the period of transportation as well as the required energy consumption. These figures can then be used to calculate other environmental aspects such as CO2 emissions.

Performance measures on real systems were undertaken to verify the model and determine any missing parameters such as resistance coefficients. As well as the latest advances of contemporary current systems, with the help of the model, the energy savings potential of new technologies and the influence of various operating strategies can be determined.

Figure 1: Basic diagram of the parametric simulation model

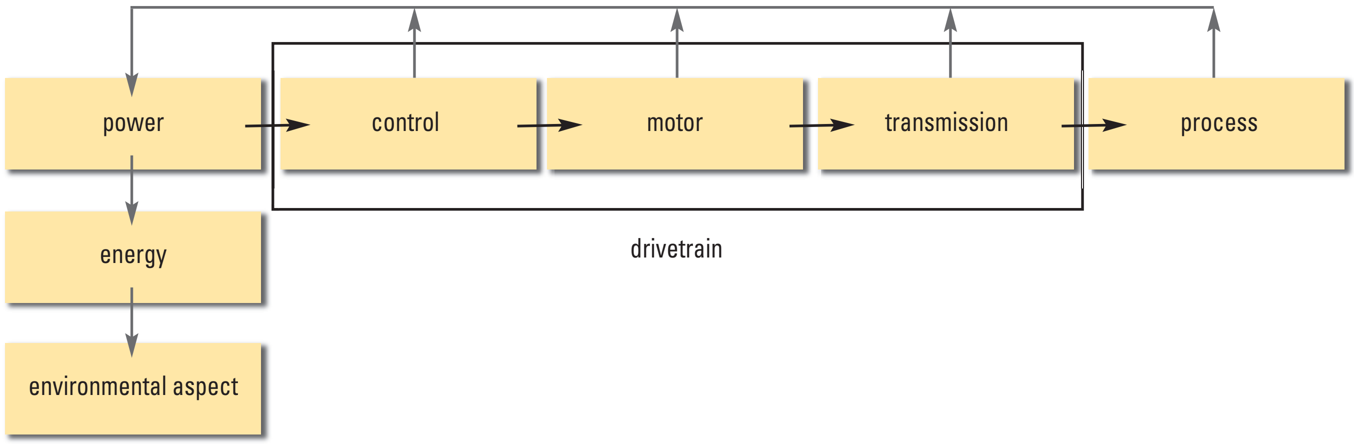
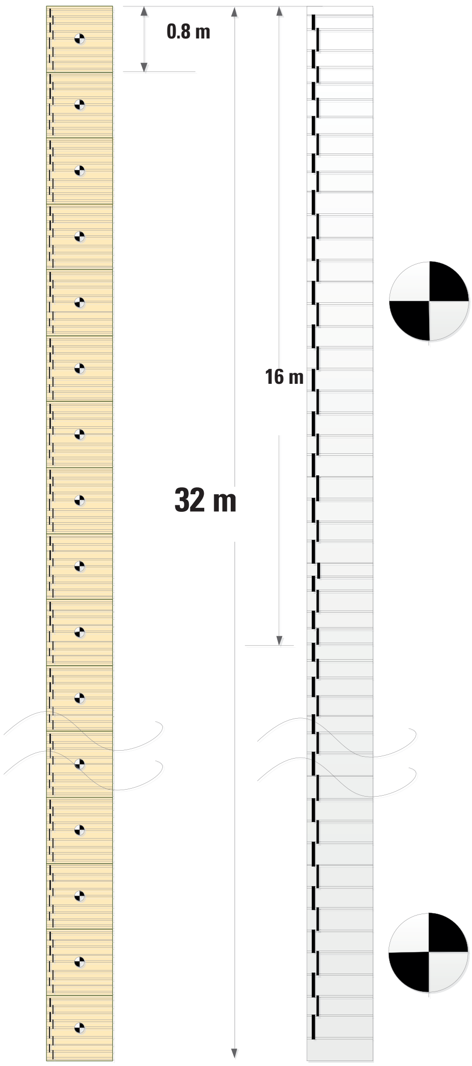


