ABB drives

Technical guide No. 5
Bearing currents in modern AC drive systems

Power and productivity for a better world™

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Chapter 1 - Introduction

General

Some new drive installations can have their bearings fail only a few months after startup. Failure can be caused by high frequency currents, which flow through the motor bearings.

While bearing currents have been around since the advent of electric motors, the incidence of damage they cause has increased during the last few years. This is because modern variable speed drives with their fast rising voltage pulses and high switching frequencies can cause current pulses through the bearings whose repeated discharging can gradually erode the bearing races.

Avoiding bearing currents

To avoid damage occurring, it is essential to provide proper earthing paths and allow stray currents to return to the inverter frame without passing through the bearings. The magnitude of the currents can be reduced by using symmetrical motor cables or inverter output filtering. Proper insulation of the motor bearing construction breaks the bearing current paths.

Chapter 2 - Generating bearing currents

High frequency current pulses

Bearing currents come in several different guises. However, while modern motor design and manufacturing practices have nearly eliminated the low frequency bearing currents induced by the asymmetry of the motor, the rapid switching in modern AC drive systems may generate high frequency (HF) current pulses through the bearings. If the energy of these pulses is sufficiently high, metal transfers from the ball and the races to the lubricant. This is known as electrical discharge machining or EDM. The effect of a single pulse is insignificant, but a tiny EDM pit is an incontinuity that will collect more pulses and expand into a typical EDM crater. The switching frequency of modern AC drives is very high and the vast number of pulses causes the erosion to quickly accumulate. As a result, the bearing may need replacing after only a short time in service.

High frequency bearing currents have been investigated by ABB since 1987. The importance of system design has been highlighted in the last few years. Each individual item involved, such as the motor, the gearbox or the drive controller, is the product of sophisticated manufacturing techniques and normally carries a favourable mean time between failure (MTBF) rate. It is when these components are combined and the installed system is looked upon as a whole, that it becomes clear that certain installation practices are required.

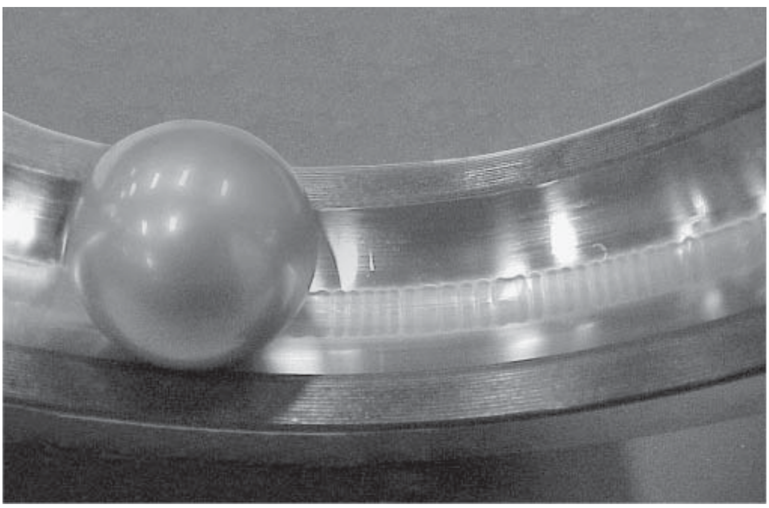

Figure 1: Bearing currents can cause “bearing fluting”, a rhythmic pattern on the bearing’s races.

Faster switching

Current AC drive technology, incorporating insulated gate bipolar transistors (IGBT), creates switching events 20 times faster than those considered typical ten years ago. Recent years have seen a rising number of EDM-type bearing failures in AC drive systems relatively soon after startup, within one to six months. The extent to which this occurs depends on the AC drive system architecture and the installation techniques used.

How are HF bearing currents generated?

The source of bearing currents is the voltage that is induced over the bearing. In the case of high frequency bearing currents, this voltage can be generated in three different ways. The most important factors that define which mechanism is prominent, are the size of the motor and how the motor frame and shaft are grounded. The electrical installation, meaning a suitable cable type and proper bonding of the protective conductors and the electrical shield, plays an important role. Du/dt of the AC drive power stage components and the DC-link voltage level affect the level of bearing currents.

Circulating current

In large motors, high frequency voltage is induced between the ends of the motor shaft by the high frequency flux circulating around the stator. This flux is caused by a net asymmetry of capacitive current leaking from the winding into the stator frame along the stator circumference. The voltage between the shaft ends affects the bearings. If it is high enough to overcome the impedance of the bearings' oil film, a current that tries to compensate the net flux in the stator starts to flow in the loop formed by the shaft, the bearings and the stator frame. This current is a circulating type of high frequency bearing current.

Shaft grounding current

The current leaking into the stator frame needs to flow back to the inverter, which is the source of this current. Any route back contains impedance, and therefore the voltage of the motor frame increases in comparison to the source ground level. If the motor shaft is earthed via the driven machinery, the increase of the motor frame voltage is seen over the bearings. If the voltage rises high enough to overcome the impedance of the drive-end bearing oil film, part of the current may flow via the drive-end bearing, the shaft and the driven machine back to the inverter. This current is a shaft grounding type of high frequency bearing current.

Capacitive discharge current

In small motors, the internal voltage division of the common mode voltage over the internal stray capacitances of the motor may cause shaft voltages high enough to create high frequency bearing current pulses. This can happen if the shaft is not earthed via the driven machinery while the motor frame is earthed in the standard way for protection.

Common mode circuit

High frequency bearing currents are a consequence of the current flow in the common mode circuit of the AC drive system.

