Electric Motors & Energy Management: Back to Basics

Ir. Dr Gobbi Ramasamy

Ir. Dr Gobbi Ramasamy is an associate professor at Faculty of Engineering, Multimedia University, Malaysia. He is a consultant providing solutions for problems associated to electric motors and drives system for various industries. He is also an Electric Energy Manager Registered to Energy Commission, Malaysia, and a Senior Member, IEEE.

In industry, an induction motor usually runs only at 50-60% loading conditions, for two reasons. Firstly, it reduces the chances of overloading the motor and minimises the thermal effect on the motor system. Secondly, the motor is literally oversized to allow room for future expansion.

It is important to note that motors operating at 50-60% loading produces a relatively greater loss compared to those operating at 75% loading (where optimum efficiency is achieved). Besides, the power factor is also affected by the loading conditions. A bigger motor (e.g. 1kW) gives much better power factor at full load and this is lowered gradually when load is reduced as shown in Figure 1.

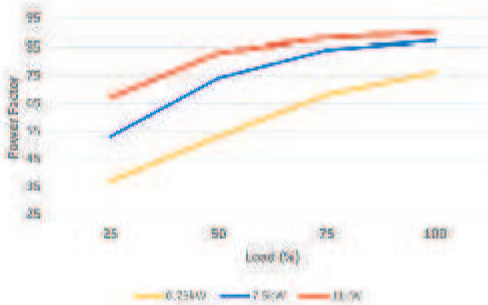

Figure 1: Power factor under various loading conditions

If a smaller motor (e.g. 0.75kW) is used, the power factor is much lower. When the motor runs at a lower power factor, the motor draws a higher current to produce the required mechanical power. Higher current means higher copper losses in the cable and motor windings. The relationship of these parameters is shown in equation 1, where I is the line current, P_m is the mechanical power which is constant for a given load and speed, P_L is the rotational and copper losses. V is the supply voltage which is constant, cosθ is the power factor.

$$I = \frac{P_m + P_L}{\sqrt{3} V cos\theta} \qquad (1)$$

In order to minimise energy usage by the motor system, the first option is to minimise losses. For this reason, the existing load should be increased and the motor should always run at 75%. Increasing loading from 50% to 75% makes the motor operate at higher efficiency, usually between 1% and 3.5% for a typical IE1 motor. Unfortunately, increasing the loading is very subjective as it depends on production line requirements. In practice this may prove difficult to implement.

In order to minimise energy usage by the motor system, the first option is to minimise losses. For this reason, the existing load should be increased and the motor should always run at 75%. Increasing loading from 50% to 75% makes the motor operate at higher efficiency, usually between 1% and 3.5% for a typical IE1 motor. Unfortunately, increasing the loading is very subjective as it depends on production line requirements. In practice this may prove difficult to implement.

The next option is to consider high efficient motors (HEMs), that is IE2 or IE3 motors. It is stated in MS1525:2014 "Energy efficiency and use of renewable energy for non-residential buildings - Code of Practice (second revision)", that only IE2 or IE3 motors shall be used based on economic justification basis. IE2 motors give higher efficiency, typically from 6% (for 0.75kW) to 1% (for 200kW and above) whereas IE3 motors give 10% (for 0.75kW) to 2% (for 200kW and above) as compared to IE1 motors. Accordingly, at lighter loading conditions, IE2 and IE3 motors have a higher efficiency than IE1. But the issue is the initial cost of changing to HEMs.

Figure 2 shows the comparison study between IE1 and IE2 motors over three years of operations for motor rating of 15kW to 75kW. The initial cost of IE2 is 80% higher than IE1 (price quoted by suppliers in Malaysia). However, based on savings in energy cost by using IE2 motors, it has been found that this cost can be recovered in under 3 years. The energy cost calculation is based on 50 sen per unit for 3,600 hours of motor operation annually.

Amid concerns over the initial cost of HEMs, most companies opt to rewind faulty IE1

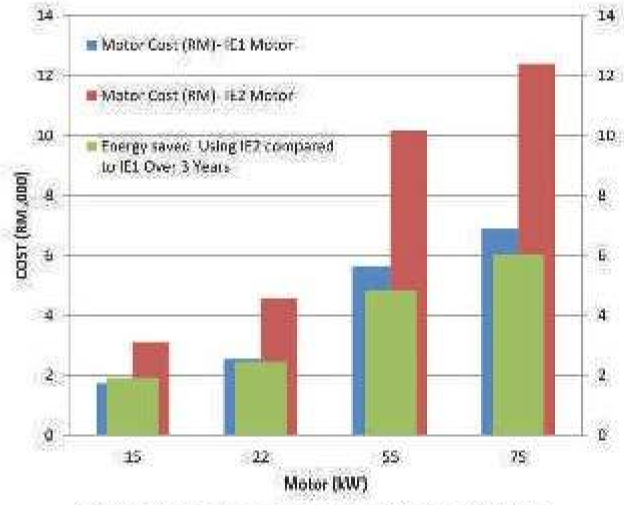

Figure 2: Cost Comparison between IE1 and IE2 motors

motors at least 4 times before considering new motors. The frequency of rewinding is, on average, once every 2 years. It is also understood that motor efficiency drops between 3% (for 0.75kW) and 10% (for 200kW and above) after each rewinding process. Figure 3 shows the cost comparison between rewinding existing IE1 and purchasing new IE2 motors. The results show that although the cost for rewinding is much lower, the lower efficiency of the rewound motors increases energy cost over the years. The graph also shows that the payback period for investing in new IE2 motors is about 2 years.