Table 1: Overview of comparative parameters of 400-volt and 24-volt drive technology

Name	Symbol	Unit	Details of 400-volt drive technology Central system	Details of 24-volt drive technology De-central system
Weight of conveyed goods	m	kg	50	50
Acceleration	a	m/s^2	1	1
Speed	v	m/s	0.8	0.8
Length of conveyor	s	m	32	32
Number of gears	-	-	2 (1 for 16 m)	40 (1 for 0,8 m)
Angle of elevation		°	0	0

For a direct comparison of both technologies, see in particular the layout shown in Figure 2. This consists of a straightline conveyor of 32m in length, 24-volt modules of 0.8m and 400-volt modules of 16m. Other parameters are shown in Table 1.

Figure 2: Comparative layouts of 24-volt drive technology (left) and 400-volt drive technology (right)



Using this overview of the parameters and comparative layouts, three different tasks were investigated:

Task 1 – continuous operation

The entire conveyor was switched on without any conveyed goods. Then a low-load carrier weighing 50 kg was transported across the entire length of the conveyor. When the unit reached the end of the line, the conveyor was switched off. This task was carried out on both modules of the 400-volt and all 40 modules of the 24-volt system.

Task 2 – intermittent service

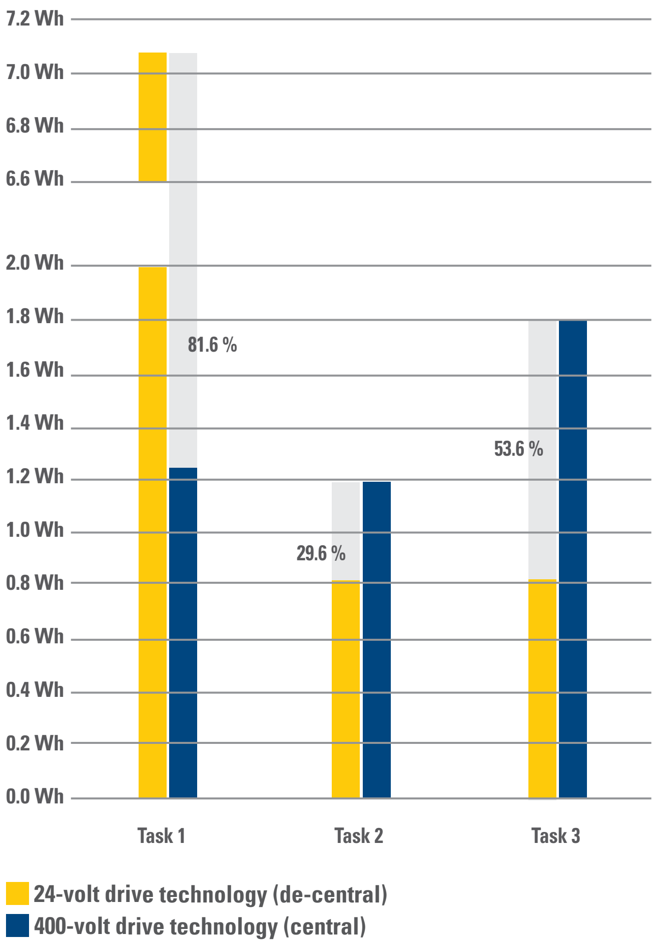
This task was used to test the intermittent mode described in section 2.2. For both forms of drive technology, the conveyor modules required to transport goods were turned on and then immediately switched off again once they were no longer needed. Here too, a low-load carrier weighing 50kg was transported and its energy consumption measured.

Task 3 - accumulation

To investigate the accumulation process, individual modules or the conveyor with the weight of one low-load carrier were switched off after 16m and then accelerated again with that weight for the purpose of further transportation.

The resultant energy consumption levels are shown in Figure 3 as follows.

