

# AC and DC Chokes in Variable Frequency Drives

TECHNICAL REFERENCE MANUAL

## INTRODUCTION

The power structure of a conventional AC drive consists of three stages. The first stage rectifies the AC supply voltage into DC voltage. The second stage, the DC link, has a capacitor in order to filter out voltage ripple and to provide stable DC voltage for the third stage to operate. The third stage is the inverter which converts the DC voltage back to AC voltage using IGBTs (insulated Gate Bipolar Transistors), to create a pulse width modulated voltage waveform. This voltage drives a current approximating a sine wave in the motor.

Additionally, chokes are usually required to be used. They are needed to shape the input current that is drawn from the supply and for stability reasons to minimize the influence from the supply impedance. In shaping the input current, they also lessen the stresses to the DC-link capacitor, increasing its lifetime.

In general, the chokes can be placed either on the AC or on the DC side of the rectifier as presented in Fig. 1 and 2, respectively.

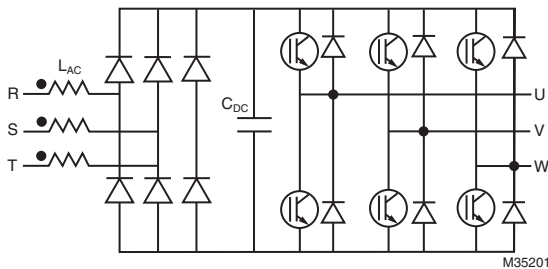


Fig. 1. Main circuit topology with AC chokes.

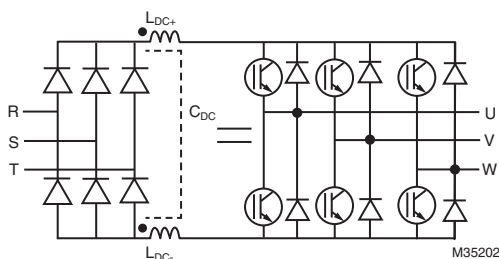


Fig. 2. Main circuit topology with DC chokes.

The AC chokes are placed in each of the three input phases of the rectifier while the DC chokes are placed in both legs of the DC link.

The reduction of peak currents does not greatly depend on the choice between the choke types. The main benefits of using DC chokes are the somewhat better attenuation of current harmonics and the smaller voltage drop caused by the chokes. However, drives using DC chokes need to have sufficient protection against mains transients.

## REDUCTION OF THE HARMONICS

The main reason for using chokes is to add series impedance to reduce harmonics and stresses on capacitors. This is achieved with both types of chokes.

The input current waveforms for both choke types are shown in Fig. 3. The values have been simulated with equal component values ( $L_{dc}/bus = L_{ac}/phase = 400 \mu H$ ,  $C_{dc} = 700 \mu F$ ).

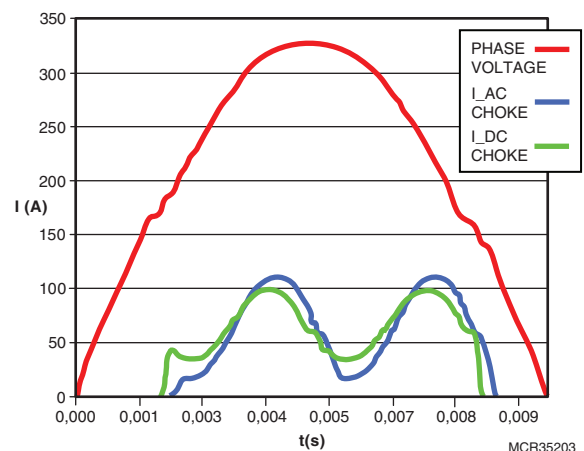


Fig. 3. Input current waveform comparison between AC and DC Chokes.

DC chokes produce somewhat better performance in reducing harmonic currents. With DC chokes, the theoretical level of current THD that can be reached is 32% while for AC chokes the theoretical level is about 37%. (These theoretical levels are calculated with an infinite inductance.)



The better harmonic performance of DC chokes is evident in the lowest harmonic frequency. The DC choke attenuates the 5th harmonic, which is by far the largest contributor to the overall THD, considerably better than AC chokes. In the case of the 7th harmonic, the attenuation is also slightly better with DC chokes.

The AC chokes reduce the higher order harmonic components better, but these are less significant for the overall performance than the 5th and 7th harmonic.