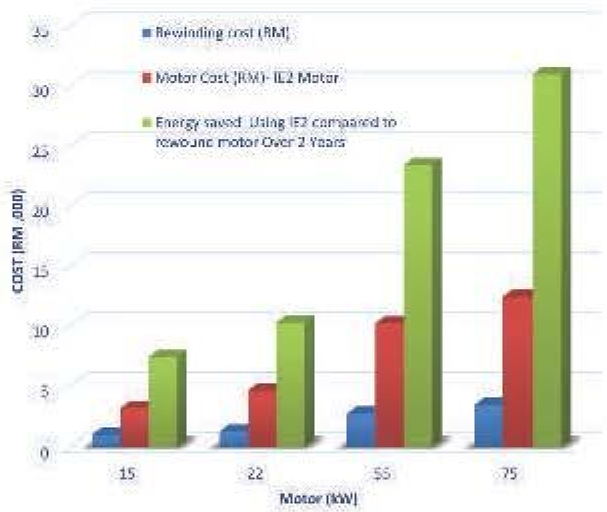

Figure 3: Cost comparison between Rewinding Existing IE1 and Purchasing New IE2 Motors

There are many industries that opt for electronic controllers to minimise the energy usage in electric motor systems. There are two controllers available in the market – soft starters and variable speed drives.

Soft starter is a simple electronic controller with thyristors which control the voltage sent to motor during *Start* and *Stop* operations. It is not able to directly control the speed, except during the starting and stopping of the motors. It is therefore suitable for applications where starting torque is relatively low (since soft starter gives much lower voltage at starting) so that starting current peak is reduced. This can be a solution to avoid high maximum demand charges.

On the other hand, variable speed drive (VSD) controls both the speed and torque throughout the motor operations (starting, constant/variable loading, and stopping). Generally, a fixed voltage, fixed frequency AC source is converted to a DC source by using an arrangement of diodes and/or insulated gate bipolar transistors (IGBTs). This process is called rectification. The DC source is then smoothed by a group of capacitors. The smoothed DC source is converted to a variable voltage, variable frequency AC source using an inverter with an arrangement of IGBTs. VSD controls power to the motor based on load requirement, so this is a better solution for saving energy, especially for motor systems running at variable speed and under variable load conditions.

Unfortunately, most old VSDs use a diodes arrangement for rectification process. This produces current harmonics at the source which will affect the power factor of the power system and directly contribute to energy losses in electrical equipment. To minimise this, a passive filter should be installed to minimise the harmonics level to within the IEEE 519 requirements.

With significant changes in our local climate, afternoon temperature can reach as high as 36 C (3) compared to 34 C reported 17 years (4) ago. In addition, the high humidity, reported within 70% to 90%, also creates an uncomfortable atmosphere at work for people and equipment. So it can be expected that, without proper ventilation, electric motors and systems will overheat. The hot spot in a motor is actually a combination of motor design (temperature rise) and the ambient (surrounding) temperature. As 50% of motor loss comes from copper loss, cooling of the motor is essential to minimise insulation failures. Besides, when self-cooled motors run at lower speed with VSD, the cooling effect will be lower and this can result in overheated motors.

Adding force cooling fans may solve this issue. In fact when the motor is connected to VSD, the location of VSD is very crucial. The IGBT at the VSD operates typically at 4 kHz switching high current and this produces excessive heat and transfers heat to the heat sink. The ventilation at the heat sink ensures the transfer of heat to its surroundings. Improper ventilation will trigger the temperature sensor at the heat sink and trip the VSD. Moreover, the hot heat sink will reduce the life cycle of IGBTs.

CONCLUSION

There are four basic issues to tackle to minimise the electricity bill for motor systems:

1. To manage the motor load
2. To improve power factor at the motor
3. To minimise current harmonics at the supply point of variable speed drive
4. To provide proper ventilation for motors and variable speed drive systems.

In addition, for greater savings, opt for IE2/IE3 motors rather than rewinding or purchase of new IE1 motors, should there be a need to replace the motors. ■

REFERENCES

[1] Code of Practice on Energy Efficiency and Conservation for Industrial Electrical Equipment- Part 3: Motors, SIRIM Malaysian Standard

[2] MS 1525 - Energy Efficiency and Use of Renewable Energy for Non Residential Building- Code of Practice, 2nd Revision 2014, SIRIM Malaysian Standard

[3] MS IEC 60034-30: 2014 - Rotating Electrical Machines - Part 30: Efficiency Classes of Single Phase, Three Phase, Cage Induction Motors (IE- Code), Department of Standard Malaysia

[4] http://www.worldweatheronline.com/Kuala-Lumpur-weather/Kuala-Lumpur/MY.aspx?day=20 20 May 2015, 12 noon.

[5] Abdul Rahman, S. and Kannan, K.S. Air Flow and Thermal Simulation Studies of Wind Ventilated Classrooms in Malaysia. Special Issue World Renewable Energy Congress, Energy Efficiency and the Environment. Renewable Energy, 8, 1(4), 1997, pp. 264-266