APPLICATION GUIDE

ACH580

Alternative motor technologies in HVAC

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The right choice pays dividends

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Figure 01. IEC low voltage motors, 0.09 to 1,000 kW, frame sizes 56 to 450

With an abundance of alternative motor technologies available for HVAC systems, it pays to make the right choice for your installation. Induction motors and the ACH580 form a reliable combination as induction motors are used throughout the industry in many HVAC applications and in a wide range of environments. ACH580 drives fit perfectly together with this type of motor by providing comprehensive functionality yet simple operation. IE4 motors and our VSD provides a perfect foundation for energy efficiency, while delivering capabilities such as exceeding nominal motor speed when maximum power is needed. The drive towards higher efficiencies is driving fundamental changes in the motor technologies. This application guide helps you to understand the differences in motor technologies and how they suit the needs of the HVAC applications.

Benefits

- Tried and trusted technology for years of trouble free operation
- ABB drives comprehensive service network and spare parts coverage
- Motor-drive packages designed and specified to be ‘fit for purpose’ for a variety of HVAC applications

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Figure 01.

Energy efficiency regulations and standards

Nowadays, more and more investments in the advancement of electric motors are made in order to reach new levels of efficiency and achieve high energy savings even under demanding conditions. Electric motors play a key role in our everyday businesses and lives. They move and run basically everything we need for business or pleasure. All these motors run on electricity - 28 to 30 percent of all electrical energy is converted to mechanical energy in electric motors. In order to provide torque and speed, they need the corresponding amount of electric energy. A motor's speed should match exactly what is required by the process in order to avoid dissipation of energy.

By using more efficient motors it would be possible to realize huge savings in energy and carbon dioxide emissions. This has prompted governments to introduce MEPS (Minimum Energy Performance Standards), setting mandatory minimum efficiency levels for low voltage electric motors.

MEPS are already in force in several regions, but they are still evolving and might differ in terms of scope and requirements. New countries are planning to adopt their own MEPS and others (US, China, EU) have even plans for implementing MEPS for high voltage motors.

The European Commission has released Ecodesign regulations to amend EU MEPS, in particular EU327/2011 (for fans 125 W - 500 kW) and EU547/2012 (for pumps). These regulations should ensure a more efficient movement of air and water and force pump and fan manufacturers to provide solutions that are designed to meet the defined minimum efficiency levels.

Both customers and suppliers have to make sure that their businesses comply with the outlined rules. The table below shows the existing regulations and standards. Regulations are defined by the European commission and local governments and are part of official legislation. They clearly build the framework for doing business in a specific country and lay down the minimum efficiency requirements. Standards specify efficiency classes in particular for direct on line (DOL) motors, drives (CDM) and for motor-drive packages (PDS).

Eco-design directive 2009/125/EC Establishing a framework for the setting of eco-design requirements for energy-related products					
Customer related regulations					
Water pumps Commission regulation (EU) No 547/2012 of 25 June 2012	Industrial fans Commission regulation (EU) No 327/2011 of 30 March 2011	Compressors Commission regulation (EU) Work ongoing	Electric motors Commission regulation (EU) No 640/2009 of 22 July 2009 amended with Commission regulation (EU) No 4/2014 of 6 January 2014	Frequency converters and power drive systems Commission regulation (EU) Open	**Comission regulations**
		ISO 1217:2009 Displacement compressors – Acceptance tests	IEC 60034-30-1 Rotating electrical machines Part 30-1: Efficiency classes of line operated AC motors (IE code)	EN 50598-2 Eco-design for power drive systems, motor starters, power electronics & their driven applications Part 2: Energy efficiency indicators for power drive systems and motor starters	**Standards**
			IEC 60034-30-2 Rotating electrical machines Part 30-2: Efficiency classes of frequency operated AC motors Work started	EN 50598-1 Eco-design for power drive systems, motor starters, power electronics & their driven applications Part 1: General requirements for setting energy efficiency standards for power driven equipment using extended product approach (EPA), and semi analytic model (SAM)	
				IEC 61800-9-1 and -2 (50598-2) "Eco-design for power drive systems, motor starters, power electronics & their driven applications" Work ongoing	

Energy efficiency of drives and systems

Increasing efficiency of drives
Nearly 70 percent of all industrial electrical energy use goes to powering electric motors. These motors are the workhorses of business, from pumps moving fluids to fans moving air to compressors, conveyors, and every type of machine that depends on rotational force to get the job done.

