SIEMENS

Ingenuity for life

Integrated Drive Systems

Efficient pump operation through the use of integrated drive systems

Pumps are used in practically every area of modern life. They consume around ten percent of the electrical energy generated worldwide, and according to a study by Coimbra University in Portugal, around two thirds of all pumps require up to 60 percent too much energy[1]. It is predominantly in the optimum configuration of drives and their respective load profiles that the greatest potential for savings exists. By changing over to high-efficiency pumping systems, four percent of the world's total electricity consumption could be saved.

Siemens offers a complete portfolio, from the drive train with integrated drive systems through tools for the configuration and calculation of savings potential to a range of services tailored specifically to individual applications.

This white paper provides an oversight into the possibilities available for saving energy through the use of new integrated drive systems for pumps.

[1] Almeida, A.T. et al.: Improving the penetration of energy-efficient motors and drives -In Cooperation with University of Coimbra / Department of Electrical Engineering (P); EDF (F); ENEL (I); ETSU (UK); NESA (Dk), Fraunhofer ISI(D), Coimbra(P).

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Legal framework conditions

The cost of energy accounts for the lion's share of a pump's life cycle costs at 82 percent. Maintenance and repair during running operation account for ten percent, while only eight percent is due to pure procurement outlay. This applies to almost all pumps used across wide-ranging fields of application – from water supply and wastewater treatment through the chemical and pharmaceutical industry to the mineral oil industry, plastics production and building technology. At the same time, 90 percent of all pumps operate not at optimum efficiency but in partial load operation, as many pumps are overdimensioned at the design stage due to misconceptions relating to safety concerns. As a result, they transport too high a volumetric flow relative to their design basis, which then has to be restricted again. This restriction or throttling process destroys a large amount of energy in the system: energy which has been supplied at high cost. This is why it is vital to make the right choices during the drive selection process.

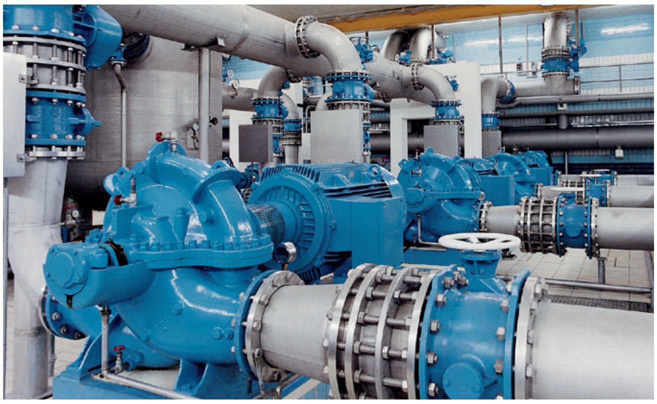
Standard induction motors have assumed a dominant position in the field of pumps, fans and compressors, with a market penetration of around 90 percent. This is due to the fact that self-starting induction motors are and will remain the most reasonably priced and reliable motor type for pump and fan applications in the foreseeable future. The new European standard DIN EN 50598 and the definition of system efficiency classes have meant that ever greater attention is being focused on the entire drive train. Whether an IE2 induction motor plus frequency converter, an IE3 or IE4 induction motor, an "IE4-comparable" synchronous reluctance motor or an "IE4-comparable" permanent magnet excited synchronous motor is used is decided by an in-depth advance analysis of the application in question and the customer's needs. However, by using converter-controlled motors alone, energy savings of up to 60 percent are possible as a result of speed-controlled operation.

The eco-compatible design standard EN 50598 sets out requirements in respect of energy efficiency and life cycle assessments for drive systems in electrically powered machines in the low-voltage range. It is based on the so-called ErP (energy-related products) EU guideline, which defines minimum standards for products relevant for energy consumption in industry, the service sector and domestic use. This means that the degree of efficiency or rather the losses of all products which use electricity to any appreciable extent have to be evaluated. The EN 50598 directs the focus away from the individual components and towards the system as a whole, extending energy efficiency requirements from the individual drive components to the system as well as the powered machine being driven.

