ENGINEERING
TOMORROW

Systematic energy saving
EC+ is the smart trend in HVAC drive technology

Increased efficiency through optimised components

The Danfoss EC+ concept

allows PM motors with IEC dimensions to be used with Danfoss VLT® frequency converters. Danfoss has integrated the necessary control algorithm in the existing VLT® converter series. This means that there are no changes for the operator. After entering the relevant motor data, the user benefits from the high motor efficiency of EC technology.

Advantages of the EC+ concept

- Free choice of motor technology: PM or asynchronous with the same frequency converter
- Device installation and operation remain unchanged
- Manufacturer independence in the choice of all components
- Superior system efficiency thanks to a combination of individual components with optimum efficiency
- Retrofitting of existing systems possible
- Wide range of rated powers for standard and PM motors

A key factor for energy savings in building services is the use of variable speed drives for compressors, pumps and fans. There are two decisive factors here: high efficiency of the machine and the motor and energy efficient application control.

In addition to increased use of higher efficiency induction motors, motors with permanent-magnet rotors are increasingly being used due to the higher efficiency. Motors with this technology are primarily known as ”EC motors“ in the HVAC sector. They operate on the basis of the brushless DC motor (BLDC) principle. They are typically used in external-rotor fans with low air throughput.

To allow users to benefit from the high motor efficiency of EC technology in all areas, Danfoss has refined its tried and tested VVC+ algorithm and optimised it for operating permanently excited synchronous motors (PNSMs). These motors, which are often referred to simply as permanent magnet (PM) motors, have the same level of efficiency as EC motors. They are, contrary to EC motors, available with the same mechanical construction as IEC standard motors and thus integrate easily in new as well as existing systems.

In this way Danfoss significantly simplifies the commissioning of PM permanent magnet) motors. It is just as easy as operating a standard induction motor with a frequency converter.

Advantages for users:

Familiar technology

Many users are familiar with operating standard motors with VLT® HVAC drives. The configuration settings are essentially the same. The user only needs to enter the motor data for the PM motor. Motor control by the building control system is also unchanged. It is therefore very easy to control different motor concepts in the same system. It is also possible to replace a standard induction motor with a PM motor. The training effort for the new PM technology is minimal.

Manufacturer independence

Users benefit from maximum flexibility thanks to the option of choosing different manufacturers for the necessary standard components. If difficulties arise in obtaining a spare part, for example, the same part may be obtained from a different manufacturer.

Optimum system efficiency

The only way to attain optimum system efficiency is to use the best possible individual components. Users who wish to save a significant amount of energy need more than just efficient components – they need an efficient overall system.

Low-cost service

Integrated systems often have the disadvantage that individual components cannot be replaced. Components that wear out, such as motor bearings, cannot always be replaced individually. This can become expensive. By contrast, the EC+ concept is based on standardised components that the user can replace individually. This keeps maintenance costs to a minimum.

Your energy bill: do you pay for components or for your system?

Improving efficiency is an easy way to reduce energy consumption. The European Union has therefore introduced minimum efficiency standards for certain technical devices. The best example in the area of drive technology is the introduction of minimum efficiency performance standards (MEPS) for three-phase induction motors. Motors that are marketed by manufacturers and users in the European Union must comply with defined minimum efficiency levels by specified dates.

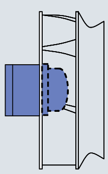
Timing	Power	MEPS	Alternative MEPS
Starting 16 June 2011	0.75–375 kW	IE2	–
Starting 1 January 2015	0.75–7.5 kW	IE2	–
	7.5–375 kW	IE3	IE2 + converter
Starting 1 January 2017	0.75–375 kW	IE3	IE2 + converter

No new three-phase motors may be marketed in the EU after the specified dates without suitable IE classification.

$$\eta_{system} = \eta_{converter} \times \eta_{motor} \times \eta_{coupling} \times \eta_{fan}$$

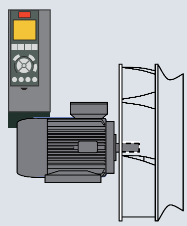
System efficiency is calculated according to VDI DIN 6014 by multiplying the efficiencies of the components.