Figure 3: Comparison of energy consumption for each layout when transporting 1 low-load carrier (50kg) for the 3 tasks



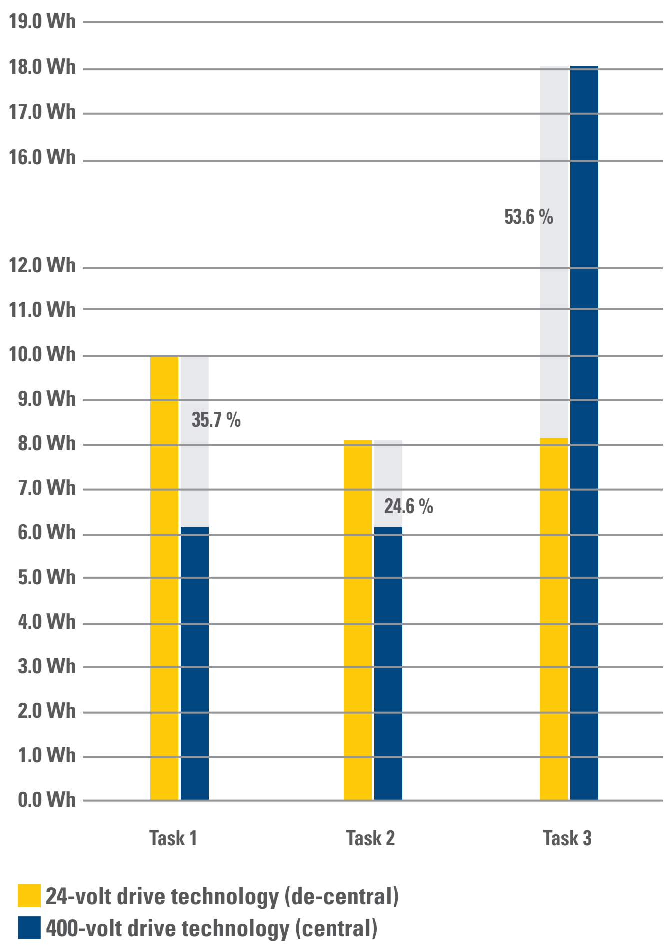
Given the amount of energy consumed for Task 1, when transportation occurred in continuous mode, the theory that less energy consumption was required using 400-volt technology was confirmed. This is primarily due to the fact that in the case of 24-volt drive technology, 40 modules and thus 40 motors were switched on at the same time and operated for the entire period the weight was carried, which was about 41 seconds. In the case of the 400-volt system, only 2 drive units were involved. The increased number of units within the drivetrain is reflected in the amount of energy consumed.

In the case of Task 2, proof is provided of more energy-efficient transportation when 24-volt technology is used for conveyance in intermittent mode. Unlike continuous operation, this mode of operation with 24-volt technology enables energy consumption to be reduced by 88% through intelligent control of energy consumption alone. Even when 400-volt technology is used in intermittent mode, by halving the length of the relevant conveyor required to transport the goods, the required energy consumption can be reduced by 9%, as shown in the sample layout.

Task 3 investigated what happens when the weights involved are decelerated and re-accelerated. It is clear here that in the case of 400-volt technology significantly more energy is required when switching on the longer conveyor lengths. For this task, there is a 53% difference between 24-volt and 400- volt technology.

When throughput is increased to 10 boxes of 50kg each (see Figure 4), Task 1 and Task 3 present a similar picture. By contrast with Figure 26, in the case of Task 2 it is clear that decentralized 24-volt drive technology requires about 33% more energy than 400-volt technology. It can thus be shown that when throughput is increased, both technologies should be explored in terms of the task and operating mode.

Figure 4: Comparison of energy consumption for each layout when transporting 10 low-load carriers (@ 50kg)



Overall these investigations show that the use of 24-volt drive technology over short conveyor distances in intermittent service and accumulating mode requires significantly less energy than comparable use of 400-volt drive technology. This means the decision whether to use 24-volt drive technology or 400-volt drive technology should be based on customerspecified throughputs and transportation tasks and the appropriate technology selected accordingly.

