Controlling Heat, Vibration and EMI in an Integral Motor

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Abstract - Controlling heat and vibration produced by the Motor & Variable Drive systems when integrated as an integral motor are the problems affecting the reliable operation of the system. In this paper a new-generation integral motor-drive has been demonstrated, true innovation in its design and development is a technological advancement. It is a 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. It proposes a compact unit built to operate in arduous industrial environments.

Index Terms –Electromagnetic Interference, Integral Motor, Sensitive Electronics, Variable Speed Drive

I INTRODUCTION

AC induction motors are widely used by industry globally. Wherever there is manufacturing or material processing a motor is likely to be found. Due to the evolution of technology and availability of semiconductors at lower cost, in last few decades, the VSD & Induction motors are used in most of the industrial applications. Though the Variable Speed Drives (VSD) and their advantages are very well know, but unfortunately, the integration of the knowledge of Electrical Motors and Power Electronics Engineering was not known by industries till last decade. Nowadays, VSDs are considered as one of the most important tools for Motor Management and Energy Saving.

Nowadays, the motor manufacturing trends are toward addition of intelligence to motors, so that the overall package requires no more space, yet is capable of increase in efficiency and working capabilities. And due to higher performance and compactness of semiconductors, the integration of the Motor Drive system called integral motor has been achieved which is now replacing the other types of low power controlled motors.

In this paper, integration of motor drive system and critical features associated with these systems are presented. The proposed integral motor is an integrated asynchronous motor-frequency controller package for variable speed applications. Integration in this case, also means that the system should be compact, reliable, cost efficient, and should be easy to install.

The proposed Motor with a unique development brings intrinsic powerful yet simple speed control of electric motors to the hand of the user. State-of-the art control technology incorporated into a normal sized motor allows a user to plug the motor into a standard PowerPoint and use it straight away with no additional installation. The compact Integral Motor offers significant startup and ongoing cost savings. The proposed Motor is the first truly integrated motor-drive unit with a design which overcomes heat, vibration and electromagnetic interference which are damaging to sensitive electronics.

In the next sections, the general problems caused by high frequency VSDs and the analysis of critical features associated with design of integral motors are presented and the guidelines to reduce the problems are provided.

II MOTOR DRIVE SYSTEMS

A. Bearing Currents and Insulation Voltage Stress

The high switching frequencies of VSD generates conducted & radiated noise, and additionally they may cause significant damage to the motor and the embedded systems by producing bearing currents and insulation voltage stress [1]. There has been many research and proposed solutions to overcome this problem. For example, Hitachi recommends the selection of lowest carrier frequency of operation for the PWM inverter to be below 5 KHz [2]. But the selection of the optimum carrier frequency of operation of the inverter is not that easy and depends upon a balance between different design parameters such as:

- The optimum harmonic reduction [3] 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 which is normally around or above 9 KHz.

The followings are some of the currently available remediation methods [4, 5, and 6] to overcome the bearing currents and insulation voltage stress problems.
Electromagnetic Interferences (EMI) - Radiated & Conducted Emission

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 (machines, transformers, cables, capacitor banks). In certain instances, harmonics can also excite resonances. 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. The EMI sources are shown in Fig.1 VSD Motor System EMI sources. 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 embedded system).

Problems can be avoided in virtually all cases by the following precautions:
- Keeping the link motor-VSD as short as possible;
- Proper grounding;
- Proper shielding;
- Passive or active harmonic filters;
- Isolation transformers (if applicable)

B. Reduction of system EMI by Integration

To reduce the space requirement 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 installation cost. The reduction of space in these systems is transferring the problems from the system level to the component level. The spatial position of the drive with respect to the motor is practically immaterial, but isolation and shielding of the two systems to minimize their mutual effect on each other is very important.

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. The high frequency EMI produced in the motor winding affects directly to decrease the immunity of the susceptible components Fig.2.

Due to these problems, achievement of the reliable best performance of a true integration of motor drive system is not easy. To solve a problem, it is important to know what the sources of the problem. For EMI to exist it is necessary to have:
- EMI Source that generates interface (Culprit)
- System or device that is susceptible to interference (Victim)
- Coupling path between the generating and the susceptible system (link or media)
So far in this paper, the associated problems with Motor-drive systems such as; Bearing Current & insulation Voltage stress, System level Electromagnetic Interferences (EMI) - Radiated & Conducted Emission have been discussed and solutions were proposed. It has also been observed that the integration (integral Motor) can cause reduction of system radiated EMI, but the Component Level EMI problem which is the main source of malfunctioning of the embedded electronics system is not considered.

As a guide line, reduction of the EMI calls for consideration of the following:

- Reduction of interface levels generated by the culprit system
- Increase the immunity threshold of the susceptible system
- Reduce the direct coupling path by:

In the next section the critical features as seen for design of proposed integral motor and how it overcomes the above inadequacy is presented.

III ANALYSIS OF CRITICAL FEATURES

To combine the motor and VVVF drive into one compact, easy to use and cost competitive unit requires deeper analysis of the critical issues such as:

- Space limitations within the existing spatial dimensions
- 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 (EMI) within the unit and externally.
- Management of other environmental effects on the sensitive drive control unit.