This series of standards comprises three parts: Part 1 regulates the general requirements and defines the fundamentals for using the process in all drive applications. Part 2 provides indicators for assessing energy efficiency, and part 3 specifies considerations regarding essential environmental aspects for the product designs of drive systems. The second part of EN 50589-2 is of particular relevance for evaluating energy efficiency. It illustrates how to determine the losses of drive and motor systems. It does this by defining eight operating points, allowing manufacturers to determine the power loss of their products with a reasonable degree of effort, and offering them the benefit of reproducible test conditions. Users are provided with an overview of the power loss or power demands of applications on the basis of application-specific load profiles, which enables them to compare products in terms of their energy efficiency.

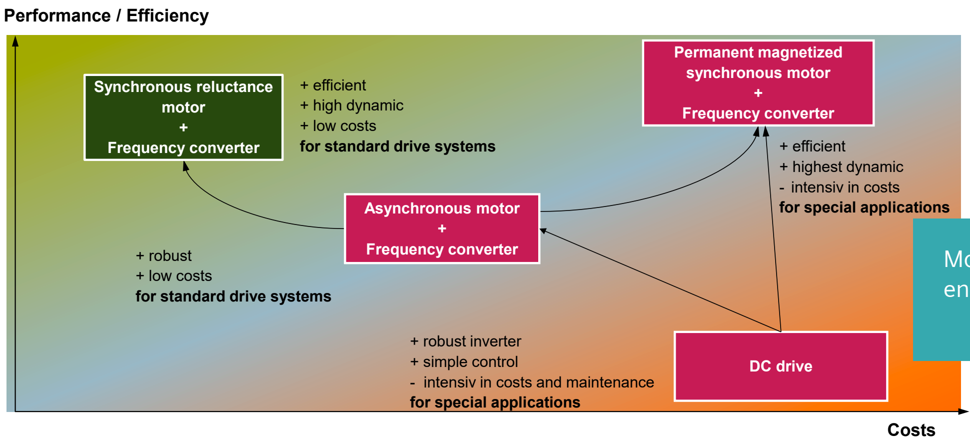
In March 2014, the IEC 60034-30-1 standard was published which defines efficiency categories for single phase and three-phase line motors at 50 and 60 Hz irrespective of their technology. This has since been extended to include the fourth efficiency level IE4. However, an exception ruling exists for motors which are fully integrated into a machine (such as pumps, fans and compressors) and which cannot be independently tested in practice. For drive applications involving frequency converters, an efficiency level classification has been defined in a separate standard on the basis of the complete drive system, whereby frequency converters are classified according IE0, IE1 and IE2 and drive systems according to IES0, IES1 and IES2. Higher figures denote lower losses here, in analogy to the already existing efficiency classes for motors.

Challenge: The transition from IE3 to IE4



The induction motor is the work horse of drive technology, and is set to remain so. It is the technology of choice for pumps, fans, compressors and other electrically powered machines. However, the attainment of higher efficiency levels poses a major challenge to manufacturers, as this requires them to reconcile maximum energy with material efficiency. To address this challenge, in the field of induction technology, Siemens has long since implemented a policy of using top quality materials and the latest production technologies in a bid to maintain compact motor dimensions. Despite their higher efficiency level, this means that the mechanical details of these motors remain constant. The only change is in terms of the electrical operating data. This offers enormous benefits wherever motors have to be installed into existing plants. However, it appears likely that the scope for energy saving using this approach will reach its limitations for induction motors seeking to comply with IE4. It will be highly difficult to achieve higher efficiency levels using this type of torque generation. The self-starting capability of induction machines practically prevents the achievement of higher efficiency levels at viable cost. As a result, achieving the highest super premium efficiency class IE4 will entail making fundamental technological changes.

The only scope remaining for the achievement of greater energy savings is by introducing drive solutions which have a different type of torque generation, such as permanently excited synchronous motors or synchronous reluctance motors. On the downside, these motors require the use of a frequency converter. Permanently excited synchronous motors are highly resource-intensive and dependent on pricing developments for the rare earth types used. An alternative would be synchronous reluctance motors which require no magnets, have a simple structure and can be implemented using a highly dynamic control. However, because they require more electrical power than induction motors, highly precise tuning of the motor and converter is required to keep system costs to a minimum. Taken overall, for any IE4 solution the more stringent demands made on energy efficiency should only be seen in the context of a system solution taking into consideration the entire drive train encompassing converter, powered machine, fan/pump and gear unit, as far higher energy savings are possible within this complete system than by considering the motor in isolation. Siemens provides a tool designed to enable calculation of losses at defined operating points in compliance with EN50598, which enables users to calculate and minimize their own power drive system (PDS) values. This means that right from the outset, the most suitable motion control and optimum motor technology can be selected. Factors such as fixed or variable speed, ambient temperatures, protection ratings, output, space requirement and so on also have a role to play here. If we consider the overall mechatronic system in respect of material input, mounting size and compactness in this context, it is possible to arrive at an acceptable compromise when considering the complete drive train as a whole.



