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# Industrial motors


| CASE STUDY | |
|---|---|
| Business Type: | Joinery factory |
| Location: | Stockton-On-Tees |
| Measure | Fitting Variable Speed Drive to an air compressor |
| Installed cost: | £13,000 |
| Simple payback period: | 2.3 years |
| System lifetime: | 15 years |

| ANNUAL SAVINGS | |
|---|---|
| Electricity: | 5,939 kWh |
| Cost: | £2,970 |
| Carbon: | 13.7 $tCO_2e$ (BEIS 2022) |

# INDUSTRIAL MOTORS

Many commercial premises will have some of their electricity consumption caused by electric motors of one sort or another. Industrial sites in particular will inevitably have a large proportion of their energy use attributable to motors. They are found in pumps, fans, conveyors, machinery and almost anything that moves under power. Unlike other electrical demands, such as lighting and heating, however, understanding their energy use takes a lot more knowledge of the principles behind how they function and the specific purpose they are fulfilling. Despite their complexity, it is worth having some understanding of motors and the energy they consume as their contribution to site usage can be much higher than it needs to be. This factsheet will focus on the most common type of industrial motor - the AC induction motor.

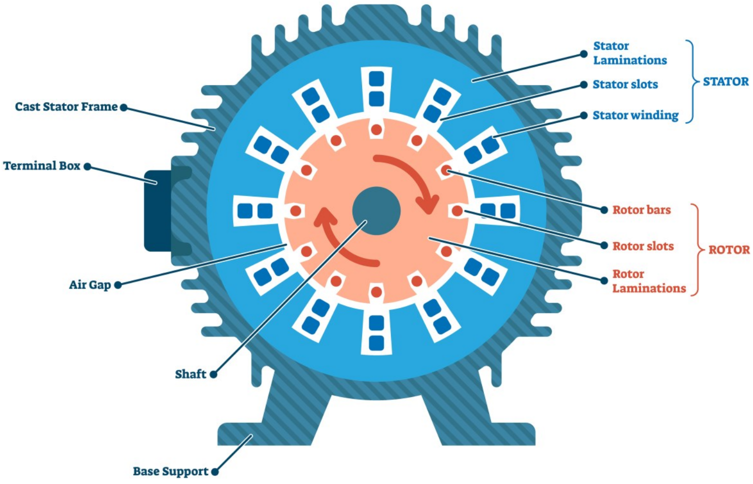
# AC INDUCTION MOTORS

These motors come in a range of standard outputs, and generally run at a fixed speed. They are found in almost any application where mechanical work is required from a mains electrical supply. An electrical current is supplied to the outer section of the motor, called the stator. This creates a magnetic field which subsequently induces a current in the windings of the central rotor. This current creates another magnetic field which repels the stator's magnetic field, causing the rotor to rotate. Because these motors rely on the alternating current to create their magnetic fields, the rate of rotation is related to the number of poles that the stator's windings are arranged in and the frequency of the alternating current, which in the UK is nominally 50Hz (50 cycles per second). The lower the number of poles in an induction motor, the higher the rpm will be but the lower the torque.

The theoretical speed of an induction motor can be worked out as follows:

RPM = (120 × frequency) ÷ no. poles per phase

For example, a 2-pole 3-phase motor would have a theoretical rotational speed of 3,000rpm if supplied with 50Hz AC. In practice, the motor will run a little slower when it is loaded and the difference between the theoretical speed and the rated speed is called the slip.




In this example, the actual rotational speed would be about 2,850rpm.

Many AC induction motors use a series of metal rods or bars instead of a rotor coil. These are sometime called squirrel cage motors because of the shape of the rotor.