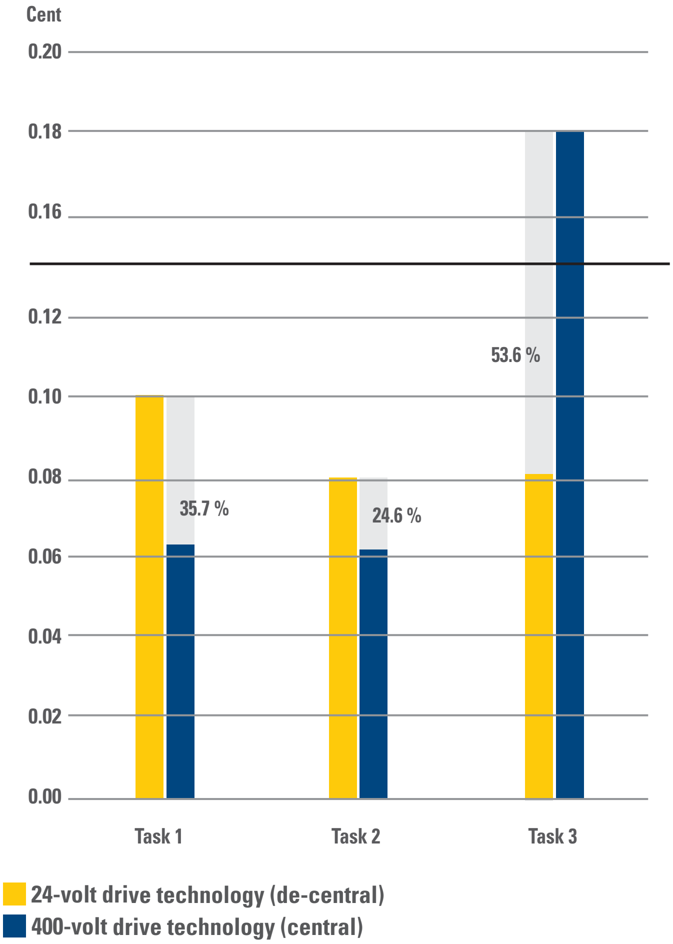
3.2 Costs

For a general roller conveyor system, various costs can be identified and quantified. The life cycle of the system can be used as a reference for classifying the costs. Manufacture of the system requires some initial outlay, operation or use of it leads to operating and maintenance costs and removal of it incurs recycling or waste disposal costs.

In this case, the initial outlay, operating and maintenance costs will be studied in more detail. Calculation of the recycling or disposal costs would require further detailed information about the material used to build the system, so no detailed analysis of that aspect will be included.

As far as the operating and maintenance costs are concerned, a direct link is identifiable between energy consumption and energy costs, see Figure 5.

Figure 5: Comparison of energy costs for 10 units loads (@ 50kg) for each layout



3.3 Flexibility

As mentioned earlier, 24-volt drive technology with decentralized drives and decentralized control units enables the use of shorter, modular conveyor segments. Intelligent use of intermittent service that, depending on the relevant transportation task, allows modules to be switched off when not in use, can increase the flexibility of such systems. As well as the aspect of reduced wear and tear and the possibility of longer maintenance intervals, the conveyor can be extended or remodeled in a similar way to a plug and play solution.

Roller conveyors thus no longer represent physical obstacles that are fixed in one position for several years but rather versatile systems that can be altered to meet the changing seasonal demands of a distribution center. Thanks to the added safety of low-voltage DC solutions, such changes can even be made by in-house staff.

3.4 Performance of a system

As described, there are various operating modes for roller conveyor systems – continuous operation and intermittent service. Depending on the required throughput, the two operating modes can be directly compared with each other and evaluated according to ecological and economic principles before one mode is selected.

