Proceedings of the World Congress on Engineering 2007 Vol I
WCE 2007, July 2 - 4, 2007, London, U.K.

Motor Management and Energy Saving by Integration of Motor Drive system

M. Ektesabi, *Member, IAENG*, H. Felic

Abstract— **In this paper a new-generation integral motor-drive has been demonstrated. It proposes a compact unit built to operate in arduous industrial environments with optimized power consumption and best practice motor management under different load conditions. It is the first truly integrated motor-drive unit with a design to overcome heat, vibration and electromagnetic interference which are damaging to sensitive electronics without requirement of any additional cooling system. The critical issues such as; space limitations within the existing spatial dimensions of motor, management of heat transfer from the motor to the sensitive drive control unit, management of vibration transfer to the sensitive drive control unit, management of electromagnetic interference within the unit and externally, management of other environmental effects on the sensitive drive control unit have been considered and discussed in this paper**.

***Index Terms*—Electromagnetic Interference, Immunity, Integral Motor, Radiated & Conducted Emission, Sensitive Electronics, Variable Speed Drive**

I. Introduction

Electric motors are used to provide motive power for a vast range of end users. Most of these motors are designed to run at 50% to 100% of rated load. Maximum efficiency is usually near 75% of rated load. Thus, a 10-horsepower (hp) motor has an acceptable load range of 5 to 10 hp; peak efficiency is at 7.5 hp. A motor's efficiency tends to decrease dramatically below about 50% load. However, the range of good efficiency varies with individual motors and tends to extend over a broader range for larger motors, as shown in Fig.1. A motor is considered under loaded when it is in the range where efficiency drops significantly with decreasing load. Fig.2 shows that power factor tends to drop off sooner, but less steeply than efficiency, as load decreases [1].

Manuscript received March 6, 2007. This work was supported in part by CMG Group, Australia.

M. Ektesabi is with the Department of Robotics & Mechatronics, Faculty of Engineering & Industrial Sciences, Swinburne University of Technology, PO Box 218 Hawthorn, Victoria-3122, Australia (Phone:+61-3-92148532; Fax:+61-3-9214 8264; e-mail: mektesabi@swin.edu.au).