While generally the overall harmonic reduction does not differ greatly between the choke types, a notable disparity is caused due to requirements placed by the new IEC 61000-3-12 standard (Electromagnetic compatibility: Limits - Limits for harmonic currents produced by equipment connected to a public low-voltage systems with input current > 16 A and ≤ 75 A per phase).

The fulfillment of the requirements of the IEC 61000-3-12 standard is achieved more cost effectively with a DC choke than an AC choke due to the difference in harmonic reduction capability especially with the fifth harmonic.

Fig. 4 shows harmonic composition of input current waveforms presented in Fig. 3 and the limit values of IEC 61000-3-12.

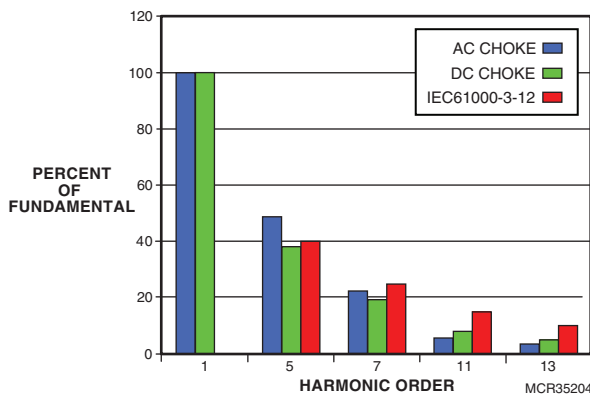


Fig. 4. Input current spectrum and IEC 61000-3-12.

The consequent effect on voltage harmonics is almost similar with both choke types. The normal voltage harmonic level is usually 2–3%. The total voltage harmonics level is only about 0.02% higher with AC chokes than with DC chokes in case of a fairly stiff supply. Considering only voltage harmonics, the difference between the choke types is practically nonexistent in normal installations.

Additionally, the displacement power factor DPF is better with DC chokes (0.99) than AC chokes (0.97).

## VOLTAGE DROP AND LOSSES

A notable difference between AC and DC chokes is their impact on the voltage drop of the drive.

Voltage drop across an AC choke reduces the input voltage to the rectifier and consequently the generated DC voltage and thus the maximum voltage that can be supplied to the motor. The voltage drop is usually in the range of 2–3%. This problem is nonexistent with DC chokes. They do not significantly reduce the voltage available for the motor as they have an effect only on the ripple in the voltage and not on the overall DC-voltage level.

In Fig. 5, the DC-link voltages for the case of Fig. 3 are shown.

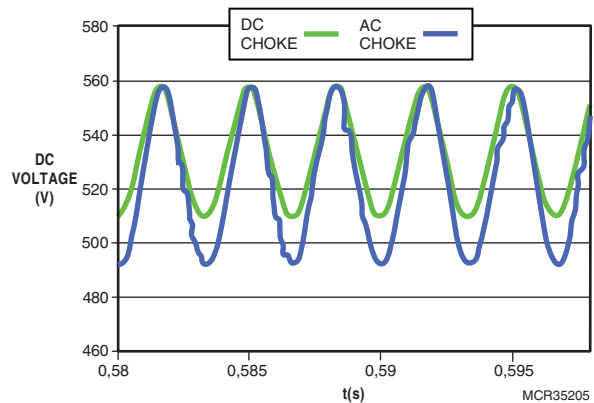


Fig. 5. DC-link voltage waveform with AC and DC chokes.

On the other hand, AC chokes can be added to drive systems later, but the voltage drop and additional losses cannot be compensated if they are not taken into consideration in the drive design.

The voltage drop due to AC chokes can be partly compensated by using larger capacitance in the DC link, which limits voltage ripple and thus enables higher voltage to the motor.

## THE PROTECTION OF THE RECTIFIER

Other equipment connected to the supply system can cause transients and spikes to the drive input. The semiconductor components of the front-end rectifier may thus be subjected to voltage spikes and current surges.

In this case, the major advantage of AC chokes is the inherent protection of the rectifier components against the supply transients. The AC chokes reduce the voltage and current stresses of the rectifier. However, it must be noted that they do not offer protection against very fast or high transients.

When DC chokes are used, the protection must be provided by other means. Fortunately, this can be done by using e.g. RC snubber and metal oxide varistors (MOVs) that protect the rectifier components against input transients. In addition, semiconductors rated for higher voltages need to be used in the rectifier.

The protection against ground faults can be achieved with both types of chokes. This requires that DC chokes are installed in both sides of the DC link.



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