Motor technologies for high efficiency level motors

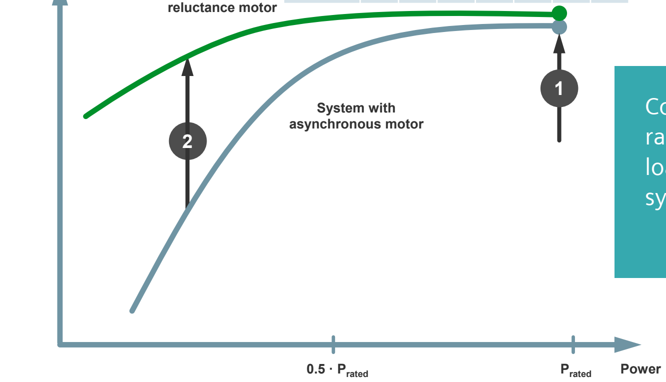
Synchronous reluctance motor – from niche to shooting star

It was in 1927 when Jaroslaw K. Kostko registered his patent for a synchronous motor in which torque in the rotor is generated exclusively by reluctance power. This means that the machine is neither fitted with permanent magnets, nor are there electrical windings in the rotor. The rotor is fitted with prominent poles and is made of highly permeable soft magnetic electric laminations. Practically the only losses sustained occur in the stator, which is idle and therefore easily cooled from the outside. As a result, suitably constructed reluctance motors are tolerant to overloading. Their simple, robust structure makes them ideal for operation in rugged environments. To create an integrated drive system, reluctance motors and converters are specifically coordinated to work together, and permit particularly efficient operation in comparison to induction motors.

The new drive series is based on the proven motor platform 1LE1 and has been coordinated to work with the Sinamics G120 converter. Simotics reluctance motors cover a wide output range from 0.55 to 30 kW and are available both with an aluminum housing for general ambient conditions (Simotics GP) and also with a grey cast iron housing for harsh environmental conditions (Simotics SD). In addition to the previously available shaft heights of 132 to 200, the motors are now also available in the shaft heights 80 and 120.

Reluctance motors offer a substantially higher efficiency level in the partial load range compared to induction motors with the same output. The synchronous principle means that the rotational speed remains constant, and a sensorless vector control ensures optimum performance. Both features enhance the controllability of the drive train.

kW	5,5	7,5	11,0	15,0	18,5	22,0	30,0
Reluctance*	91,9	92,6	93,5	93,9	94,2	94,5	94,9
IE4*	90,7	91,5	92,3	93,0	93,3	93,7	94,1
IE3*	88,0	89,0	90,1	90,9	91,5	92,0	92,6
IE2*	85,9	87,0	88,4	89,2	89,9	90,3	91,1



Comparison of energy efficiency at the rated operating point and in the partial load range for an induction motor and a synchronous reluctance motor