H. Felic is with CMG Technology, No. 19 corporate Ave, Rowville, Victoria-3178, Australia

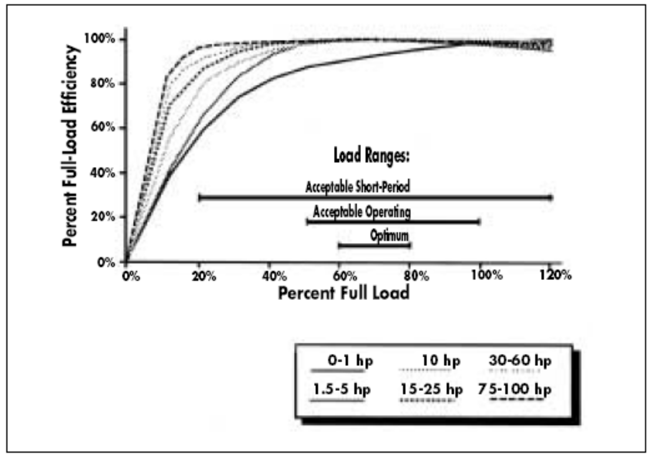

Fig. 1 Load Efficiency

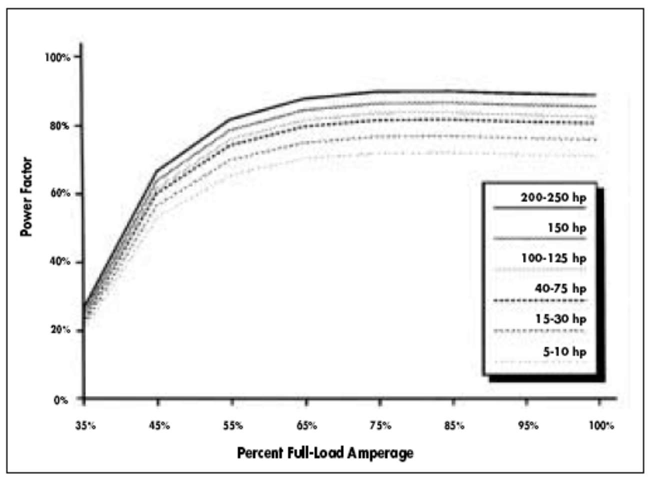

Fig. 2 Motor Power Factor

If the operation uses equipment with motors that operate for extended periods under 50% load, modifications in the system will improve the energy consumption. Sometimes motors are oversized because they must accommodate peak conditions, such as when a pumping system must satisfy occasionally high demands. Options available to meet variable loads include two-speed motors, adjustable speed drives, and load management strategies that maintain loads within an acceptable range.

To date, most public and private-sector efforts to improve motor system energy efficiency have focused on the motor, rather than other individual motor-driven system components or, more importantly, on the system as a whole [1].

A large portion of the cost of electricity for manufacturing is associated with pumps, fan and blower systems, and air compression. Industry buys high share of electricity to operate motor-driven systems. The potential savings in system improvement opportunities are very large - over 100 billion kwh/year energy savings and billions of annual energy cost savings opportunity with existing and new technology [2]. System improvement opportunities may include: improved sizing and proper matching to load, use of more efficient drive trains, improved system layout, updated and well-maintained controls, improved operation and maintenance, and use of Variable Speed Drives (VSDs) [3].

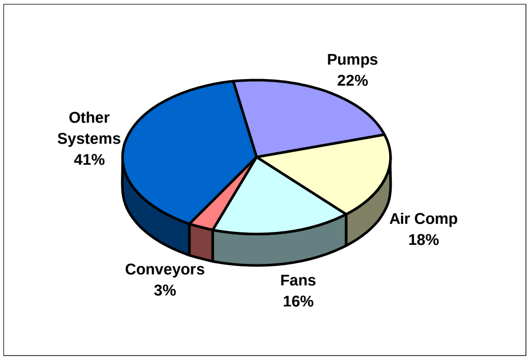

Fig. 3 Motor Electricity Consumption

A. Optimizing energy consumption

Figure 3 shows that the Pump and fan applications account for around 38 per cent of the end uses of motive power.

In pump and fan applications, the power consumed is proportional to the operating speed cubed. Efficiencies of pumps and fans vary greatly and depend on operational requirements. Fine-tuning the system can have a big impact on energy consumption. One should keep in mind that although the pump (or fan) and the system are two separate entities, they are totally dependent on each other. Changing one will have a significant impact on the performance of the other[4].

The key areas where fluid energy is most commonly wasted are:

- excess head (pressure) that must be throttled
- more flow than necessary to accomplish the purpose of the system
- unnecessary flow paths
- excessive frictional losses.

Most industrial systems have pumping requirements with several operating points or variable flow and pressure requirements. Picking the pump (fan) with the optimum efficiency for a specific delivery is only part of the story. The other part is controlling the flow rate to match the process requirements which may be obtained in several ways:

- Recirculation - continuously runs the fluid round the system through a buffer tank
- Throttle control - uses valves or flaps to control the flow rate
- Cycle control - turns the pump on and off to control the flow
- VSD or ASD - stands for variable or adjustable speed drive, and controls the pump's speed to control the flow.

The most efficient control option is the one that most closely matches the ideal pump curve, which is shown in the graph below (figure 4) .