# SOFT STARTERS

When a motor is first switched on, it will draw a high current until it reaches its designed rotational speed. This current can overload some supplies, and generate a large amount of heat, which can reduce the life of the motor if it starts and stops too frequently. Most induction motors will state a maximum number of starts per hour that they should be subjected to, with larger motors tending to allow fewer starts. Motors in some types of industrial equipment are configured to run continuously, even when they are only required intermittently because of this need to limit the number of starts. It is possible, however to reduce the high startup current of an induction motor by installing a drive which allows the current to gradually increase. Such a device is called a ‘soft starter’. These can achieve three benefits: they can extend the life of the motor, limit the maximum current required from the grid supply and allow for intermittent use of the motor to reduce energy consumption.


# VARIABLE SPEED DRIVES

If a motor can have its speed reduced, significant power savings can be achieved. However, AC induction motors operate at a single speed due to the frequency of the alternating current supplying them, meaning they do not have the ability to save energy in response to a reduction demand other than simply switching off entirely. As explained above, frequent starting and stopping of motors can cause rapid deterioration of the motor due to excessive heating. The solution to this is to install a variable speed drive, or VSD, which electronically manipulates the frequency of the supply to make the motor turn at a desired speed.

Many devices can benefit from the addition of a VSD to control their speed, but most commonly they are found controlling pumps and fans as these have quite variable demands and the potential for energy savings is particularly high.

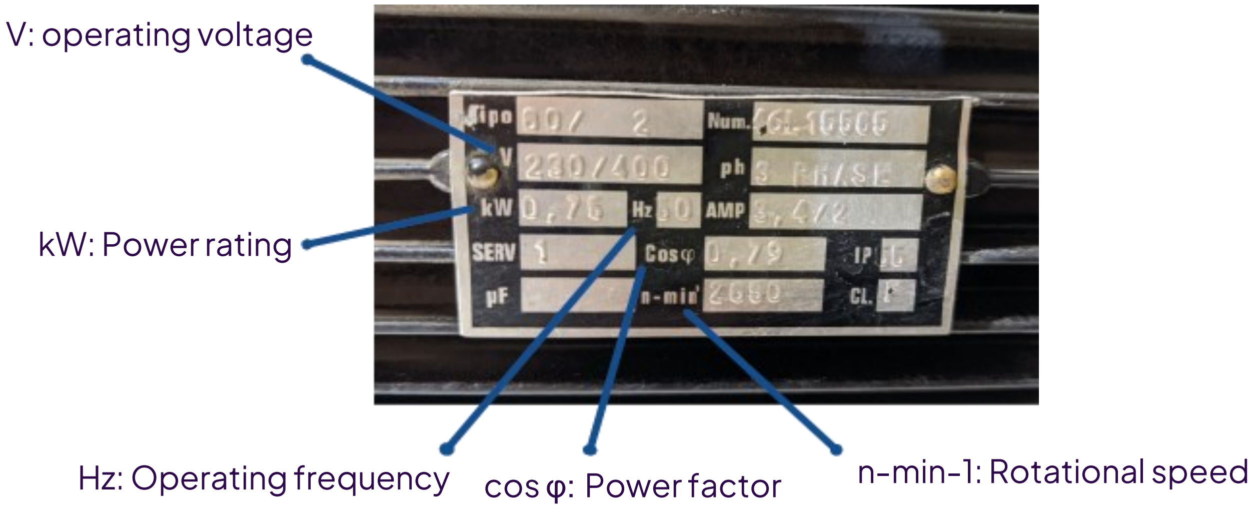
As they have to do work against the drag caused by the liquid or air, the power required by a pump or fan increases with the cube of its speed. If, for example, a fan motor's speed was reduced by 20%, it does not simply reduce power consumption by the same proportion, it will actually reduce this by almost 50% of its full speed power. Speed control is only practical in most situations if it is based on some kind of sensor to provide automated feedback dictate the motor speed. For example, heating pumps can have their speed controlled based on the room temperature or the temperature of the water returning to the boiler. A kitchen extraction fan could have its speed controlled based on the level of $CO_2$ in the air.