A typical three-phase sinusoidal power supply is balanced and symmetrical under normal conditions. That is, the vector sum of the three phases always equals zero. Thus, it is normal that the neutral is at zero volts. However, this is not the case with a PWM switched three-phase power supply, where a dc voltage is converted into three phase voltages. Even though the fundamental frequency components of the output voltages are sy mmetrical and balanced, it is impossible to make the sum of three output voltages instantaneously equal to zero with two possible output levels available. The resulting neutral point voltage is not zero. This voltage may be defined as a common mode voltage source. It is measurable at the zero point of any load, eg. the star point of the motor winding.

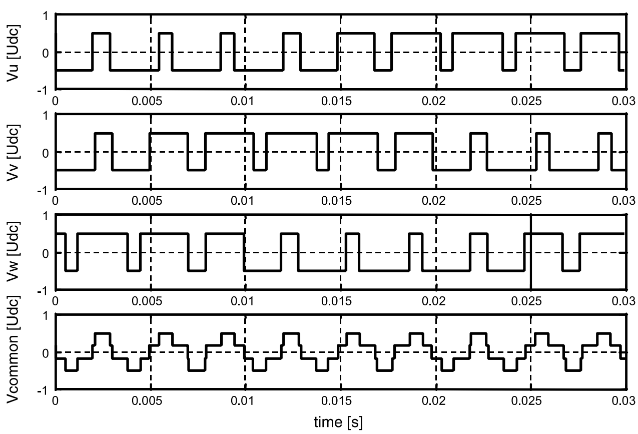

Figure 2: This schematic shows the phase voltages of a typical three phase PWM power supply and the average of the three, or neutral point voltage, in a modern AC drive system. The neutral voltage is clearly not zero and its presence can be defined as a common mode voltage source. The voltage is proportional to the DC bus voltage, and has a frequency equal to the inverter switching frequency.

Any time one of the three inverter outputs is changed from one of the possible potentials to another, a current proportional to this voltage change is forced to flow to earth via the earth capacitances of all the components of the output circuit. The current flows back to the source via the earth conductor and stray capacitances of the inverter, which are external to the three phase system. This type of current, which flows through the system in a loop that is closed externally to the system, is called common mode current.

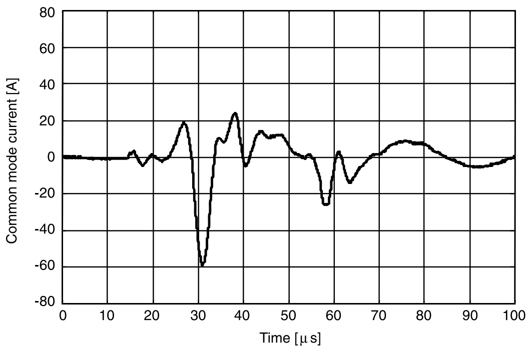

Figure 3: An example of the common mode current at the inverter output. The pulse is a superposition of several frequencies due to the different natural frequencies of the parallel routes of common mode current.

Stray capacitances

A capacitance is created any time two conductive components are separated by an insulator. For instance, the cable phase wire has capacitance to the PE-wire separated by PVC insulation, for example, and the motor winding turn is insulated from the frame by enamel coating and slot insulation, and so has a value of capacitance to the motor frame. The capacitances within a cable and especially inside the motor are very small. A small capacitance means high impedance for low frequencies, thus blocking the low frequency stray currents. However, fast rising pulses produced by modern power supplies contain frequencies so high that even small capacitances inside the motor provide a low impedance path for current to flow.

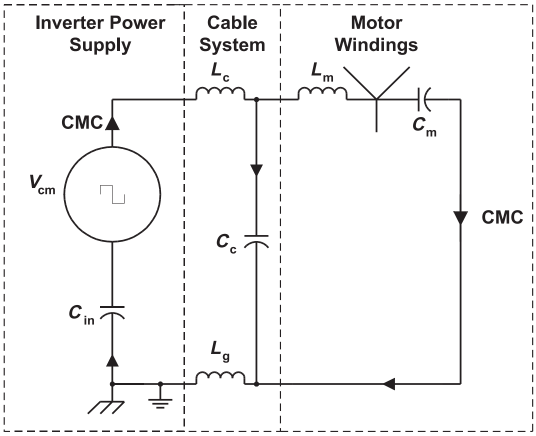

Figure 4: Simplified loop of the common mode current of a PWM inverter and induction motor. The inverter power supply acts as a common mode voltage source (V_{cm}). Common mode current (CMC) flows through the common mode cable and motor inductances, L_c L_m and through the stray capacitances between the motor windings and motor frame, combined to be C_m. From the motor frame, the current proceeds through the factory earth circuit which has the inductance L_g. L_g is also fed common mode current from the stray cable capacitance C_c. The inverter frame is connected to the factory earth and couples the common mode current/ earth currents through stray inverter to frame capacitances, combined as C_{in}, back to the common mode voltage source.

How does the current flow through the system?

The return path of the leakage current from the motor frame back to the inverter frame consists of the motor frame, cable shielding or PE-conductors and possibly steel or aluminium parts of the factory building structure. All these elements contain inductance. The flow of common mode current through such inductance will cause a voltage drop that raises the motor frame potential above the source ground potential at the inverter frame. This motor frame voltage is a portion of the inverter's common mode voltage. The common mode current will seek the path of least impedance. If a high amount of impedance is present in the intended paths, like the PE-connection of the motor frame, the motor frame voltage will cause some of the common mode current to be diverted into an unintended path, through the building. In practical installations a number of parallel paths exist. Most have a minor effect on the value of common mode current or bearing currents, but may be significant in coping with EMC-requirements.

Detta är endast ett utdrag. Kontakta mig om du vill läsa dokumentet i sin helhet.

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