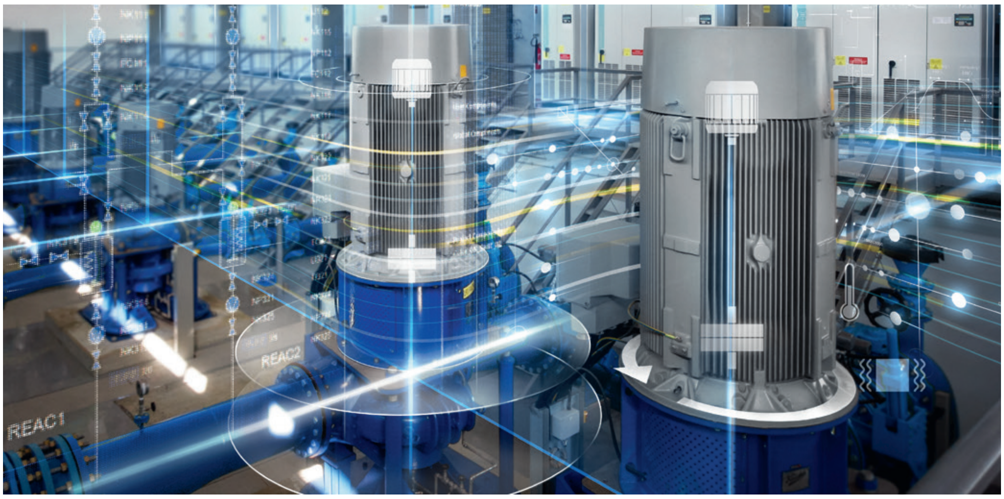
Ramp-up times are short thanks to the motor's low inherent moment of inertia combined with the vector control. The low losses in the rotor result in high thermal utilization of the motor. This allows the motor to permanently withstand loads of up to 120 percent (service factor 1.2).

In terms of its design and handling, the motor corresponds to 1LE1 induction motors. The standard Sinamics G120 converter incorporates vector control designed specifically for reluctance motors. Identification of the pole position prevents jerking movements of the drive on activation, and a flying restart enables synchronization with the running motor. Integration into the automation environment as part of the TIA concept is enabled by Profibus and Profinet interfaces.

The efficiency of a drive system is defined at the rated operating point to determine the efficiency class. If we compare IE4 induction motors here with a drive system using reluctance motors, the energy efficiency of the latter is significantly higher in the partial load range. This also means that with the "Blue Angel" load cycle used in the pump industry, far greater efficiency is achieved using the reluctance system. The initial costs of a system using a 15 kW reluctance motor will be recouped under these conditions in between five and thirteen months compared to IE3 or IE2 drive systems. The lower procurement costs compared to a system with IE4 motor make this a more economical option from the outset.

By optimizing induction motors towards greater efficiency (copper rotor, laminations), the inherent moment of inertia of IE3 and IE4 motors can be typically enhanced to twice the moment of inertia of synchronous reluctance motors. This becomes noticeable in dynamic applications with a higher overall torque and motor current. Synchronous reluctance motors have approximately the same inherent moment of inertia as three-phase induction motors of energy efficiency class IE1.

Integrated Drive Systems



With its Integrated Drive Systems, Siemens is also abreast of the trend for ever smarter drives with optimum motion patterns and faster networking. This is of particular significance against the backdrop of ever more rapid fundamental changes to production and process technologies. The special concept behind Siemens Integrated Drive Systems is the holistic approach to the entire drive train and driven processes instead of focusing on individual components. In the case of pumps, this approach is particularly beneficial given that the choice of the right drive variant and control decisively impacts on the energy efficiency of the entire process. This makes Integrated Drive Systems the key to tangibly improved energy efficiency and consequently lower operating costs, and this applies just as much to retrofit projects as to newly planned systems.

In order to leverage maximum energy-saving potential in pump drives, as well as supplying a broad spectrum of highly efficient drive components Siemens is primarily concerned to ensure their optimum coordination with converters and motors. This approach makes the achievement of extremely low losses in the partial load range and compliance with the highest efficiency class IES2 according to the new EN50598 standard a tangible reality. With its Integrated Drive System portfolio, Siemens offers drive systems to cover the entire performance range:

- Synchronous reluctance systems offer the best energy efficiency for lower output applications, both in the partial load range and at the rated operating point, achieving values which far exceed those required for IES2 classification. At the same time, they possess high performance density and dynamic response, precise sensorless speed control and high overload capability as key requirements for robust, reliable operation.
- For the upper output range, Siemens offers a high-performance drive system comprising a combination of a Simotics FD motor and Sinamics G120P converter specifically for pump and fan applications. As well as ensuring high energy efficiency, this solution benefits from low noise emissions.
- For speed-controlled applications not requiring a high level of energy, Siemens offers what it terms an investment-optimized solution at a minimized system price: The VSD10 drive system with G120, designed specifically for converter operation based on induction technolog.
- For pumps without speed control, motor starters and induction motors are the number one choice as an efficient and perfectly coordinated system solution. Motor starters from Siemens are IE3 and IE4-ready for operation with the latest motors. Their soft start and stop action reduces pressure fluctuations, prevents water hammers and reduces mechanical stress on installed systems.

