Motor madness

Man enough, simple and lowest cost have been the rules of thumb for specifying electric motors on plant. Brian Tinham explains how the guidelines are changing

With the rules governing our choice of electric motors set to change (Plant Engineer, May/June 2009, page 3) from 2011, it's time to start reviewing approaches not only to specifying high efficiency motors and associated equipment, but also maintenance. Why now? Because the new legislation is highlighting just how much energy (and hence also cost and pollution) could be saved immediately by upgrading and, just as important, how variable speed drives (VSD) and novel plant configurations can contribute to better automation and product quality.

First a reminder: mandatory minimum efficiency standards for industrial induction motors are being phased in from 16 June 2011, starting with a requirement for all new devices to conform to the new IE2 high efficiency rating (equivalent to today's best, Eff1 – meaning higher efficiency two-, four- and six-pole motors), as defined under IEC 60034-30. Phase two follows in January 2015, when motors in the 7.5 to 375kW range, purchased in the EU, will have to meet IE3 (a new premium efficiency class), unless they're used with a VSD – in which case, IE2 motors are still allowed. And finally, in 2017, phase three will require plant engineers to use IE3 motors right down to 0.75kW – ushering in an era of more advanced motor technologies, such as permanent magnet types and switched reluctance.

Three key points

Three points are particularly worth noting. One: the EU directive (EuP: EcoDesign Requirements for Energy Using Products), from which the legislation derives, is designed to slash Europe's carbon emissions. The European Commission accepts that motors consume 65% of electricity at industrial sites – an assertion made believable when you consider that many motors consume their entire purchase price in energy every month (so around 100 times their cost over a lifecycle). Hence, the EC believes that, by 2020, its legislation will lead to electricity and pollution savings equivalent to the entire annual energy consumption of Sweden. British industry alone, it says, will save £200 million and at least 1 million tonnes of CO_2 per year. So it's not small beer.

Two: note the exclusion in phase two, where applications using inverter drives aren't forced to upgrade to IE3. The EC accepts the case that VSDs cut energy consumption in all sorts of variable torque and/or variable demand applications (typically fans, pumps, conveyors, machines and compressors) simply by operating motors at the speed required, rather than, as is so often the case, leaving them running at full speed. So, if you haven't already, it's time to investigate VSDs.

Three: this isn't only about an initial higher cost for industry. Yes, higher efficiency motors are currently more expensive, but there are also benefits from upgrading – and not only in terms of cheaper running costs (1.5–7%, depending on kW rating). Maintenance and downtime also reduce, because higher efficiency motors run at lower temperatures – so longer bearing and winding life.

What's more, there are all sorts of applications where high efficiency motors and VSDs can turn standard practice on its head. For example, they can operate as direct-drive units, even under low speed, variable load – potentially eliminating the capital, installation and service costs of conventional induction motor and gearbox combinations. It's also the case that premium efficiency permanent magnet (synchronous) motors offer much better control at slower speeds and, with the right VSD, don't need speed or position feedback – meaning opportunities for higher accuracy and more resilient operation.

Indeed, just such a development has earned three ABB engineers the Marcus Wallenberg prize (the Nobel prize of the international forestry industry) – with SEK 2 million (£160,000) due to be presented by King Carl Gustaf of Sweden on 28 September in Stockholm. Jouni Ikäheimo, Vesa Kajander and Bengt Welin used permanent magnet motor and VSD technology to provide excellent torque characteristics, very precise low-speed control and

Points

Pointers

- Legislation governing motor selection is changing in June 2011
- Variable speed drives will enable ongoing use of lower cost motors
- Energy and carbon savings are the drivers
- Higher efficiency motors make for better engineering practice
- In certain cases, gearboxes and ancillary plant are eliminated
- Accurate motor sizing, however, remains an important point for energy saving

high efficiency for a direct drive system (DDS) for huge paper machine rollers – for the first time, without gearboxes or auxiliary components.