In other applications, the power consumed by motors does not vary with the cube of their speed; instead, it is a simple linear relationship. In these cases, so a 20% decrease in speed would only result in a 20% drop in power. This does not mean speed control is not worthwhile, particularly where a motor is running continuously. In such situations a VSD may not be the most cost-effective solution, though, and there may be a simpler, lower cost option such as changing the pulley ratios in a belt drive if it is unlikely to need changing more than once or twice per day.

# POWER FACTOR

Certain equipment on site such as electric motors, transformers and some types of lighting use up more of a site's power supply (usually quoted in 'kVA') than their specified power ratings would indicate. Over a whole site, this can lead to a portion of the supply being taken up without it doing useful work. This portion of supply capacity is called 'reactive power' and the level of reactive power depends upon the type of equipment being powered. The amount of reactive power consumed by an AC motor depends on its "power factor", which is sometimes written as 'cos φ'. A power factor of 1.0 is the ideal scenario, in which all of the current being drawn from the supply is doing useful work. Anything above around 0.9 is considered a reasonably good power factor.

**Typical motor data plate**



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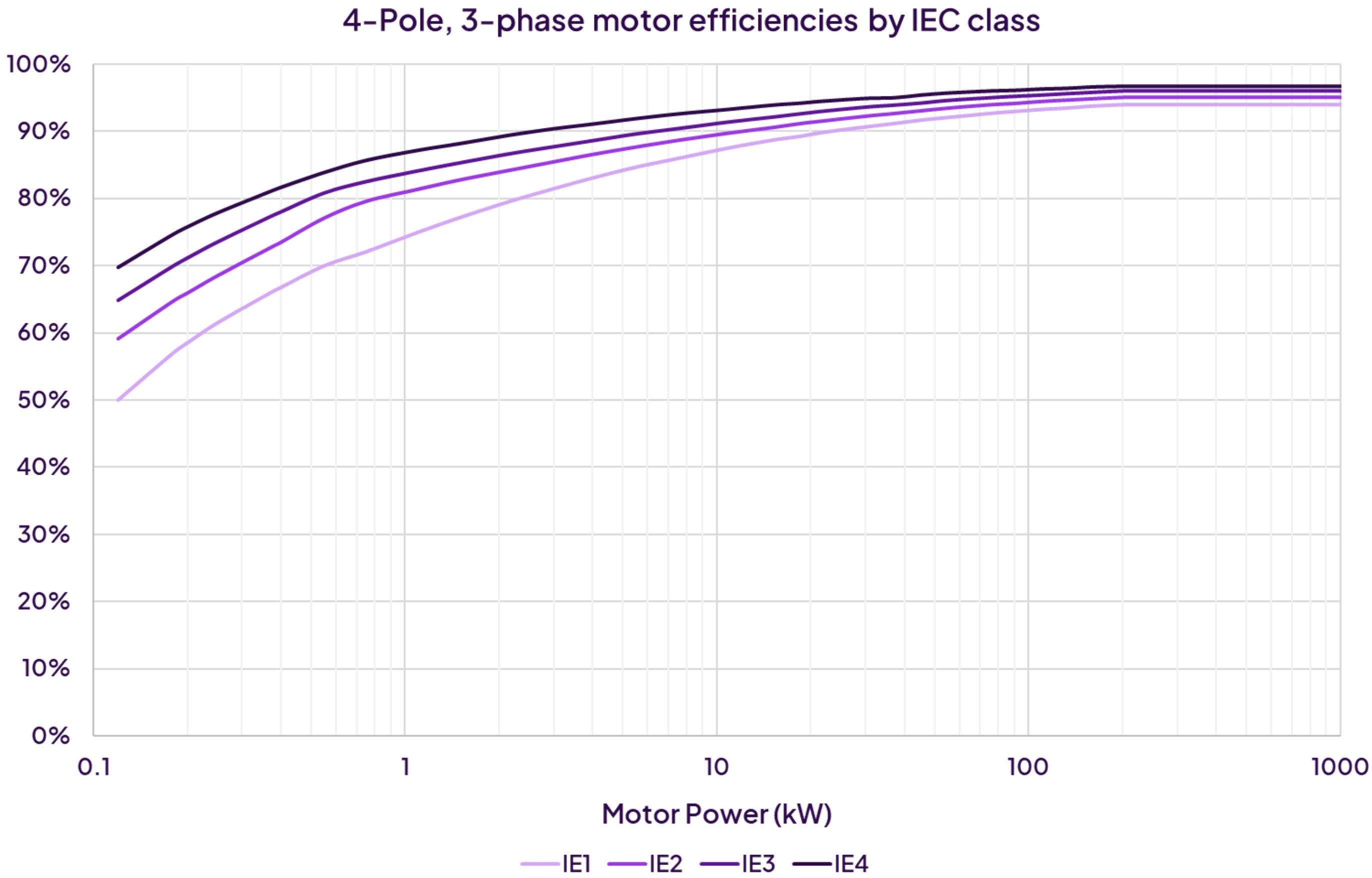
Over a whole site, a poor power factor of less than 0.9 means a proportion of the electrical supply is effectively unavailable and can therefore limit productivity. Poor power factor can also result in reactive power surcharges on electricity bills, which for large industrial sites can be quite significant. The current drawn by this reactive power also increases the heating in cables and therefore speeds up the degradation of some equipment.

Power factor becomes worse when motors are not run at their full load, which is one reason why it is important to make sure that motors are properly specified for the task. Poor power factor can be improved by installing Power Factor Correction (PFC) equipment to the electrical supply of the building, bringing the power factor closer to 1.0. For large sites this can bring about a very cost-effective improvement with rapid payback periods.


## MOTOR EFFICIENCY

As well as the amount of time and the speed that a motor operates, consideration should be given to the motor itself and how efficiently it converts electricity into mechanical work. In March 2014, the international standard IEC 60034-30-1 was published which aimed to standardise efficiency classes for AC induction motors between 0.12 and 1,000kW. These classes are as follows:

| Code IEC 60034-30 | Efficiency Class |
|---|---|
| IE1 | Standard Efficiency |
| IE2 | High Efficiency |
| IE3 | Premium Efficiency |
| IE4 | Super Premium Efficiency |
| IE5 | Ultra Premium Efficiency |




Since January 2017, all new motors supplied in the EU that are between 0.75-375kW have had to achieve IE3 efficiency class or IE2 in conjunction with a VSD. This regulation still applies in the UK despite its departure from the EU. Motor efficiency tends to increase with rated power, so the efficiency classes have different efficiency limits for given motor sizes. Tables of these values showing each motor size, type and efficiency class are available from various online resources. Efficiency gains between classes may appear small, but many industrial motors run continuously and therefore small savings rapidly accumulate. With old motors that are likely to be due replacement within the next few years, it is worth