For intermittent service, which can be used for throughputs of 100-1000 units per hour, it makes sense to use 24-volt technology with decentralized drives and decentralized control units in order to reduce not only the costs but also the energy consumption of the system. On the other hand, for continuous operation and piece numbers of several thousand units per hour, it pays to use 400-volt technology with central drives and controls.

4 Summary and outlook

In the course of this study, an in-depth comparison was made of 24-volt drive technology and 400-volt drive technology for roller conveyor systems. In principle, 24-volt and 400-volt technology can be described using similar classification criteria. These include the operating mode, the design of the drivetrain and the type of transportation of the units concerned. Based on this overview, which reflects the current state of roller conveyor technology, the advantages and disadvantages of 24- volt technology were able to be determined. Apart from safe usage, this technology stands out for the increased degree of flexibility derived from dividing one long conveyor into smaller, decentralized modules, which leads to energy-efficient operation and immediate cost savings. Over longer conveyor distances, the use of 400-volt drive technology is still indicated, since 24-volt drive technology involves a host of motors which cause increased maintenance and servicing costs and significantly diminished availability of the system as a whole. Given these advantages and disadvantages, a comparison between 400-volt and 24-volt drive technology was able to be drawn based on the criteria: "energy consumption", "costs", "system performance" and "flexibility". To validate the amount of energy consumed, six different scenarios were investigated.

The amount of energy consumed for a comparable layout when operated in continuous mode, intermittent service and accumulating mode was then investigated. When transporting a low-load carrier of 50kg it was able to be established that 24-volt technology used in intermittent service is 30% more energy efficient and when used in accumulating mode as much as 50% more energy efficient than comparable use of 400-volt drive technology. The costs of initial outlay can also be reduced through use of 24-volt technology in both accumulating conveyor modules and conveyor modules, provided the conveyor distances do not exceed a critical length. Flexibility increases as a result of dividing a conveyor up into smaller modules, since these represent a versatile solution that is able to grow with the company and can be adapted at any time to expand existing segments, or build new conveyor routes.

As a general rule, 24-volt drive technology can be used in many different application areas. Thanks to the fundamentally modular system of continuous conveyors, 24-volt technology is thus ideal for certain transportation tasks.

5 Authors

Karlsruhe Institute of Technology (KIT), Institute for Material Handling and Logistics (IFL)

In 1901 Georg Benoit founded a chair for lift and transport machines at the Technical University Karlsruhe. This was the first of its kind in the world and laid the foundations for the current Institute for Material Handling and Logistics. As well as its name, the institute's research and teaching priorities have continually changed in line with industrial developments. This has been achieved by maintaining close alliances with the industry and the various industrial associations at all times. In 2007, Kai Furmans took the helm of the IFL. Drawing on his industrial experience, Prof. Furmans expanded the institute's work areas of distribution and production logistics.

The areas of activity undertaken by the Institute for Material Handling and Logistics are conducted at the network, facility and machinery level. At the network level, the research field of logistics systems focuses on strategic questions such as the design of networks and supply chain management. At the plant level, the research field of Logistics addresses analytical and simulation models of internal and external production systems.

The research field of Conveying Technology was realigned following the retirement of Prof. Arnold in 2005, although the previous work areas of "Vibration Behavior of Material Handling Systems" and "Sortation Systems" were retained. In addition to those areas, emphasis began to be placed on the development of adaptable, de-centrally controlled material flow systems and modeling and development of measures to increase the energy efficiency of intralogistics systems.

The subject of the energy efficiency of intralogistics systems has been highlighted and advanced by the institute at various trade fairs and conferences.

The project "Analysis and Quantification of the Environmental Effects of Intralogistics Conveying Systems" enabled wide-ranging expertise to be developed on the effect of different types of material handling systems on energy consumption. Models of the relevant environmental aspects in relation to almost all types of intralogistics systems have also been developed and validated by the IFL.

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