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The technologies behind electric motors and variable speed drives are revolutionising plant efficiency and emissions. Brian Tinham looks under the covers

Embracing

High efficiency electric motors and energy-reducing variable speed drives – critical though both are in transforming plant efficiency and running costs today – are but two components in the whole energy-saving scene. For plant engineers serious about wanting to save energy and cut costs, without necessarily spending a fortune, it's also important to consider the rest of the picture. And that means examining the whole drive train, including gearing, belts etc.

It's a truism, yes, and the good news is that it's not rocket science. The surprising news, however, is that relatively few of us seem to think of it that way, according to Chris Pails, an engineering specialist at maintenance, repair and overhaul equipment specialist Brammer. "Engineers who adopt high efficiency motors might save themselves 5% on running costs – and that can be significant. But they could be missing out on 30–40% that might come, for example, from replacing fluid couplings or inefficient gearboxes," he explains. "Yet we see these [missed opportunities] happening all the time."

He recalls one instance involving a rotary drum on an aggregate plant, which had a rewound electric motor and belt drive arrangement to a fluid coupling and then to an old worm gear, all consuming 22kW. "Motors of that age are at best 80% efficient, belts 90%, fluid couplings 80% and the worm gear maybe 80%. So they could have replaced all of that with a helical bevel gear unit and stepped down from 22kW to only 15kW, just by removing all that inefficiency," says Pails.

Why wasn't such a drivetrain fitted in the first place? "OEMs rarely specify helical bevels, because they cost more and clients won't pay the price. So plant users tend to end up with plant that's not the most efficient, from day one," he explains. "And then, when it comes to older plant needing refurbishment, engineers tend to stick to traditional methods and like-for-like replacements – so the inefficiencies just continue."

He gives another example, this time concerning big conveyors driven by ageing 55kW motors, again via fluid couplings, where the plant engineers were specifying high efficiency Eef1 (IE2 under the modern European standard) replacements. "There was huge inefficiency with the rest of the mechanical package, but they weren't even looking at that. Engineers need to take a step back and appreciate the whole situation."

Cutting electrical kW

Pails isn't denying the power of modern motors and particularly drives to make a considerable difference to the relationship between output mechanical power and torque versus input electrical power and cost. "There's no doubt that the efficiency of the electrical system and how much you pay for it reflects right back to electricity consumption and cost," he agrees. "All I'm saying is that there's more to it – and, while you might not be able to make your conveyors run on less kW mechanically, you certainly can make them run on less kW electrically by going back to the drivetrain."

That said, the technologies behind motors and drives themselves have advanced significantly in the last few years – hence the feasibility of the new European legislation governing industry's staged changeover to higher efficiency motors (see panel). Pails confirms that Brammer is seeing plant managers increasingly specifying new IE2 high efficiency motors (the mandatory minimum, post July 2011), but observes that this suggests the 'payback from efficiency' message is still not reaching most engineers.

Changing motor efficiency legislation

Starting on 16 June 2011, new mandatory minimum efficiency standards for industrial induction motors are being phased in. From that date, all new motors purchased must conform to the IE2 high efficiency rating (equivalent to today's best, Eff1 under the old voluntary code – meaning higher efficiency two-, four- and six-pole motors), as defined under IEC 60034-30.

Phase two will follow in January 2015, when new motors in the 7.5 to 375kW range must meet IE3 (premium efficiency class), unless they are used with a variable speed drive – in which case IE2 motors will still be allowed. The European Commission accepts that drives significantly reduce energy consumption in the vast majority of variable torque and/or demand applications (typically fans, pumps, conveyors, machines and compressors) by only operating motors at the speed/power required.

Then, in 2017, phase three will require plant engineers to purchase IE3 motors right down to 0.75kW. There is no mention yet of IE4, but, as the drive for greater efficiency and reduced emissions accelerates, it's only a matter of time.

efficiency

"Very few consider permanent magnet-based motors [as in some premium efficiency IE3 and eventually IE4 units], even though these are between two and four per cent more efficient – which means any extra you pay up-front pales into insignificance, compared to their lifetime savings," he explains. And, given that IE3 electric motors are now readily available for the vast majority of applications at up to 250kW (so there's no real limit), he's clearly right – even accepting the 20–50% higher price tags than IE2 units.

What's more, higher efficiency motors bring other savings. ABB has been championing this cause for years and Steve Ruddell, an engineer by training and manager of the industrial giant's automation and motion division in the UK, makes the point that higher efficiency motors also run cooler.

"That means an extended lifecycle for the asset, because the motors are less likely to fail as a result of premature insulation or bearing ageing, both of which are caused by excessive temperature. Similarly, maintenance costs are reduced, since bearings don't have to be re-greased as frequently. And there's a statistically significant reduction in recorded downtime, again due to lower running temperatures reducing the incidence of winding and bearing failures," he asserts.