Example efficiency calculation for a drive system with a 450 mm radial fan



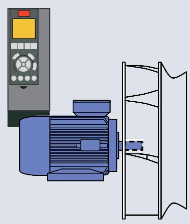
EC motor + integrated electronics + fan

η_{Drive} = 89%
η_{Fan} = 68%
η_{System} = **60%**



Induction motor + VSD + direct drive fan

η_{Drive} = 83%
η_{Fan} = 75%
η_{System} = **63%**



PM/EC motor + VSD + direct drive fan

η_{Drive} = 89%
η_{Fan} = 75%
η_{System} = **66%**

The stated drive efficiencies (converter x motor) are based on measurements, while the fan efficiencies are taken from manufacturer catalogues. Due to the directly driven fan, $\eta_{coupling}$ = 1

However, system operators must always take the entire system into account in order to ensure effective energy savings. For the simple reason that motors with a duty cycle less than 80%, for example, are excluded from this requirement. Frequent start and stop cycles with this duty mode result in increased energy consumption with IE2 motors which exceeds the savings during operation. This also applies to applications such as fans and pumps. In these applications, more energy can be saved by using a frequency converter for speed control than by using even the most efficient motor.

2 x 2 = 4? The devil's in the details

The decisive factor for users is not the efficiency of individual components, but rather the efficiency of the overall system.

A practical example can be seen in the EC versions of radial fans with external-rotor motors. To achieve extremely compact construction, the motor extends into the intake area of the impeller. This impairs the efficiency of the fan, and therefore the efficiency of the entire ventilation unit. As a result, high motor efficiency does not lead to high system efficiency.

What are EC motors?

In the HVAC market, the term ”EC motor“ is commonly understood to mean a specific type of motor, which many users associate with compact construction and high efficiency.
EC motors are based on the idea of using electronic commutation (EC) instead of conventional carbon brush commutation for DC motors. For this purpose, manufacturers of these motors replace the rotor winding with permanent magnets and incorporate commutation circuitry. The magnets boost the efficiency, whilst electronic commutation eliminates the mechanical wear of carbon brushes. As the operating principle is based on that of a DC motor, EC motors are also called brushless DC (BLDC) motors.

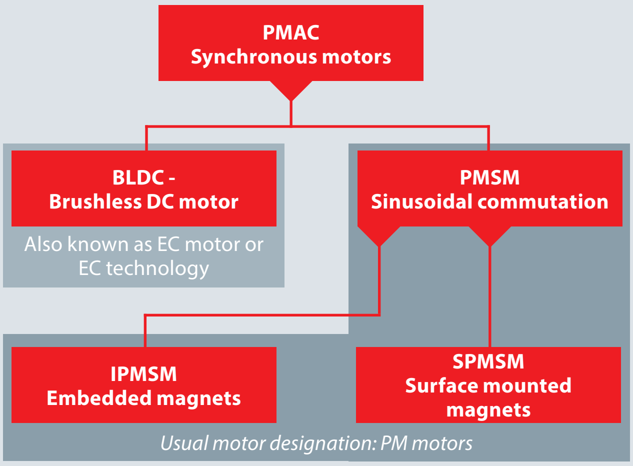
These motors are generally used in low power ranges of a few hundred watts. Motors of this type used for applications in the HVAC sector take the form of external rotor motors and cover a wide range of powers, presently extending to approximately 6 kW.

The technology

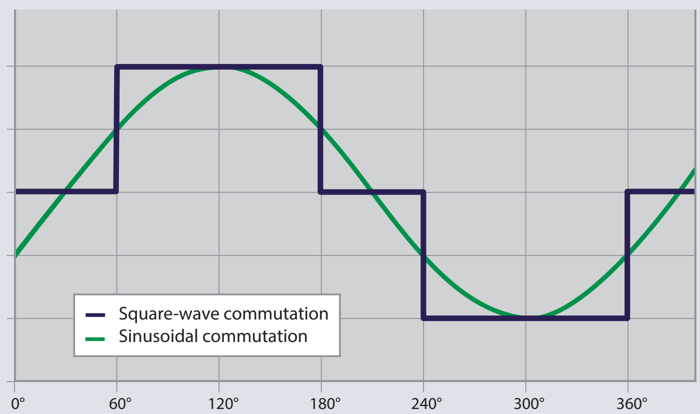
Due to the built-in permanent magnets, permanently excited motors do not need a separate excitation winding. However, they need an electronic controller that generates a rotating field. Operation directly from the mains is generally not possible, or in many case only with reduced efficiency.
To drive the motor, the controller (e.g. a frequency converter) must be able to constantly determine the current position of the rotor. Two methods are used for this, either with or without feedback on the current rotor position provided by a sensor or an encoder.