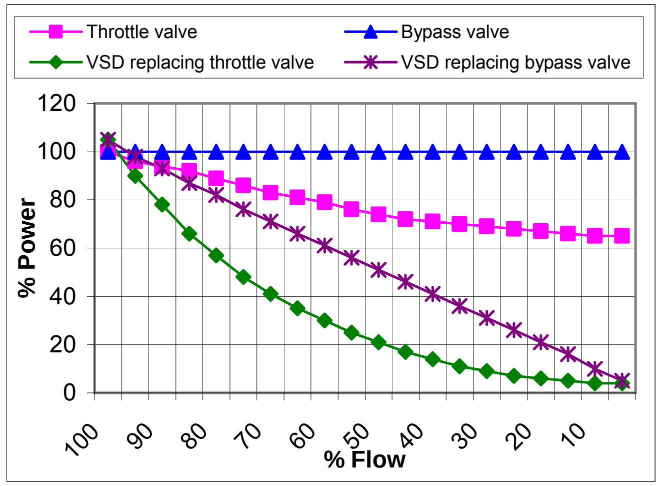

Fig. 4 Power requirement for various control options

From the above discussion and the Power requirement of various controls, the advantages of VSDs are obvious. Nowadays, VSDs are considered as one of the most important tools for Motor Management and Energy Saving. On the other hand, the advancements in semiconductor technology made the low cost, compact and reliable VSDs possible.

One of the critical features of VSD is the high switching frequencies which generates conducted & radiated noise, and they may cause significant damage to the motor by producing bearing currents and insulation voltage stress. Fortunately this problem is well known and there are many ways to overcome this problem [5 -9]. Hitachi suggested [10] to reduce this effect lowest carrier frequency of operation for the PWM inverter should be selected. But, the selection of the optimum carrier frequency of operation of the inverter depends upon a balance between different design parameters such as; the optimum harmonic reduction in the motor which is inversely proportional to the carrier frequency, optimum average switching power loss which is proportional to the switching frequency , optimum losses or heat generated in the motor which is related to total harmonics in the motor winding which in turn in related to requirement of cooling system or fan of the motor and finally, the lowest level of Audible Noise generated by the drive system.

The other critical feature of VSD is the effect of insulation voltage stress which particularly increases and has more serious effect if the length of cable between the VSD and motor increases. Because harmonics increase heating in induction motors with a commensurate impact on expected motor life, older motors with long cable runs may have a shortened lifetime and higher insulation failure when used with VSDs.

Current harmonics in the VSD input stage can also feed back into the power bus grid, and can disrupt other types of equipment. Harmonics can also cause supplementary losses and temperature-rise of all the elements in the supply system. These high frequencies can produce electromagnetic interference (EMI) both as high frequency airborne radiated interference mostly in the inverter to motor cable, as well as the conducted noise in the supply cables.

If proper precautions are not taken, the harmonics can disturb nearly sensitive electronic devices. The fast transitions in current level include high frequencies that, while necessary to the operation of the drive, can have detrimental effects on other pieces of equipment (e.g. leading to measurement or counting errors, and unexpected operation of the processor and digital system).

Possible EMI problems can be avoided in virtually all cases by keeping the link motor-VSD as short as possible, proper grounding, shielding and using harmonic filters are other safe measures.

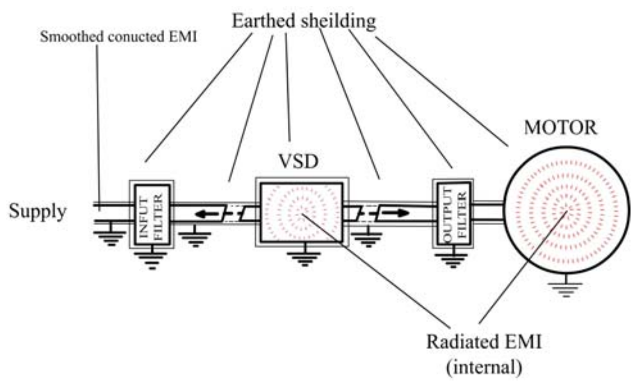

Fig. 5 EMI reduction by EMC Filter and Shielding

B. Reduction of system EMI by Integration

To reduce the space requirement of VSD – motor system and to overcome the above EMI problems, many of the manufactures bring together the motor and the drive in a closer form called integral motor, which in turn reduces required space & installation cost (Fig.3). The reduction of space in these systems is switching the problems from the system level to the component level problems. Unlike the proposed motor, the other integral systems use an additional cooling fan for the drive or the motor to over come the heating effects produced due to excessive switching losses or harmonic losses [11].