Ikäheimo explains that, traditionally, paper machine rolls are driven by four-pole 50Hz induction motors rotating at around 1,500rpm, with a reduction gearbox taking speed down to about 600rpm, depending on diameter and function. Attempting control without the gearbox means matching motor speed precisely to roller speed, which, for induction motors, has always meant greater numbers of poles to enable slower running – so taking a hit in terms of poor efficiency, low power factor and, in turn, unduly high operating current.

Advanced development

Hence permanent magnet motors: "Our work has been to build an industrial solution, and to develop the mechanical and electrical design to enable smooth running during load changes," explains Ikäheimo. He talks, for example, of enhancing the rotor design to generate the very smooth magnetic flux distribution required. And Kajander adds: "We also specified the drive firmware to eliminate the need for speed and position encoders on the motor, using ABB's DTC [direct torque control]."

Removing the gearbox saves space, capital cost and service costs. And let's not underestimate savings from cutting out auxiliary components – gearbox cooling and lubrication, couplings, condition monitoring equipment etc. But the competition judges were also impressed by the system's runnability (less backlash in the drivetrain) and availability. DDS, they noted, cuts electricity and oil consumption, reduces noise and, if applied to all large paper machines, could reduce energy usage by more than 1,200GWh worldwide – equivalent to the output of two coal-fired power plants.

Extrapolate that to the thousands of plants with large fans, pumps and the like that could benefit from better control, and the potential for environmental savings is profound.

It's impressive, and you can see why some engineers are suggesting that higher efficiency (rather than cheapest) motors, as well as drives, should have been the default for years – even on general duties. And as Ian Ritchie, managing director of maintenance components manufacturer Brammer, suggests: "With help available from the Enhanced Capital Allowance Scheme and interest-free energy efficiency loans through the Carbon Trust, investing now will have an immediate positive impact, in terms of reducing energy and emissions, and enhancing production efficiency."

Paul Gale, process improvement manager at specialist board manufacturer Abbey Corrugated, agrees. With hundreds of electric motors at his Blunham, Bedfordshire site, and energy one of the plant's biggest costs, Gale says he is now only specifying IE2 electric motors when it comes to replacement. That's leading, he says, to savings of between £1,000 and £10,000 per motor over a 10-year lifecycle, depending on size. "As one of just 12 pathfinder companies for the Carbon Trust standard on energy efficiency, we are committed to taking whatever steps are necessary to reduce energy consumption," says Gale. "It's clear that IE2 motors are the way to go, particularly in light of the new legislation."

That's fine if you go for motor replacement. But, in the current economic climate, it's easy to understand why some plant managers defer capital equipment purchases and instead recommend motor rewinds – and it's not clear yet whether the new legislation will stop that. So what should you do? Brammer's Ritchie makes the point that, for most frame sizes, extending motor life by rewinding or repair is likely to cost significantly more – possibly thousands of pounds – during the product's life than replacing it with an IE2 product.

"An electric motor can be quick and cheap to repair, so having it rewound and reconditioned may seem the obvious choice. However, a rewound motor will

King Carl Gustaf of Sweden is to present ABB's Jouni Ikäheimo and Vesa Kajander, below, with the Marcus Wallenberg prize for their use of permanent magnet motor and VSD technology

typically suffer a drop in efficiency of between 0.5 and 2%, unless the work is carried out to a very high standard. So a rewound motor may well have efficiency several percentage points below that of a new, high efficiency motor. While the initial cost of the repair may be lower, that reduced efficiency means increased running costs that quickly outweigh any capital saving. Further, a rewound motor is rarely offered with the same guarantee as a new product, so could cost more in breakdowns."

Sizing and control

But if you do take the opportunity to go for new, there's another issue: motor specification. Received wisdom has it that more than half of our installed base of electric motors is oversized, due to contingencies built in during the specification process. Combine these with rounding up to the nearest frame size and, for example, a basic duty requirement of 7kW may turn into an 11kW motor, using 50% more power than needed. Which is madness.

As Ritchie points out: "It's also worth considering that motor efficiency reduces at low loading, so a smaller motor running at a higher load is more efficient than a partially-loaded, larger motor." The problem is that the relatively low purchase price of motors is deceptive, suggesting an insignificant penalty for over-specifying. "However, when you consider that a 22kW motor can use more than its purchase price in electricity in just two months, and can accumulate running costs of £60,000 over a 10-year period, over-specifying is not so cheap," warns Ritchie.

