Introduction

Variable speed drives have been used in industrial applications for years because of their ability to provide precise process control. They have also become the standard method of control for heating ventilation and air-conditioning (HVAC) systems due to their precise control and significant energy savings.

The operational concerns for HVAC systems are quite different from those for industrial applications. In most HVAC installations there is a large installed base of sensitive electronic equipment such as computers, outstations and radios. Airports, hospitals and research facilities will for example make much heavier demands on the variable speed drives than the industrial plants.

This feature note will deal with one aspect of electrical noise generation in variable speed drives: Radio Frequency Interference (RFI) on the AC power line. We describe the causes and effects of such noise as well as the considerations that are to be made in connection with the selection and installation of a variable speed drive.

Causes of Radio Frequency Interference (RFI)

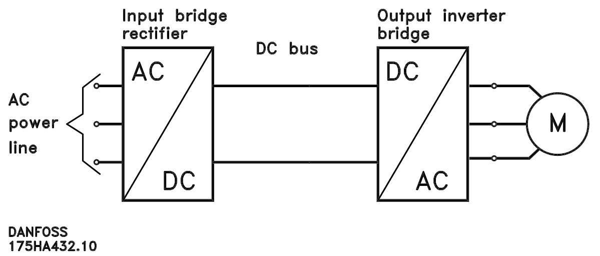

Figure 1: Schematic of Basic Drive design

Most variable speed drives operate by using a bridge rectifier to convert the incoming AC voltage into a DC bus voltage. The inverter bridge of the drive then converts the DC bus voltage into the controlled voltage and frequency that the motor requires.

For the most common types of drives in use today, IGBTs are used to convert the DC voltage into an AC voltage with controlled amplitude and frequency. To perform this control most drives incorporate sophisticated control circuitry with micro-processors of high clock frequencies.

Both the inverter and the control circuitry generate electrical noise at frequencies higher than 150 kHz.

If the drive is not designed carefully, this noise will be conducted to the surroundings, causing malfunction of other electronic equipment, especially if it is not designed with a high level of immunity to such high frequency noise.

Measuring Radio Frequency Interference

The levels of RFI from a drive is dependent on many different factors. The design of the drive is most important, since this determines how low the distortion can get.

The measuring results for different drives may vary a lot, so to get a real picture it is important to know exactly how the measuring was made. Some of the most important factors are:
Impedance between drive chassis and ground
Type of motor cable used or transfer impedance of cable screen
Length of motor cable

Radiated emission is almost impossible to reproduce. The reason is that even a slight change in the measuring set-up will influence the results a lot. Measuring made on site will always be unreliable, since it is impossible to create a clean environment.

Radio frequency interference limits

The most important international standard defining RFI limits for drives is:
EN 55011/CISPR 11

EN55011 sets three different limits:

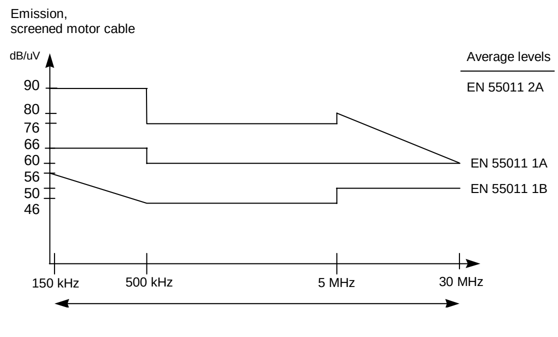

Figure 2: Average conducted emission levels

Of these limits only 1A and 1B have been applied as legal requirements.

Each level contains limits to quasi peak and average conducted emission as well as quasi peak radiated emission.

Figure 2 shows the limit for average conducted emission. Conducted emission is a cause for concern. With EN 55011 demands for Quasi Peak and Average were combined in one standard to get more equal demands and remove the need to determine which of the two requirements that should apply to the equipment. The level is approximately 10dB mV lower than the quasi peak levels.

Often the quasi peak limits do not cause any major problems in the design of the RFI filter. The average limits, however, have caused problems to many manufacturers.

■ RFI filters

RFI filters are available in many different designs. The most economical and best functioning filter will match the drive very carefully.

An RFI filter mainly consists of common mode reactors and capacitors.

Whether a filter is good at filtering the frequencies exceeding the limit of the norm will always be dependent on the design. If the filter is not designed for the drive, the filter components will have to be oversized resulting in increased costs.

■ Installation considerations

When installing a drive, it is important to check the manufacturers' guidelines and some general rules of thumb:

a. Avoid pigtails

A pigtail is as shown in figure 3, where the screen-end is twisted and connected to the PE-terminal or a ground screw.