(a) ABB Motor (b) Proposed Motor

Fig. 6 Position of Drive with respect to Motor

C. Component Level EMI

In an integral motor with a metallic enclosure drive system, the culprit component has the direct radiation as well as reflected radiation over the susceptible components. The Radiated & Reflected radiation in a small chamber is not controllable and may cause misfiring/failure or malfunctioning of the system. The other fact which increases this effect is the close distance of the drive and the motor in an integral motor. In addition to the effects we mentioned earlier. The effects of high frequency EMI produced in the motor winding close to the electronic parts in an integral motor in turn decreases the immunity of the susceptible components.

II. Proposed Integral Motor

Keeping in mind the guide lines from the last section, the EMI/EMC problems may be approached at the component, PC board or enclosure levels. However, it is much more efficient to deal with these problems as close to the source or susceptible victim as possible. Switching from the system level EMI to the component level EMI is possible if, we consider that the Culprit system's radiation affects the susceptible systems in the same way as that of the radiating Culprit components (Power switching devices/Power modules) affecting the other more susceptible components such as analogue and less immune digital components. To overcome the conducted EMI, the PCB design will require proper track design for power & control signal, increasing the separation of the power and signal tracks and by filtering of each component at its input/output. Additional EMC line filter will filter out the effect of conducted EMI To/From the supply line.

Shielding the system can be used as first line of defense for radiated emission. Shielding is very useful tool for reduction of interference of the culprit system with other external susceptible systems. However, it does not protect the internal susceptible components within the system. An Integral motor with the drive in built within the motor, if properly shielded may provide good external EMC compliance, but care should be taken in design of the PCB and its tracks to provide sufficient immunity to electronics within the system.

The proposed integral motor vs the conventional system is shown in Fig. 7, in which the savings in size and the installation is demonstrated. Integral motor provides lower system cost and more flexibility in use of systems. In addition, the proposed integral motor has been designed with integrated drive system which has internal Electromagnetic Compatibility (EMC) filters and is an integrated part of the motor. The internal EMC filters have minimized the Radiated and Conducted EMI.

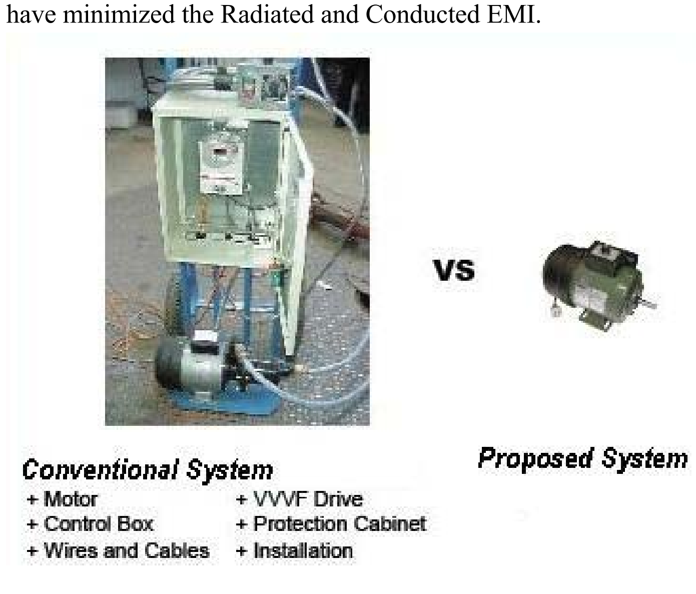

Fig. 7 Conventional System vs Proposed System

The integral motor in this case, will have a short link between the motor and the drive which minimizes the amount of disturbance powers if a proper filter is used.

The metallic casing of the integral motor and proper grounding of the system provides an easy shielding of the system with least effect of external radiation to the surrounding environment.