But it's not just about motors. As already mentioned, just as important are the VSDs – and not simply for phase two of the new legislation. Why? Because, although they, too, consume energy, it's peanuts compared to the 30—40% (sometimes far more) they typically save on pump, fan and conveyor applications. Also, drives themselves have witnessed huge technical and programming improvements in recent years – making installation and commissioning far simpler, while often improving operational flexibility and further reducing energy consumption, particularly on low speed and/or light loads. And with many now having built-in three term (PID) controllers to cope even with quite advanced pump and fan automation, there's no longer any need to buy or install separate controllers.

What's more, if you're worried about problems with electrical harmonics disturbing your supply – one of the few potential penalties of switching devices like VSDs – even that thorny issue is increasingly being addressed as standard on low and medium voltage devices. Organisations such as ABB and Danfoss are among leaders bringing out low harmonic drives that eliminate the problem.

Danfoss, for example, has just launched drives using active filters that look for and superimpose compensating currents in real time, whatever the load – linear (regenerative power units, resistive loads, ac machines etc) or non-linear (welding machines, arcing devices etc). The company also suggests that its AHC (active harmonic compensator) technology is effective with flicker (caused by large fluctuating loads) and certainly better than SVCs (static VAR compensators). Meanwhile ABB and others offer harmonic surveys as part of their site service to help plants get the problem under control. PE

Centre: Ian Ritchie of Brammer: financial incentives now make buying energy-efficient motors attractive

What a difference a drive makes

Plant engineers at a newly refurbished web laminating line in Stockport, operated by API, say they have doubled productivity and cut energy costs by 45%, following installation of variable speed drives (VSDs). Blackburn-based Optima Control Solutions developed the system, completing its installation and commissioning of Parker Hannifin AC890 drives in three weeks.

Optima managing director Michael Hill explains that, originally, the laminator used a mechanical system with machine shafts or rollers being driven from PIV (positively infinitely variable) gearboxes, powered by dc motors with belts and pulleys. It was unreliable, difficult to maintain, expensive to run and made product changeover a lengthy process that generated considerable scrap, since each PIV had to be manually adjusted. Also, the system provided poor control over web tension – meaning it couldn't be used on the specialised films and foils mostly used by API.

Optima replaced the common mechanical drive with a series of drives, each controlling its own roller section with discrete control loops. Now, 13 closed-loop ac vector motors, each under VSD control and with a common dc bus, provide efficient power management – with energy naturally balanced between the units under load and those that are regenerating when braking.

Says Hill: "The drives have helped us make considerable improvements to machine functionality, to reduce setup times and make the plant easier to operate. For example, as standard the drives [have] tension control, and the ability to control line speed setpoints and set speed ratios between drives. They also have onboard I/O, which we used for speed setpoints or load cell signals." Operators can now control individual web tensions for each section of the machine, he says – also enabling API to run a much wider range of materials through the refurbished line.

It's a similar story at Romiley Board Mill (above right), which manufactures paperboard from recycled fibre. Technical manager Ernie Domville says the firm increased paper output by 10%, with the help of ABB drives on three electrically-driven machine sections, which are now synchronised with the rest of the paper machine, in turn driven by a line shaft. He explains that the firm wanted to increase output by adding a new dryer section to its existing paper machine. However, to avoid costly mechanical modifications to the line shaft, the new section needed to be electrically driven, while the new configuration of the machine also required independent speed control for its existing calender and reel-up sections, using sectional drives.

Making that work with VSDs turned out not to be difficult. In operation, the first drive now receives feedback from an encoder on the line shaft and this setpoint is then cascaded from one drive to the next. Each drive then controls the speed of a 37kW ABB high efficiency ac motor, in sync with the overall machine line shaft. In a conventional setup, a PLC would have managed each of the three sections independently, each driven by a dc drive. But with the control capabilities of these drives, that wasn't necessary. "All functions for sectional speed control and communications are within each drive, which means that a controlling PLC is not required," confirms Domville.