These motors are the key to help you reduce your energy use and CO_2 emissions, or even find more energy efficient solutions for your customers. That's why we've developed a wide portfolio of low and medium voltage AC drives, as well as a portfolio of DC drives. Drives (variable speed drives or variable frequency drives) are designed to run your motors based upon the current demands of your processes rather than running them at full speed and reducing output using mechanical controls like throttles, dampers or gears.

To get the best efficiency out of your system, it is also important to take into consideration different types of motors. Matching the drive with a suitable motor can increase efficiency levels even further, saving you even more energy and money.

Drive efficiency by IE class
The European Commission has released the EN 50598 standard which defines the IE classes for complete drive module (CDM) and the new IES classes for the power drive system (PDS). It applies to drives and motor and drive packages with a voltage range of 100 to 1000 V, and a power range up to 1000 kW.

EN 50598-1 takes an approach on the complete drive module (CDM) where the manufacturer gives information about the losses at different operating points. The IE class is defined by the nominal operating point. For the customer the CDM IE class is not very relevant, as the drive and the motor need to be tested as a combination to show meaningful results for the complete system.

Package efficiency with IES class
The EN50598-1 and IEC61800-9-2 standards outline efficiency classes for drive-motor systems and allows a comparison of different drive-motor packages. The best way to compare total efficiencies is with specific motor-drive combinations in the operating points where the application system will be running.

Extended product efficiency
EN 50598-2 defines energy efficiency indicators ("IE" and "IES") for the complete drive module (CDM) and the combination of the CDM and motor to form a "power drive system" or PDS. The standard includes methodology to determine the CDM and PDS losses, assigning the IE and IES values. This standard applies to motor driven equipment from 0.12 to 1,000 kW (100 to 1,000 V).

Compatibility with different kinds of motors

Many types of electric motors are currently available for use in commercial HVAC applications and have to be considered in order to achieve best possible results. All different motor types have both advantages and disadvantages and it is important to evaluate them against the requirements of the specific HVAC application. It makes sense to have a closer look into the different motor technologies as choosing the right motor at the beginning can save a lot of energy and cost in the long run.

Induction motors (IM)
Induction motors are commonplace in industry due to their power and efficiency. The absence of commutator or brushes also make them reliable and relatively maintenance-free and there are constant efforts to make them increasingly efficient. However, these motors do have some drawbacks. The asynchronous speed results in conductor losses in the rotor that negatively affect efficiency, generate more heat and result in warmer bearings with a reduced lifetime.

Permanent magnet motors (PM)
The construction of PM motors is based on the standard induction motor design. The rotor magnetization is enabled by the use of permanent magnets which are mounted on the surface of the rotor or actually embedded within. The PM motor is synchronous, meaning that the rotor rotates in synchronism with the magnetic field. The motors can simplify drive systems by effectively eliminating the need of speed reduction devices and providing more precise speed control. They are designed exclusively for frequency converter supply, where they provide high speed accuracy even without speed sensors because they are synchronous motors without rotor slip. In addition, PM motors do not generate as much heat as IM motors, resulting in lower rotor/bearing temperature and thus in longer insulation and bearing lifetimes. PM motors provide more torque for the same size of package or the same amount of torque in a smaller package.

However, the use of rare-earth elements (REEs) is usually quite expensive and the costs can vary greatly. In addition, their strong magnetic rotor field can make servicing – a key feature of a mainstream industrial motor – more difficult. Another disadvantage is the generation of potentially dangerous voltages to the motor terminals due to the free movement of the motor shaft. This is particularly relevant in ventilation applications.

Synchronous reluctance motors (SynRM)
SynRMs in combination with the today's sophisticated VSD control electronics make it possible to fully exploit these super-efficient electrical machines. In SynRMs, the rotor is designed to produce the smallest possible magnetic reluctance (the resistance to the flow of a magnetic field) in one direction and the highest in the perpendicular direction. The rotor turns at the same frequency as the stator field (as in the permanent magnet motor).

SynRMs perform better than conventional induction motors. They can be designed for highly efficient performance or to provide a higher power density for a smaller footprint than an equivalent IM. They need less maintenance, have a reduced inertia and are extremely reliable. Without magnets and without a cage, the rotor construction is simpler than either IMs or PM motors. The lower operating temperature of a SynRM has multiple benefits – including longer insulation life and extended bearing greasing intervals across the lifetime of the product, so avoiding motor outages.