Suitable solutions for management of the above critical features are presented as,

A. Space

The spatial configuration of motor allows only two possible locations for the drive control unit. Within a peripheral box traditionally used for housing terminals and capacitors or, alternatively, inside the motor at the rear end of the unit, adjacent to the fan, shrouded by the cow. In this paper, the latter alternative was favorable due to the reduced amount of changes needed to the manufacturing process as well as effective cooling of the drive system (Fig.3).

B. Heat

Of the two possible spatial locations the external peripheral location would have required an additional cooling mechanism whereas having the control unit mounted in the rear end of the motor utilized the existing fan used to cool the motor. Further consideration of heat and methods for dissipation gave consideration to ways of shielding the sensitive control unit components. A traditional end shield was used to shield the heat, along with an innovative epoxy material used to pot the electronics in their enclosure. The electronic enclosure was also design as a heat sink for electronic components and is finned for further heat dissipation.

C. Vibration

Damaging vibration was countered by the absorptive properties of the epoxy resin chosen in which the electronic control unit was potted. Increased rigidity to the overall system was another benefit provided by the potting against vibration.

D. EMI

EMI affects sensitive electronics components so it was of particular importance to deal with the strong EMI effects of the motor on the sensitive drive control unit. The intelligent and integrated design of the proposed system used the metal motor body, its two end shields, and the electronic enclosure to encase the strong internal magnetic field of the motor and the EMI of the drive separate from each other. The ability to draw all interference away by properly earthing the encasings provided the means to eliminate EMI effect cause by or caused to the complete unit.

E. Ingress Protection (IP)

Motors are, in many cases, used in harsh environments. Along with heat and vibration, dust and moisture are other significant environmental influences. Extra consideration was need for the sensitive electronic controls. The third important characteristic of the epoxy resin potting material is the protection it gives to sensitive electronic components.

This combined with a v-ring between shaft and enclosure and a gasket between the enclosure and back end shield provided the necessary protection.
A key factor in the success of the product development is the identification of the potting material used to protect the electronic components (Fig.4). Protection by the material had to meet four different types: protection against, heat, ingress of dust/moisture, vibration and EMI.

Traditionally distancing the motor and drive gave the drive protection from heat transferred by the motor. Along with the potting material, electronic components with higher heat tolerance were chosen, and a technique of innovatively positioning components was used which leveraged the cooling effects of the existing motor fan.

EMI issue resolution involved identification and combination of a suitable shielding technique to minimize the nuisance caused. Firstly, low emission motor components and design was developed to minimize interference to the sensitive drive components. Secondly, the special potting material was identified which loaned EMI shielding effects to the sensitive components. Thirdly, utilizing the existing motor encasings and earthing to one point provided an amazing innovation to contribute to the solution. Finally, PCB layout design was used to minimize interference.

F. Environmental Improvements
Reduction of power consumption by the integral motor over traditional non-electronic speed control methods provides ongoing significant reduction in associated greenhouse gas emission.

G. Usability Improvements
The Integral Motor has significant usability improvements over all competing motor speed control alternatives.
- No ancillary components and no skills are required in its installation.
- The Integral Motor is also easily adaptable to uncontrollable existing systems in which case all that is required is a substitution of an existing motor.
- The reduced amount of space required allows the Integral Motor to be easily placed in location previously complicated or even unachievable.
- The Integral Motor, including its VVVF drive components, can be installed in environmentally challenging locations previously too harsh for any other electronic system.

IV. EXPERIMENTAL RESULTS
Keeping in mind the guide lines from the last section, the EMI/EMC problems may be approached at the component, PCB 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-drive system 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 Conducted EMI (Fig.5).

![Fig. 5 Conducted Emissions with Common Mode Filter](image)

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 (Fig.6).

![Fig.6 Radiated Emission with Filter](image)

An Integral motor with the drive in built within the motor (Fig.7), 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.
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 to this type of problem is simple: the designer has to use the most immune available components and then an insulation shielding technique 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

V CONCLUSION

In this paper, the associated problems with Motor-drive systems such as Bearing Current & insulation Voltage stress, System level Electromagnetic Interferences (EMI) - Radiated & Conducted Emission have been discussed and solutions were proposed. It has also been observed that the integration (integral Motor) can cause reduction of system radiated environmental EMI. In the proposed system it is tried to minimise all the above issues. It has a short link between the motor and the drive which minimises the amount of disturbance powers with an inbuilt proper filter. 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 and care has been taken in design of the PCB and its tracks to provide sufficient immunity to electronics within the system. The effect of high radiated and conducted EMI from the motor winding as well as the switching components has been reduced to an accepted level by a well designed power electronics, control system and choice of reliable components. The reduction of the radiated EMI which provides the immunity of electronic systems has been obtained by addition of an insulated shielding media (epoxy). This media provides shielding to heat transferred from the motor and of course it adds mechanical strength to the parts to withstand higher vibration in arduous industrial environments.

REFERENCES:


