CPD FUNDAMENTALS » SERIES 12 » MODULE 5 » PUBLISHED IN EIBI MAGAZINE OCTOBER 2014

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MARK THROWER MANAGING EDITOR

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MODULE FIVE

MOTORS & DRIVES

Get the best from motors and drives

Chris Burgess, director, Alpha Energy Consultancy

In a single year, the cost of electricity to power a motor can be up to ten times its purchase cost – this means a motor costing £500 to buy can over a ten year life of continuous operation, consume electricity worth £50,000.

Electric motors, although widely used throughout industry and commerce, are often hidden from view and opportunities to save energy can easily be overlooked. But out of sight should not mean out of mind.

This CPD module provides an overview of induction motor technology and the current EU Regulation relating to motor efficiency and finally introduces a number of basic energy saving opportunities.

There are many types of electric motor to suit specific applications but by far the most common type in commerce and industry is the AC induction motor. Although small AC motors are sometimes single-phase 240V machines most are three-phase 415V because of the superior performance.

The main components of an induction electric motor are the stator, rotor, mechanical casing and cooling fan mounted on the rotor shaft. The stator windings carry the load current which creates a rotating magnetic field. This induces a current in the rotor forming a second magnetic field. The two magnetic fields interact so that the rotor starts to rotate and a torque is produced.

The motor runs at a single speed depending upon the AC frequency (50Hz) and the number of phase windings (poles). However, the actual rotational speed of the motor is slower than that of the magnetic field in the stator. The difference in speed is called slip – as the load increases on the motor shaft (rotor) the slip increases to produce a higher torque.

The efficiency of an electric motor is the ratio of shaft power to electrical energy input. There are a number of different energy losses, mainly emitted as heat, which reduce the efficiency below 100 per cent.

Two energy losses remain constant regardless of motor loading and comprise iron losses which are caused by the energy required to overcome resistance to the varying magnetic fields in the core material, plus bearing friction and cooling fan air resistance. Other losses vary with the motor load as a result of magnetic flux leakage and losses caused by heating from the current flow through the stator windings and rotor conductor bars.

To meet the demands for higher efficiency, manufactures have improved motor design and construction methods to reduce these losses.

Efficiency classes

The International Electrotechnical Commission (IEC) has introduced standards relating to the efficiency of electric motors. IEC Standard 60034-30-1:2014 “Rotating electrical machines - Part 30-1: Efficiency classes of line operated AC motors” defines efficiency classes for single-speed AC motors and establishes a set of minimum efficiency values based on frequency, number of poles and motor power.

It amends an earlier version of the standard to widen the scope of motors subject to efficiency classes and introduces the new highest IE4 efficiency class. The most notable types of motor not covered by the latest version are power-drive systems and motors completely integrated to an application or frequency converter. A separate standard, IEC 60034-30-2 will be soon issued to define efficiency classes for motors for use on variable frequency supplies.

The standard defines four IE (International Efficiency) classes:

- standard efficiency IE1;
- high efficiency IE2;
- premium efficiency IE3;
- super premium efficiency IE4.

Figure 1 shows the minimum efficiency values related to each IE classification for 50hz 4-pole motors from 0.12 to 1,000kW.1

Minimum efficiency levels

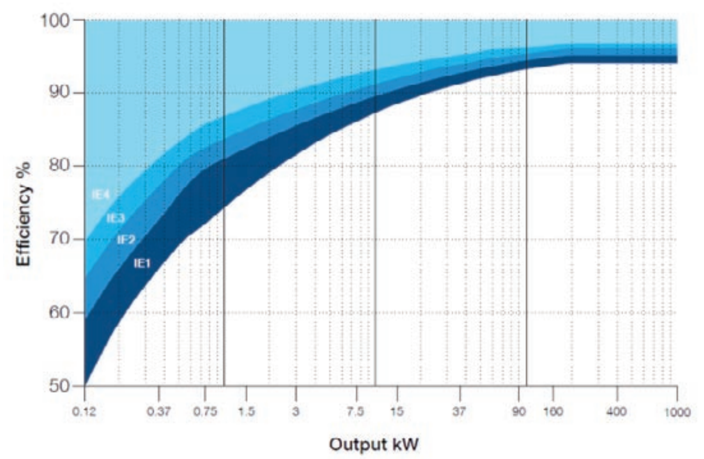
EU Regulation 4/2014 came into force this year to amend certain aspects of the earlier motor efficiency regulation (EC 640/2009). These regulations are commonly referred to as the European Minimum Energy Performance Standard (EU MEPS).

EU MEPS sets mandatory minimum efficiency levels for electric motors introduced into the European market and covers most single speed, three-phase induction motors up to 375 kW.

It is being introduced in three stages. From mid-2011, motors between 0.75 and 375kW have had to meet the IE2 efficiency level. Next January, motors between 7.5 and 375kW must have a minimum efficiency class of IE3 or a minimum IE2 if they are operated with electronic speed control (VSD). The motor size for these efficiency requirements reduces to 0.75kW in January 2017.

The amended regulation clarifies which motors are excluded from its scope and relaxes certain requirements for information to be shown on the motor rating plate. Marking of nominal efficiency at only 100 per cent rated load is now required for small motors but for others the requirement to show nominal efficiency at 100 per cent, 75 per cent and 50 per cent of rated load remains in place. All motors must show their IE class as well as their year of manufacture.

Figure 1 - IE efficiency classes for 50Hz 4-pole motors (Courtesy ABB)



The simplest way to start an induction motor is to use a direct-on-line starter. The disadvantage is that this results in a high starting current, often several times the rated current of the motor. The high starting current generates heat within the motor; this is why motor manufacturers often specify a maximum number of 'starts' per hour to prevent excessive heating and increased motor wear.

If it is necessary to restrict the starting current of a 3-phase motor a star-delta connection can be used. This reduces the starting current and torque to about 25-30 per cent of that reached with a direct-on-line starter. However, it is always necessary to make sure that the reduced torque is sufficient to accelerate the load.

A soft start control limits starting current depending on the torque requirement of the load by gradually increasing the motor voltage to provide a smooth start. This can extend the life of the motor and increase the maximum allowable number of starts per hour, which is useful where the motor needs to be switched on/off to save energy. When the motor is up to speed it is common to bypass the soft starter to avoid power loss during continuous operation.

Starting with a variable speed drive is a solution when there is a benefit in controlling speed during continuous running, however it is usually not the best option for motor starting only.

Power factor is the ratio between active power, measured in kW and apparent power measured in kVA. An induction motor consumes both active power, which is converted into mechanical work and reactive power, which is needed for magnetisation and is not converted to work. Power factor can be as low as 0.7 for small motors but up to 0.9 or higher for large motors.

If there are a large number of motors on a site, the aggregate consumption of reactive power can to have the undesirable effect of reducing the site power factor to a level where installation of power factor correction capacitors is necessary.

Modern motors are designed for maximum efficiency between around 75 per cent and 90 per cent full load with only a minimal drop-off in efficiency down to 50 per cent. Significant reductions in efficiency only occur below 25 per cent full load.

The rating plate on the electric motor gives its output power (kW) at the shaft. The actual power drawn from the supply will, therefore, be the shaft power plus the power lost due to motor inefficiency.

Transmission systems

There are three common transmission systems, the simplest and most efficient being a direct drive where the load is directly coupled to the motor shaft. It requires little maintenance but is less flexible because the motor has to be in direct line with load.

A belt-pulley transmission is more flexible and often used in plant such as air handling units. The output speed can be adjusted by the pulley system of different sized wheels connected by a belt. Transmission efficiencies vary depending upon the type of belt used.

Traditional 'V' belts are the least efficient, with synchronous, flat and ribbed belts about 5 to 6 per cent more efficient. This means changing a 'V' belt system to a synchronous belt can be attractive, particularly for larger transmission systems. Also relevant is that the efficiency of 'V' belts drop-off by as much as 10 per cent with maintenance issues such as poor tension and incorrect alignment. The third type of transmission system is a gearbox where the efficiency varies depending upon the type of gear, from 85 to 90 per cent for worm gears to 98 per cent for a helical gearbox.

Although the efficiency of the motor is important the efficiency of the entire drive system should not be overlooked. As an example, in a motor drive system the electronic controller may lose 5 per cent and with a transmission and motor efficiency of 92 per cent and 90 per cent respectively, the overall system efficiency from electricity input to power delivered is less than 79 per cent.

The simplest way to save energy with a motor is to switch it off whenever possible. This might be achieved through switch off campaigns and staff awareness initiatives or by installing automatic controls. In either case it is important that production issues are considered before implementing any switch off policy, and that account is taken of the maximum number of motor 'starts' allowable.

An electric motor can be quick and cheap to repair so having it rewound is often the natural choice when it breaks down. However, motors that are rewound are likely to suffer a drop in efficiency of between 0.5 and 2 per cent, unless the repair is carried out to a high standard. Although cheaper, reduced efficiency will mean increased running costs which could quickly outweigh the initial saving.

Evaluate life-cycle cost

In considering options for a new motor drive or to replace a failed motor, the life-cycle cost should be evaluated including purchase, installation, maintenance and eventual disposal costs plus the cost of electricity consumed over the motor life. Remember the cost of electricity typically represents only 1 to 3 per cent of the total life cycle cost and this type of evaluation often demonstrates that the lowest purchase cost option is not the most cost effective over the operational life of the motor.