ABB's SynRM motor hardware is identical to that of ABB's equivalent IMs. Only the rotor is different. This simplifies spare part provision and maintenance. It also means that replacing an existing IM with a SynRM is easy. Recent advances in the efficiency of ABB SynRMs has been so rapid that existing IE efficiency classifications have been outstripped. While the EU requires IE3 as a minimum, ABB already has a catalog of IE4 SynRMs. The potential of SynRMs has not yet been fully explored and higher efficiency levels are still quite feasible.

Ferrite assisted synchronous reluctance motors
In 2014, ABB was already giving an outlook to the next step in the SynRM product range, when a 15 kW model with an IEC shaft height of 160 mm ("SH160") was showcased at Hanover fair as the first public ABB demonstrator of an "IE5"-enabling technology. IE5, at the moment undefined by IEC 60034-30-1, is

envisaged to have 20 percent lower losses than the IE4 class.

A unique feature of this motor is that it uses ferrite (iron oxide, Fe_2O_3) magnets, which are generally more cost-effective and more easily available than rare-earth permanent magnets. Their use results in a more economical and ecologically sustainable product. Ferrites have been used before in low power motor applications, but in industry a ferrite-based motor alone could not compete against an IM. A motor has to have a dominant reluctance character, assisted by ferrite magnets, to be strong enough. With the rapid development and increasing intelligence of VSDs, full control and utilization of these motors will be possible – as in the case of SynRMs. These motors are designed for customers chasing ever- higher efficiency and power density levels. Moreover, with power factor levels equal to PM motors and excellent field- weakening properties, it will enable new, more compact motor-plus drive package solutions. ABB is working to develop a range, from 0.55 to 18.5 kW, targeting, for example, the HVAC market.

Electrically commutated motors (ECM)
These motors are typically tightly integrated drive and motor combinations. The motor is often a ferrite synchronous motor, but sometimes other magnetic materials are used. It has similar characteristics to a PM motor as the rotor is running at the same speed as the magnetic field. The biggest differences are due to the tight integration of the drive electronics to the motor. The modulation of the drive and the output current of the inverter are optimized to the motor resulting in a compact package.

This means that the whole unit has to be replaced if anything fails, whether it is the bearings, capacitor, motor insulation or IGBT. Package designs are manufacturer specific, so sourcing the spare unit can take time. Additionally, the inverter is typically designed to be low cost, which means poorer performance with supply voltage sags and dips, higher harmonic content on the supply network, and a lack of HVAC specific features, such as BACnet communication and override function.