Integrated Drive Systems

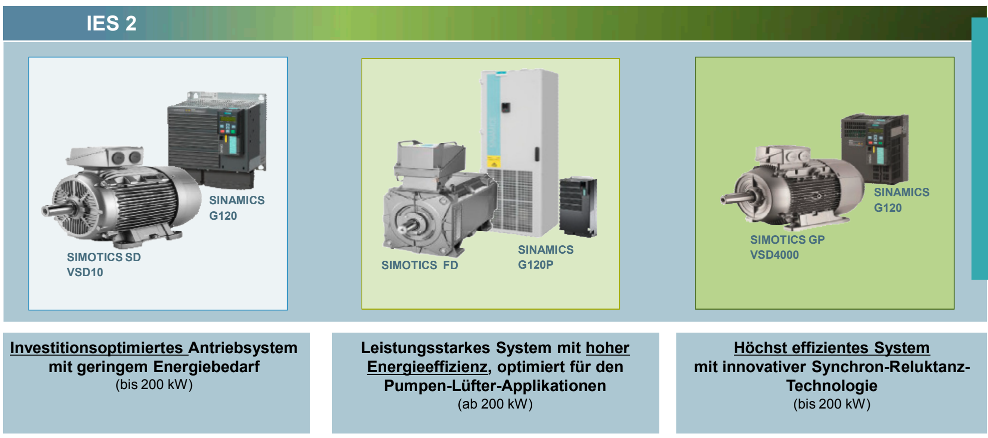
With Integrated Drive Systems, the same efficient, user-friendly mechanisms of the TIA Engineering Framework can be used for engineering, configuring and commissioning Sinamics and Simotion drive components. If these modular machines are designed right from the start using a CAD system such as NX and Teamcenter, time and cash savings of up to 40 percent are possible as a result of integrated simulation and optimization.

At the same time, Siemens has developed a platform strategy involving the repeated use of certain identical parts such as stators, end shields, terminal boxes and enclosures which have the greatest impact on production and would otherwise require a large number of new tools to be produced. For this reason, here the same dimensions are retained and different versions are created by using alternative winding variants or a choice of mechanical attachments and so on.

The Simotics product series is just such a basic platform. For the standard motors, an 1LE platform exists in an Asian and a European variant in compliance with the IEC standard, as well as a North American variant which complies to the NEMA standard. Customized adaptations are possible in both of these motors without the need for purchasing additional tools each time. The standards are not identical due to the use of different production techniques, for instance in Asia, but the framework parameters still remain the same.

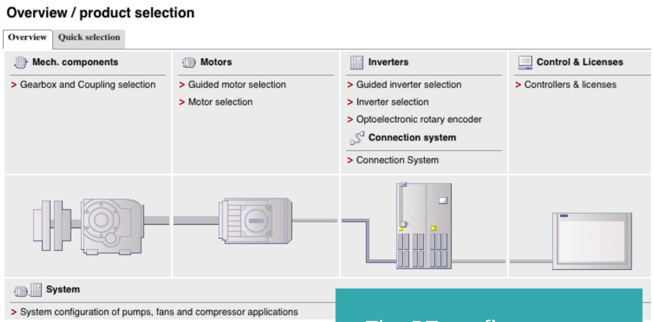
Taken overall, Integrated Drive Systems represent a consistent further development of the company's existing business strategy by using an overarching approach to combine its competence in the field of drive systems with Siemens industry expertise to enable the implementation of fully integrated and application-specific solutions. By integrating gear units, couplings, motors and converters, Siemens provides a drive system offering which is unique anywhere in the world. In addition, the company offers systems and services to cover the entire life cycle starting from the design process through commissioning and energy-efficient operation to final decommissioning.

Integrated Drive Systems not only optimize both the hardware and control in terms of efficiency and plant availability, they also generate additional scope for up to 15 percent lower maintenance costs over the entire life cycle. Services such as integrated diagnostics and remote servicing, drive train condition monitoring and worldwide aftersales support guarantee optimum availability during the operational phase.