An Integral motor with the drive in built within the motor (Fig.8), if properly shielded may provide good external EMC compliance, but care should be taken in design of the PCB and its tracks to provide sufficient immunity to electronics within the system. In this system the cooling fan cools the VSD as well as the motor and there is no requirement for an additional fan.

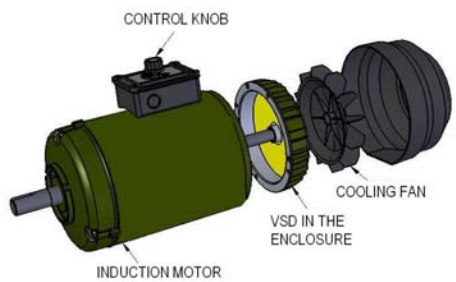

Fig. 8 Construction of Proposed Integral Motor

Electronic components within the integral motor will experience high radiated and conducted EMI from the motor winding and the switching components. It requires well design of power electronics and control system to be reliable under these conditions. The solution is to use the most immune available components and then an insulation shielding can be used to reduce the direct destructive EMI to an accepted level for susceptible components. In this paper an insulation layer of Epoxy has been used which added up the following advantages to the system;

- Good electric insulator and Lower Level of EMI
- Good thermal conductive property resulting to increase in thermal surface & better cooling of the components
- Increase the level of IP protection of the electronic components
- Increasing the mechanical strength of the control system to withstand vibration

III. Conclusion

In this paper a new-generation integral motor-drive has been demonstrated. It proposes a compact unit built to operate in arduous industrial environments with optimized power consumption and best practice motor management under different load conditions. Advantages of the proposed Integral motor are compactness of combo motor and drive system with no external cabling/wiring. The motor provides a perfect shielding for least amount of radiated emission. It has an inbuilt filter for EMC compliance. It has been designed to provide lower EMC noise for immunity of the internal electronics as well as other neighboring systems. It can be a stand alone system for the best load/application performance with no commissioning and programming. It is a truely integrated motor-drive unit with a design to overcome heat, vibration and electromagnetic interference which are damaging to sensitive electronics without requirement of any additional cooling system.

References

[1] *Paul E. Scheihing; "*U.S. Department of Energy's Motor Challenge Program: A National Strategy for Energy Efficient Industrial Motor-Driven Systems", *Department of Energy, Industrial Technologies Program Washington, DC, USA,* 09/27/2005.

[2] European Commission Conference : 'Energy Efficiency Improvements in Motors and Drives"; October 29-31, 1996; Portugal

[3] Energy Using Product (EuP) Directive Preparatory Study ; Lot 11: Motors Analysis of existing technical and market information First Stakeholder Meeting ; DG TREN, Brussels, June 29 2006

[4] Australian Greenhouse Office, Department of the Environment and Heritage, http://www.greenhouse.gov.au/motors

[5] Sidney Bell, Timothy J.Cookson,Steven A.Cope,Richard A.Epperly, Annika Fischer, David W.Schegel,and Gary L.Skibinski," Experience With Variable-Frequency Drives and Motor Bearing Reliability" , IEEE Transactions On Industry Applications, Vol 37,No.5, September/October 2001

[6] Jay Erdman, Russel J. Kerkman, Dave Schlegel, and Gary Skibinski : "Effect of PWM inverters on AC motor bearing currents and shaft voltages", IEEE Transactions on Industry Applications, Vol 32, No.2, March/April, 1996

[7] Ong R, Dymond J. H., Findlay R. D., "A comparison of techniques for measurement of shaft currents in rotating machines", IEEE Transactions on Energy Conversion, Dec. 1997.

[8] Mehran Ektesabi and Hasib Felic: CMG torque newsletter, Issue4, September 2002.

[9] R Schiferl and M Melfi : Bearing Current Problems: Causes, Symptoms, and Solutions, Rockwell Automation, September 2005.

[10] Application Note (AN082604-1) : "Minimizing Motor Shaft Bearing Current", Hitachi America Ltd, 2004.

[11] ABB LV Motors/Cat/Bu/General Purpose motors/integral GB 09-2003.

ISBN:978-988-98671-5-7