	Induction motor	Synchronous reluctance motor	Ferrite assisted synchronous reluctance motor	Permanent magnet motor	Electronically commutated motors (ECMs, EC motors)
Typical power range	Wide power range	IE4 SynRM 5.5 - 315 kW (ABB)	Focus 0.55 - 18.5 kW (ABB)	Wide power range (depending on manufacturer)	0.05 - 15 kW
Typical efficiency range	Up to IE3, some IE4 available	Up to IE4	Up to IE5	Up to IE4	Typically between IE3-IE4
Speed range above FWP	Up to 2 x nominal speed	1.4 x nominal speed or more	Up to 1.5 - 2 x nominal speed	Up to 1.2 x nominal speed	Speed range defined by integrated application mechanics
DOL/VSD	DOL and VSD	VSD, special control SW needed	VSD, special control SW needed	VSD, special control SW needed	Built-in VSD for speed control is required
IEC frame comparison to IE2 induction	IE3 and IE4 typically bigger	Same or smaller	Same or smaller	Same or smaller	Typically much shorter with wider diameter, tailored to the application mechanics
Applications	All industrial applications such as pumps, fans, compressors, conveyors, extruders, winches, cranes	Most industrial applications including pumps, fans, compressors, conveyors, extruders Check control availability	Ideal for applications with highest efficiency demands Check control availability	Most industrial applications where high efficiency is important Check control availability	Pumps, fans
Advantage	- Well-known, robust and proven technology - Simple and easy to maintain	- High efficiency and reliability - Higher power density - Cool motor - Lower bearing temperature and longer bearing lifetime - No rotor-cage - Magnet-free, can be controlled without encoders - Cost-efficient solution.	- Highest efficiency class - High power factor and low current demand - Ferrites are more cost-efficient than rare-earth permanent magnets	- Significant energy saving potential - Permanent magnets reduce rotor losses and increase motor efficiency - Compact motor - Low noise levels - Low bearing temperature	- One package with everything integrated - Quick to install with only power and reference or Modbus connection required - EMC compliant installation
Disadvantage	- Difficult to reach highest efficiency levels - Higher bearing temperature compared to others	Lower power factor and higher current demand that may impact drive size (not visible on the network side)	- Generates voltage on the terminals without locked shaft - To perform system maintenance, the installer needs to know that the shaft cannot rotate eg, due to airflow in duct	- Expensive rare-earth PM materials - Generates dangerous voltage on the terminals without locked shaft - To perform system maintenance, the installer needs to know that the shaft cannot rotate eg, due to airflow in duct	- No application-specific functionality - Limited under-voltage performance to voltage dips - High harmonics (typically comparable to no-choke VSD) - Not stocked universally, longer delivery times - Lack of BACnet support makes integration to building automation more difficult (only Modbus RTU support)
Maintenance	- Easy - No magnetic forces - Test run can be done direct-on-line - Universally available from anywhere	- Easy - No magnetic forces - Test run requires a drive	- Easy - Low magnetic forces - Embedded magnets, no magnet damage during rotor removal - Test run requires a drive	- Difficult - Strong magnetic forces - Removing rotor from the stator is difficult and requires special toolsl - Potential magnet damage in case of surface mounted magnets - Test run requires a drive	- Replace everything at once if any sub-component such as bearings, semiconductors, capacitors, motor insulation, etc. fails - Not stocked widely, longer lead times

The highest efficiency with motor/drive packages

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Figure 02.
Indicative efficiency of the drive and motor combination is measured with identical inverter at 15kW power level with four different motors

Every technical solution to system configurations has its own benefits and drawbacks. In order to reach optimum system efficiency, the efficiencies of the individual components have to be optimized in a manner that does not cause more losses to other components within the system. Selecting the best combination of individual components ensures the highest system efficiency is achieved. The total system, or package efficiency, inclusive of all components, is what matters most. In the case of an air handling unit, it is the power taken from the network to drive the motor to mechanical load to the motor/drive coil efficiency to the airflow and pressure itself.

ηsystem = ηdrive · ηmotor · ηcoupling · ηfan · ηcoil

This requires testing and having the information and freedom to choose the total combination of equipment to offer the best performance. The best total efficiency is built from the usage of best components in combinations that have been verified.

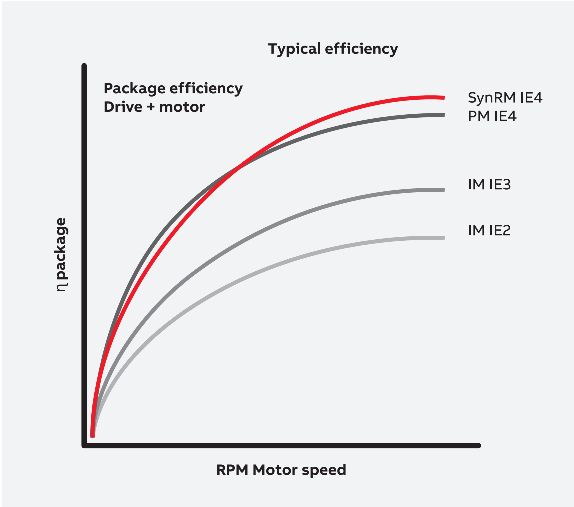

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Figure 02.

More requirements than just efficiency in HVAC

Efficiency alone does not cover the requirements of the applications. Customers need to consider the integration of their components into other existing, or new, equipment and systems. Pipes and ducts can create limitations that are not planned in the initial design. IEC size motor and drive combinations have the ability to fit in existing installations and offer the user and designer flexibility to correct for the unforeseen challenges of "system effect" in duct or pipe. With existing ductwork the ability to generate enough static pressure is essential and traditional motor/drive packages have the ability to meet the required design criteria and pressure requirements without overdimensioning.

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For further information please contact your local ABB representative or visit:

www.abb.com/drives/HVAC
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3AUA0000203128 REV C EN 28.9.2017 *20149