Putting some meat on those bones, Ruddell cites studies showing that for every 10 Kelvins reduction in temperature, average motor insulation life doubles. He gives the example of a 22kW four-pole electric motor at IE1 and IE3, each with 75% loading, and advises that, while the higher efficiency motor is more than double the purchase price of its IE1 counterpart, the annual saving in electrical charges alone is nearly £500, while the lifetime saving is £9,700, assuming an energy price of 0.09p/kWhr. For such a unit, that results in a payback of just 19 months – surely a no-brainer.

"Lowest price and lowest efficiency just doesn't make sense any more: you're saving a penny today to spend a thousand pounds tomorrow," says Ruddell. And he suggests that ABB is already well on the way to developing ultra-high efficiency IE4 motors, too. "These will come through very quickly now. You won't have to wait until 2015. And they won't necessarily be based on permanent magnet technology," he says, coyly – although he won't reveal the technologies involved.

Incidentally, ABB has not only just re-released its

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High efficiency motors cut losses on bio-ethanol plant

The first W22 high efficiency motors supplied by WEG in Europe have been installed on a green production plant producing sustainable bio-fuels. Three 200kW four-pole 315L frame W22 motors were supplied to BioWanze in Belgium, with inverters, to drive a mill that processes wheat and beet syrup producing bio-ethanol – eventually enough to provide half the bio-fuel consumption in Belgium.

WEG's high efficiency motors were installed on a cooling tower and BioWanze says they were selected for their ability to reduce motor losses by 10–40%, compared to traditional ac induction motors, as well as for their low noise and vibration characteristics – mostly due to the aerodynamic frame, which increases airflow, and reduces overall temperature and hot spots.

These motors also feature a new WSeal system, which uses a W-ring with a metal cover to protect the rubber sealing from ultraviolet light, while also protecting against ingress of water and dust – so preventing damage to the rolling bearings.

motor dimensioner (a useful slide rule that gives frame size, foot and flange dimensions etc for four- and two-pole motors to 160kW), but also launched a similar ready-reckoner providing projected energy savings by switching from DOL (direct on line) fixed speed motors to variable speed, using its drives. You select your motor power rating, electricity price, shift pattern etc, and the slide rule does the rest.

In September, there will also be an equivalent iPhone app version – available free from the Apple store – with an email link back to ABB, for plant engineers to request a free on-site energy audit. Then, later in the year, Ruddell says there will be another app showing savings to be had by swapping out existing Eff2/IE1 (standard efficiency) motors for IE3, for example.

Driving the revolution

That brings us neatly to the subject of drives, and the first statistic worth noting is that fewer than 5% of the UK's installed base of electric motors are estimated to be under variable speed drive control – a change of just two percentage points in a decade. Ruddell accepts that not all motor applications are right for speed control. However, he believes the incredibly slow take-up of drives is due to a mix of apathy and scepticism – the latter because the savings, particularly on pumps and fans, so often seem too good to be true.

So how much? Ruddell says it's not unusual to hear of fully 50% improved efficiency and he claims never to have heard of a payback period on a pump or fan retrofit exceeding two years – and that it's usually far less. He also says that, by contrast, the zeal of converts is extraordinary, with hundreds of well-known names having long since embarked on serious plant-wide campaigns, following trials, to get off large fixed-speed motors wherever possible.

By the way, Ruddell and others also insist that the latest generation of drives is at least 10% more efficient even than their decade-old counterparts – and with significantly improved additional control and synchronisation functionality. "The technology is based on inherently more efficient power plates and electronics that also enable, for example, better flux optimisation – so that motors running with variable torque and load on centrifugal pumps or fans don't run at full torque when it's not required. We reckon that alone can generate an additional 10% saving on many pump and fan applications," he says.

"Whatever way you look at it, if you're currently running a drive greater than 10 years old, simply changing up to next generation technology will yield at least a 10% energy saving," insists Ruddell. And to help plant managers make the leap, ABB is currently offering a 'swappage' scheme, under which users get at least 17.5% off the list price when they buy a new drive to replace any existing unit, irrespective of manufacturer.

What's more, the old unit then goes into ABB's eight year-old recycling programme, which this year has already recycled 13 tonnes of waste drives and recovered 90% of component materials by weight, following the WEEE (Waste Electrical and Electronic Equipment) Directive – even though drives are not covered by that legislation. PE

Eco payback in half a day

Within just half a day's use, a variable speed drive can compensate for the entire environmental cost attributable to its own manufacture and disposal, according to a study by ABB, carried out with Tampere University of Technology in Finland.

Ecological payback was calculated for drives rated at 0.75kW, 7.5kW and 250kW, and the global warming compensation periods were six days, 1.1 days and half a day, respectively. ABB makes the point that after that period a plant's carbon footprint starts to shrink as the drive continues to save emissions throughout its lifetime.

"Our study shows that using variable speed drives is one of the most cost-effective measures to achieve rapid and radical CO_2 reductions," says Steve Ruddell, manager of the industrial giant's automation and motion division in the UK and Ireland. "I believe that, in five years' time, there will have been a sea change in the way companies look at investment decisions and they will be just as keen to save CO_2 as they are to save money today," he adds.

The way forward: scrapping old motors and drives, and replacing them with new technology