**Class IE1 4-pole motor, output = 3kW**

Efficiency = 81.5%

Runtime per year = 8,760 hours

Energy consumption = 32,245kWh/year

Energy cost at 50.0p per kWh = £16,123/year

Annual $CO_2$ emissions (BEIS 2022)= 9.6t$CO_2$e

**Class IE4 replacement**

Efficiency = 90.4%

Runtime per year = 8,760 hours

Energy consumption = 29,070kWh/year

Energy cost at 50.0p per kWh = £14,535

Annual CO2 emissions (BEIS 2022)= 8.6tCO2e

Annual saving = 3,175kWh or £1,588 per year

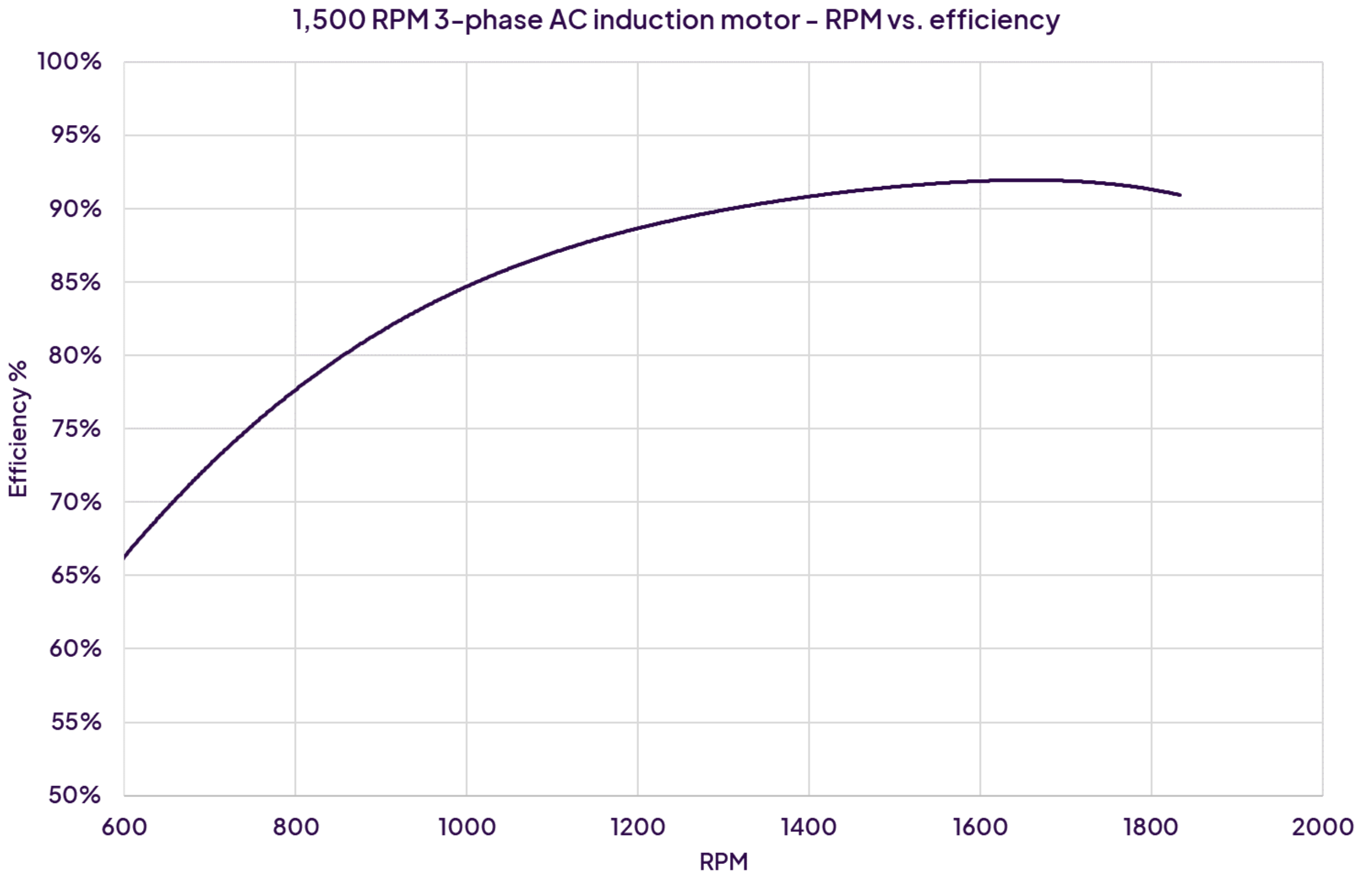
Motor cost = £850 installed

Simple payback period = 0.54 years

Annual $CO_2$ savings (BEIS 2022)=1.0tCO2e

# MOTOR MANAGEMENT AND MAINTENANCE

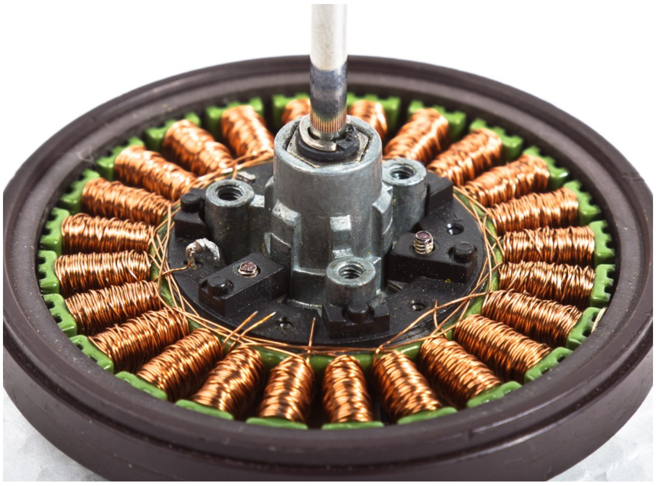
In an industrial setting, motors are likely to be so numerous that they warrant a dedicated system to properly manage their performance. It is often worthwhile creating a register of motors and drives, along with their power output and full load speed ratings. The load on a motor basically means it has some resistance to motion, measured in kW. An example of this would be a conveyor that lifts items upwards. The motor is therefore having to do work against the weight of the items on the conveyor. Motors run most efficiently when they are fully loaded, i.e. they have to work at their rated power. An unloaded induction motor will draw less power than a fully loaded one and will be less efficient. It is therefore important to size a motor as closely as possible to the expected load.

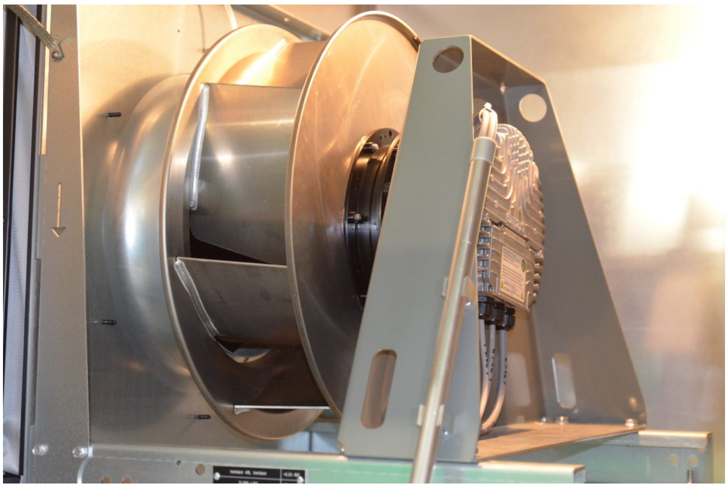