Compliance with requirements stipulated by EN 50598 and classification in system efficiency class IES 2 (highest level)

Energy saving from the planning stage

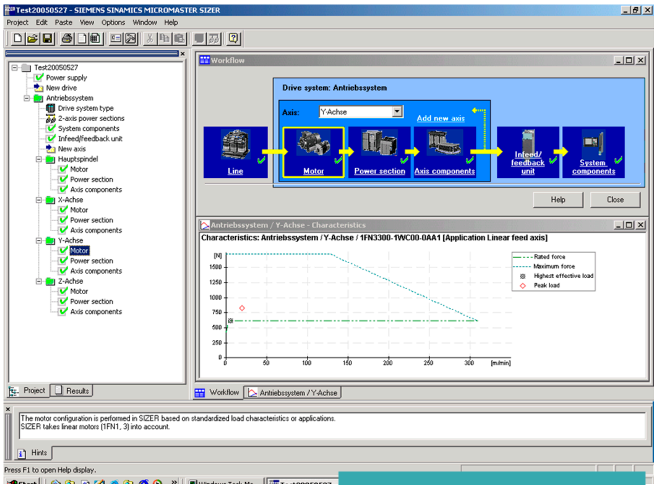


The DT configurator takes care of pump system configuration.

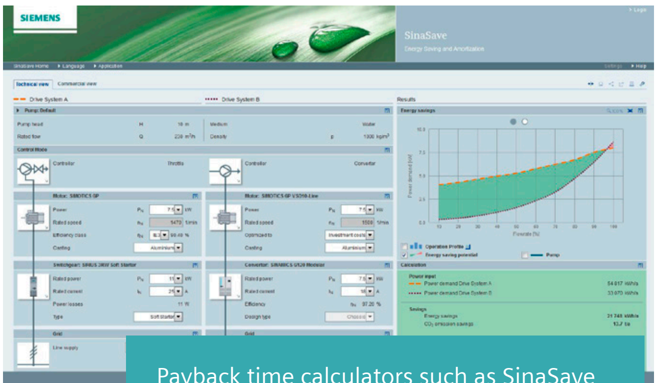
The Sizer engineering tool for Siemens Drives decisively simplifies the engineering process for low-voltage drive systems: Starting from the concrete application, the tool provides step-by-step support when defining the mechanical system and also configuring the necessary converters, motors and gear units. In addition to engineering results such as characteristics, technical data, installation drawings and dimension drawings, Sizer also calculates performance and load-dependent energy usage. This allows the entire drive train to be designed to the exact operating point for all movement tasks in a machine. During subsequent operation, this guarantees the highest energy efficiency and performance.

The Drive Technology Configurator (DT Configurator) provides support to users selecting the optimum products for an application – starting from gear units, motors and converters, through the associated options and components to controllers, software licenses and connection systems. Converters are selected on the basis of an application matrix without any need for expert knowledge. Product group pre-selectors enable targeted navigation through selection menus, 2D/3D models and data sheets, or alternatively direct product selection is possible by entering the article number for rapid, efficient configuration.

The web-based energy efficiency tool Siemens SinaSave calculates energy saving potential and payback times, and compares the results to different drive products or systems. All comparable drive systems and the relevant drive components are graphically displayed. Extended functions are also available with different control types and extensive product combinations of IDS solutions for pump and fan applications.



The Sizer offers fast, simple drive system engineering



Payback time calculators such as SinaSave compute the most energy-efficient drive technology