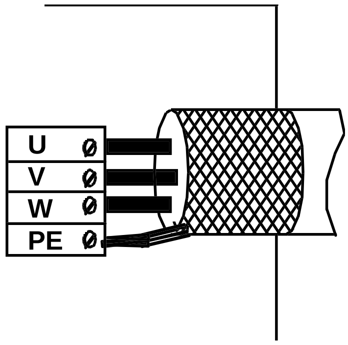

Figure 3: Motor cable with pigtail

This type of ground connection increases the transfer impedance to ground and increases the noise levels that can be measured on the mains cable. Figure 4 shows measured values of transfer impedance for different lengths of cable screen and pig-tails. As can be seen even a fairly short pig-tail has the same transfer impedance as 150m of cable screen above 10 MHz.

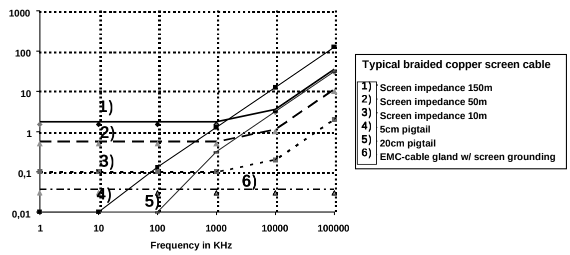

Figure 4: Comparison of transfer impedance for cable screens and pigtails

Figure 5 below shows the impact on compliance when a good installation (curve 1)
is changed to an installation with a pigtail of 5 cm at the drive end, while the motor end is left untouched (curve 2). Where the good installation complies with EN 55011 1B, the installation with 5 cm of pig-tail barely complies with EN 55011 1A. As indicated in figure 4 a longer pig-tail would reduce compliance even further.

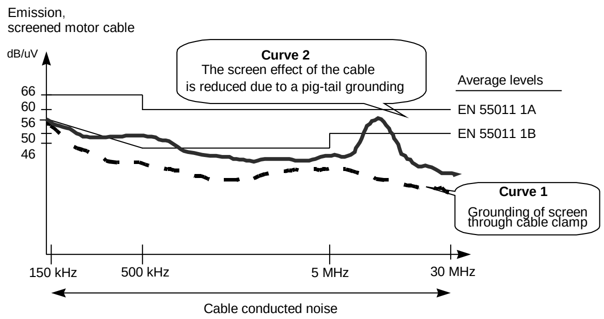

Figure 5: Comparison between good installation and pigtail installation

b. Use screened motor cable from the drive to the motor, also inside panels.
Usually the cable between the panel and the motor is screened. Unfortunately, output contactors inside panels are often connected with unscreened cables. That will give problems with noise being radiated between the cables.

Figure 6 shows a comparison between a good installation (curve 1) and a bad one, using unscreened motor cables inside the panel (curve 2). In this example great care was taken to separate the mains cable from the motor cable. It is sometimes not possible to avoid the use of unscreened motor cable inside the panels, but as curve 2 shows compliance with EN 55011 1A is achievable.

Often the mains and motor cables, however, are placed much too close and this causes transmission of noise directly between mains and motor cables, thus by-passing the RFI filter and losing compliance with EN 55011, as shown in curve 3.

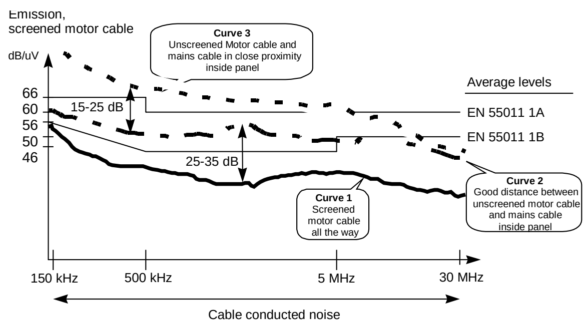

Figure 6: Using unscreened cables inside the panel.

c. Connect the screen at motor and VLT:
To get an effective screening of the electric and magnetic field from the motor cable it is necessary to connect the screen at the motor and at the VLT. Connecting the screen only in one end will screen the electric field but will have no effect on the magnetic field. As the noise from the motor cable is mainly magnetic fields the screen will be very ineffective when connected only in one end.

Equalising currents will rarely case any problems to the installation. As a rule of thumb the screen should therefore always be connected in both ends. If then a problem should occur, then it is recommended to connect a 1 µF capacitor at the drive end, rather than just disconnecting the screen.

■ Conclusion

To ensure optimum performance it is highly important to select the right drive and filter and to do the installation work right. A good drive with the appropriate RFI filter cannot ensure compliance, if the installation work is not done properly.

Many buildings incorporate equipment that is sensitive to radio frequency interference. This is not only the case for airports, telecommunication facilities and hospitals. Ordinary appartment buildings and office complexes also have a lot of sensitive equipment installed. It is therefore especially important to limit radio frequency interference in HVAC installations.