A basic difference with permanently excited motors is the waveform of the back EMF (Electro Motive Force). When operating as a generator, a motor with permanent magnets produces a voltage known as the back EMF. To ensure optimum control of this type of motor, the controller must match the waveform of the supply voltage as closely as possible to the waveform of the back EMF. In the case of BLDC motors, manufacturers use square-wave commutation due to the trapezoidal voltage waveform.

Permanently excited synchronous motors (PMSMs) have a sinusoidal back EMF and therefore operate with a sinusoidal voltage (sinusoidal commutation). A further distinction is made between sinusoidally commutated motors depending on whether the magnets are glued onto the rotor (SPMSM) or are integrated in the rotor laminations (IPMSM). Due to these somewhat unwieldy abbreviations, the term ”PM motor“ is often used in practice to refer to motors with sinusoidal commutation.



PMAC = Permanent Magnet AC; BLDC = Brushless DC; PMSM = Permanent Magnet Synchronous Motor; IPMSM = Interior PMSM (embedded magnets); SPMSM = Surface PMSM (magnets mounted on rotor)



PM motors
– an alternative to EC?

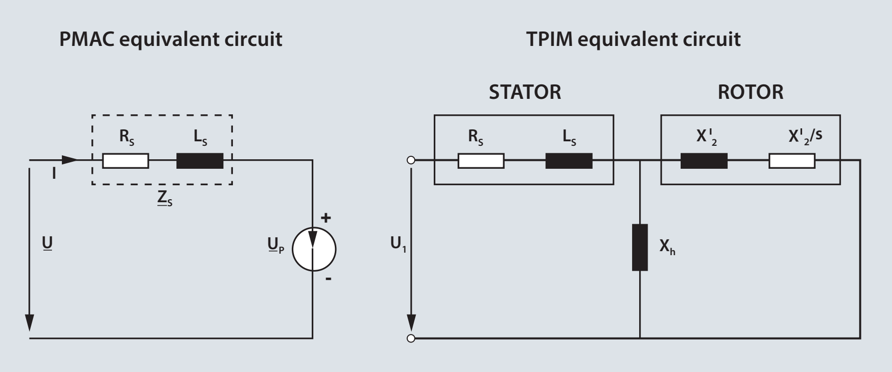
As with all technologies, each type of permanent magnet motor has its own specific advantages and disadvantages. Sinusoidally commutated PM motors are easier to implement from a structural perspective, but they have more complex control circuitry. The opposite is true of EC motors: Producing a square-wave back EMF is more difficult, but the structure of the control circuitry is simpler.

However, torque ripple is worse with EC technology due to square-wave commutation as are higher iron losses. In addition, the current is 1.22 times as large as with PM motors because it is distributed over two phases instead of three.

Efficiency

Using permanent magnets in the rotor virtually eliminates rotor losses in the motor. This results in increased efficiency.

The efficiency advantages of EC motors in comparison with commonly used shaded-pole and single-phase induction motors are particularly significant in the power range of a few hundred watts. This is also responsible for the fact that EC motors have extremely high efficiency. Three-phase induction motors are typically used for higher rated power in excess of 750 watts. Compared with these motors, the efficiency advantage is significantly less, and it decreases as the power level increases. EC and PM motor systems (electronics plus motor) with comparable configurations (mains supply, EMC filter, etc.) have similar efficiency levels.



TPIM = Three-phase induction motors
Comparison of the simplified equivalent circuits shows that PM/EC motors do not have any rotor losses. This yields a higher level of efficiency compared to three-phase motors.