In use, it is worth ensuring that motors are properly sized by taking measurements of their power output. This can be done either electronically at the supply to the motor or mechanically, by measuring the motor's shaft RPM. Large discrepancies between rated values and measured values could indicate that the motor is improperly sized and may benefit from replacement or having its belt drive/gearing altered. Other tasks for checking performance during use include taking temperature readings of the motor and its transmission system. This will clearly highlight areas of a motor driven system that have high friction as having a raised temperature. This can be followed up with reactive maintenance such as cleaning, lubrication, bearing replacement or adjusting belt tension.

## MOTOR MANAGEMENT AND MAINTENANCE

Where motors are too small for a VSD to be economical, there is another option, which is to replace the motor itself with an electronically commutated motor (ECM). These take an AC supply and electronically convert it to DC, which is then used to power a DC brushless motor (similar to what is found in modern power tools). These have full speed control and can be a highly cost-effective option, particularly in situations such as small or non-centralised ventilation systems.





## PERMANENT MAGNET AC MOTORS

Permanent magnet AC motors are used where precise control over speed or motor torque is required. They use powerful magnets in the rotating part of the motor instead of a coil. The stator has to be supplied with power from a dedicated electronic driver circuit. This type of motor is extremely efficient but the rare earth magnets that are used in them are expensive and the electronic driver circuit increases the cost further.

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January 2023