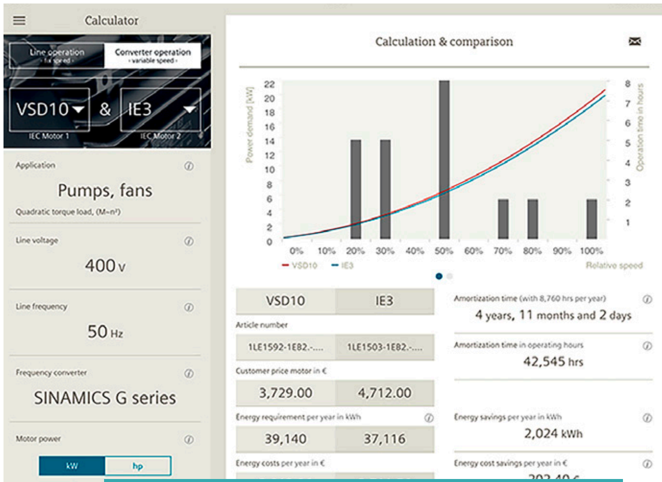
Energy saving from the planning stage

The TIA portal as a common engineering framework for factory automation

Significant time savings can be achieved during the design phase by engineering using the Totally Integrated Automation (TIA) portal and integration into an automation and control level. The drive engineering software Drive ES or Sinamics Startdrive as part of the TIA portal enable integration into the Profinet PROFIenergy protocol, as well as allowing designers to build components such as PID controllers for pressure regulation into the Simatic S7 control environment. As well as using the TIA portal, commissioning can also be quickly and simply performed using the Intelligent Operator Panel with pre-installed PLK-specific wizards. Leveraging the benefits of Integrated Drive Systems in any automation environment also enables smart plant process management, monitoring and diagnostics.

In operation, the PROFIenergy tool captures measured values directly at the relevant load. This allows loads to be coordinated and centrally shut down during production breaks, while other automation components remain operational. The motor management system Simocode pro monitors all important performance parameters of low-voltage motors, and can be integrated into a higher-level energy management system for use in automatic load management.

The Simotics EE Comparator enables a direct comparison to be made between Simotic low-voltage motors, both for fixed-speed and variable-speed operation. For fixed-speed operation, motors with different IE classifications such as IE1, IE2, IE3 and IE4 can be compared, taking into account individual operating time and motor loads. In the new variable speed operation module, the most cost-effective drive system can be determined based on a pump application with individual load profiles. A few key items of data are sufficient for the app to calculate energy efficiency, possible energy cost savings and the payback period. The values can be directly compared and the break-even point is graphically displayed. In the MEPS (Minimum Efficiency Performance Standards) module, local minimum efficiency requirements for low voltage induction motors for selected countries can be displayed.



The Simotics EE Comparator enables the comparison of different low-voltage motors

To guarantee maintenance of the drive train based on its current condition, Siemens offers services designed to continuously monitor key components which cover every conceivable requirement. Drive Train Condition Monitoring is a part of Integrated Drive Systems, and is designed to enable the timely detection and remedy of faults and impending damage in the drive system. The hardware and services provided are tailored to individual requirements.

Special functions save energy

Integrated energy-saving converter functions help ensure energy-efficient turbomachinery operation. ECO Mode, for instance, is a special function designed to reduce magnetic motor flux in the partial flow range, so making an additional contribution to reduced motor losses. If operating points are required in the rated motor output range, by using specially optimized switching patterns the entire drive train can be operated with minimal losses and optimized performance. The sleep mode enables the drive to switch on and off as required using parameterizable load curves. In addition, several drives can be connected using a cascade circuit depending on the output requirement. This means that only one drive is controlled, while the others operate on the mains supply at the rated point with maximum efficiency. The Profinet-based data interface PROFIenergy additionally allows unrequired loads to be switched off, helping to largely avoid costly load peaks.

The use of energy management systems in industry is gathering increased momentum. The reasons include not only rising energy costs and ever more stringent environmental requirements, but also endeavors by companies to gain certification to the DIN ISO 50001 energy management standard. The energy data management option package Simatic Powerrate for WinCC or Simatic PCS7 provides the necessary energy flow transparency through consistent energy data capture and processing in the control system at plant level. Simatic Powerrate logs all energy-relevant consumption data from across the plant, assigns it to different loads, visualizes it clearly and saves the data in the archive. This allows hidden savings potential to be reliably detected for targeted energy consumption optimization. For high load management, trend calculations of average current consumption can be performed and output limits defined. On the basis of a previously stored priority list, loads can be automatically switched on and off.

Reports in compliance with DIN ISO 50001 are automatically generated using Simatic B.Data and can be displayed in any web browser. If required, notifications can also be sent by email. Based on archive data, the tool generates an energy data forecast which then forms the starting point for energy optimization of production and shift calendars. Simatic B. Data also generates basic load profiles and key performance indicators, and compares data with similar production conditions. Siemens also offers this package in the form of a service agreement.

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