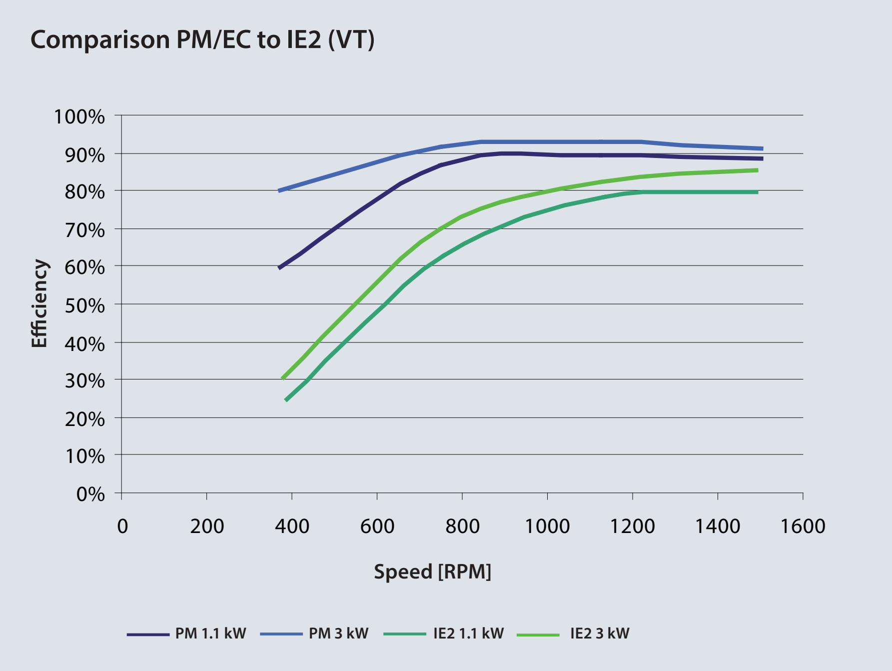


Diagram shows values measured by an independent university.
Losses for the required control electronics are included in the figures.

PM motors with standard IEC dimensions

Three-phase induction motors with standardised mounting dimensions and frame sizes specified in IEC EN 50487 or IEC 72 are presently used in many applications. However, most PM motors have been based on different designs. Servo motors are a typical example. With their compact design and long rotors, they are optimised for highly dynamic processes.

To allow the high efficiency of permanently excited motors to be utilised in existing systems, PM motors with standard IEC frame sizes are now also available. This allows older-model standard three-phase induction motors (TPIMs) to be replaced by more efficient motors in existing systems.

There are essentially two types of PM motor with IEC dimensions currently available.

Option 1:
Same frame size PM/EC and TPIM have the same frame size.

Example:
A 3 kW TPIM can be replaced by an EC/PM motor of the same size.

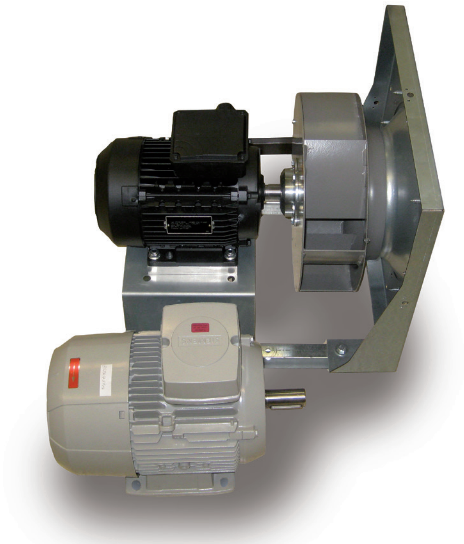
Option 2:
Optimised frame size PM/EC and TPIM have the same rated power. Since PMSM motors are usually more compact than TPIMs with the same rated power, a smaller IEC frame size is used than for the TPIM.

Example:
A 3 kW TPIM can be replaced by an EC/PM motor with the frame size of a 1.5 kW TPIM motor.

EC+: new technology in familiar surroundings

The Danfoss EC+ concept is designed to fulfil many user requirements. It allows PM motors to be used with standard Danfoss frequency converters. Users are free to choose the required motor from the desired manufacturer of their choice. This allows them to obtain the motor efficiency of EC technology at relatively low cost whilst retaining the option of optimising the entire system as necessary.

The combination of the best individual components in the same system also offers many advantages. By using standard components, users are not dependent on a particular manufacturer and the availability of spare parts is assured for a long time. No adaptation of the connecting dimensions is necessary with subsequent conversions or extensions. Commissioning is similar to the commissioning of a three-phase induction motor. Only the motor parameters are slightly different. As with the use of standard components, this also means that there is no additional training needs for commissioning or service staff.



Dimensional comparison of a standard three-phase induction motor (below) and an optimised PM motor (above)

Drive parameters are entered according to information on the motor nameplate and in the technical motor specifications sheets.

Saving energy: vital for our future or just marketing hype?

There are few subjects that users encounter more frequently than energy saving. Every new device, installation or solution saves more energy and is more environmentally friendly than the last one. However, this also shows that there is no ultimate solution for increased energy savings.

A high level of awareness promotes careful use of valuable energy

For a long time energy was very cheap, so many firms and consumers did not have any economic incentive to save energy. Attitudes to energy use started to change only after energy prices rose sharply, making it an expensive commodity.

Thermostatic radiator valves, which have now become standard equipment in buildings, are a good example of this trend. When Danfoss first presented them in the 1950s, they drew very little interest. It was not until the energy crisis at the beginning of the 1970s with rising energy prices that demand suddenly increased dramatically.