When specifying new motor systems there is often scope to save capital and running costs through better sizing of the motor and by taking steps to minimise the driven

load and transmission losses. In practice motors are often rated well above the power required because various margins and contingencies are added during the design stage. This increases capital cost and means the motor operates at lower power factor and efficiency to increase energy consumption.

An electronic variable speed drive converts the fixed frequency electricity supply input into a variable frequency output. This controllable frequency allows the drive to vary the motor speed and torque generated to deliver the required output controlled by feedback from a measured parameter such as water or air pressure.

> **"Although the efficiency of the motor is important, the efficiency of the entire drive system should not be overlooked"**

VSDs are usually more expensive than simple motor controls, although can have paybacks typically around two years. However, motors drive a variety of loads and it is important to recognise the basic characteristics to be able to identify the best opportunities to save energy:

- variable torque load (fan, pump and centrifugal compressors) is where torque varies with the speed squared and power varies with the speed cubed. This means that any speed reduction will save significant amounts of energy, for example a 20 per cent speed reduction will give a 50 per cent saving in energy;
- constant torque load (conveyors, screw compressors and crushers) is where torque does not vary with speed and the power is directly proportional to speed. This means that a 20 per cent speed reduction gives 20 per cent saving in energy; and
- constant power load (machine tools and winders) is where although torque varies with speed the power remains constant which means there is rarely any energy saving with speed reduction.

VSDs are, therefore, most attractive in variable torque load applications such as fans and pumps and particularly where the delivered output is controlled by inlet or outlet throttling or dampers which can be removed.

The starting point to evaluate opportunities to reduce energy consumption of the motors installed throughout an organisation is to produce a motor inventory recording rating, loading, age and running hours for each motor.

To help evaluate saving options, it is useful to measure the power consumed by each motor starting with the largest and oldest motors. A simple clamp-on ammeter can give a snapshot of the motor current from which power can be calculated. A portable energy data logger provides a more accurate picture of motor power and loading over time.

Planned maintenance is important and should be carried out in accordance with manufacturer's guidance to achieve long-term reliability and efficient operation. Attention should be paid to simple measures such as keeping motors clean, especially the cooling fins which dissipate motor heat, as a motor running 'hot' uses more energy and is at higher risk of failure.

The motor policy should, therefore, include a plan for repairing or replacing failed motors, including a comparison of life cycle costs and a schedule for motor maintenance.

References:

ABB Motor Guide February 2014
CIBSE Guide F – Energy efficiency in buildings.

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CPD ENTRY FORM

DRIVES AND MOTORS

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

QUESTIONS

Q1. A motor costing £500 and in continuous operation over 10 years could consume electricity costing?

- ☐ £1,000
- ☐ £5,000
- ☐ £50,000
- ☐ £500,000

Q2. Which is not one of the main components of a 3-phase AC induction motor?

- ☐ Stator
- ☐ Brush gear
- ☐ Cooling fan
- ☐ Rotor

Q3. Under the EU MEP Regulations what classification is given to the highest motor efficiency?

- ☐ IE1
- ☐ IE2
- ☐ IE3
- ☐ IE4

Q4. At what date does the IE3 classification become mandatory for new motors between 7.5 and 370kW?

- ☐ June 2014
- ☐ January 2015
- ☐ January 2017
- ☐ It's a requirement now.

Q5. With a modern motor, the efficiency starts to drop off at what motor loading?

- ☐ 90 per cent
- ☐ 75 per cent
- ☐ 50 per cent
- ☐ 25 per cent

Q6. In a motor driven system where is energy lost?

- ☐ Motor controller
- ☐ Motor
- ☐ Transmission system
- ☐ All three

Q7. What is the key disadvantage of direct on line motor starting?

- ☐ Slow speed of response
- ☐ High capital cost
- ☐ Reduced torque
- ☐ High starting current

Q8. With a variable torque load such as a fan or pump what parameter varies with speed cubed?

- ☐ Absorbed power
- ☐ Flow rate
- ☐ Torque
- ☐ Velocity

Q9. With a variable torque load such as a fan or pump reducing the speed by 20 per cent saves how much energy?

- ☐ 20 per cent
- ☐ 40 per cent
- ☐ 50 per cent
- ☐ 80 per cent

Q10. In general what type of load would offer the best energy saving potential for a VSD?

- ☐ Machine tools and winders
- ☐ Conveyors and crushers
- ☐ Fans and pumps
- ☐ Any type of load

Please complete your details below in block capitals

Name .... (Mr. Mrs, Ms) ....

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