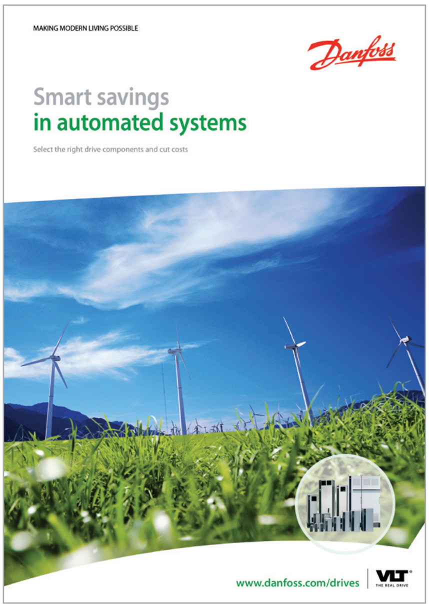
Today demand is boosted by energy costs as well as a high level of environmental awareness and political measures. The introduction of compulsory minimum efficiency levels, for drive systems among others, is intended to increase the energy efficiency of technical products.

Are there any simple solutions?

Considerable savings can be made quite simply in many areas; other savings require more effort and specialised knowledge. An example of this is energy-saving lamps. Energy consumption is usually reduced by replacing standard light bulbs with energy-saving lamps.
However, the fact that different types of energy-saving lamps are available at different prices indicates that not all products are the same. Mains interference, the colour spectrum of the lamps, allowable start-up processes and problems with disposal due to mercury are some of the ”side effects“ which are only revealed at a later stage.

Applications and systems matter

If an energy-saving lamp is installed in a room which requires light only very occasionally (e.g. a cellar), it is questionable whether this is worthwhile from an environmental or economic perspective. Although it is generally advisable to increase the efficiency of individual components, this may not make sense in the context of the overall system.
Danfoss describes a number of important aspects of energy saving with drive systems in the brochure “Smart savings in automated systems“. This applies to a wide range of drive technology applications, including major applications in building services.



What do users need to consider for speed control of fans and pumps? These and other aspects of energy savings in drive systems are addressed in the brochure “Smart savings in automated systems“

1.5 million

VLT® HVAC Drives installed worldwide saving more than the annual energy consumption of 60 million households.

What VLT® is all about

Danfoss VLT Drives is the world leader among dedicated drives providers – and still gaining market share.

Environmentally responsible

VLT® products are manufactured with respect for the safety and well-being of people and the environment.

All activities are planned and performed taking into account the individual employee, the work environment and the external environment. Production takes place with a minimum of noise, smoke or other pollution and environmentally safe disposal of the products is pre-prepared.

UN Global Compact
Danfoss has signed the UN Global Compact on social and environmental responsibility and our companies act responsibly towards local societies.

EU Directives
All factories are certified according to ISO 14001 standard. All products fulfil the EU Directives for General Product Safety and the Machinery directive. Danfoss VLT Drives is, in all product series, implementing the EU Directive concerning Hazardous Substances in Electrical and Electrical Equipment (RoHS) and is designing all new product series according to the EU Directive on Waste Electrical and Electronic Equipment (WEEE).

Impact on energy savings
One year's energy savings from our annual production of VLT® drives will save the energy equivalent to the energy production from a major power plant. Better process control at the same time improves product quality and reduces waste and wear on equipment.

Dedicated to drives
Dedication has been a key word since 1968, when Danfoss introduced the world's first mass produced variable speed drive for AC motors – and named it VLT®.

Twenty five hundred employees develop, manufacture, sell and service drives and soft starters in more than one hundred countries, focused only on drives and soft starters.

Intelligent and innovative
Developers at Danfoss VLT Drives have fully adopted modular principles in development as well as design, production and configuration.

Tomorrow's features are developed in parallel using dedicated technology platforms. This allows the development of all elements to take place in parallel, at the same time reducing time to market and ensuring that customers always enjoy the benefits of the latest features.

Rely on the experts
We take responsibility for every element of our products. The fact that we develop and produce our own features, hardware, software, power modules, printed circuit boards, and accessories is your guarantee of reliable products.

Local backup – globally
VLT® motor controllers are operating in applications all over the world and Danfoss VLT Drives' experts located in more than 100 countries are ready to support our customers with application advice and service wherever they may be.

Danfoss VLT Drives experts don't stop until the customer's drive challenges are solved.

Danfoss VLT Drives, Ulsnaes 1, DK-6300 Graasten, Denmark, Tel. +45 74 88 22 22, Fax +45 74 65 25 80
www.danfoss.com/drives • info@danfoss.com