

Variable Speed Drives The Advantages of DC Chokes versus AC Line Reactors – Data Bulletin



8800DB1705

AC line reactor or DC choke used with drives

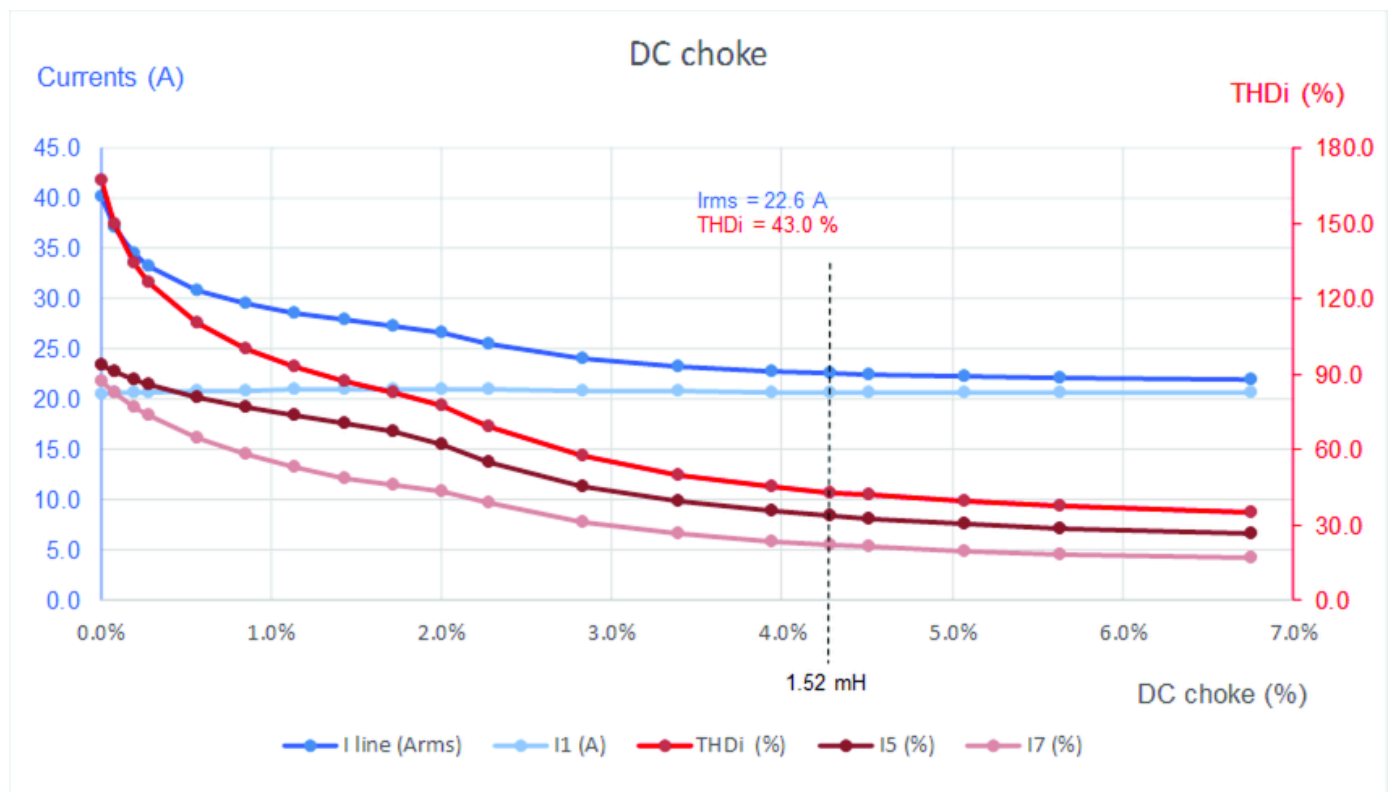
Input current harmonics

To compare the drive’s input current harmonics mitigation with AC line reactors and DC chokes, a variable speed drive designed to operate a 20 hp, 480 V, 60 Hz, 3-phase induction motor at rated torque is used as an example in this paper. The choke’s impedance values range from 0–7%. The drive’s internal main DC bus capacitor is 1500 μ F.

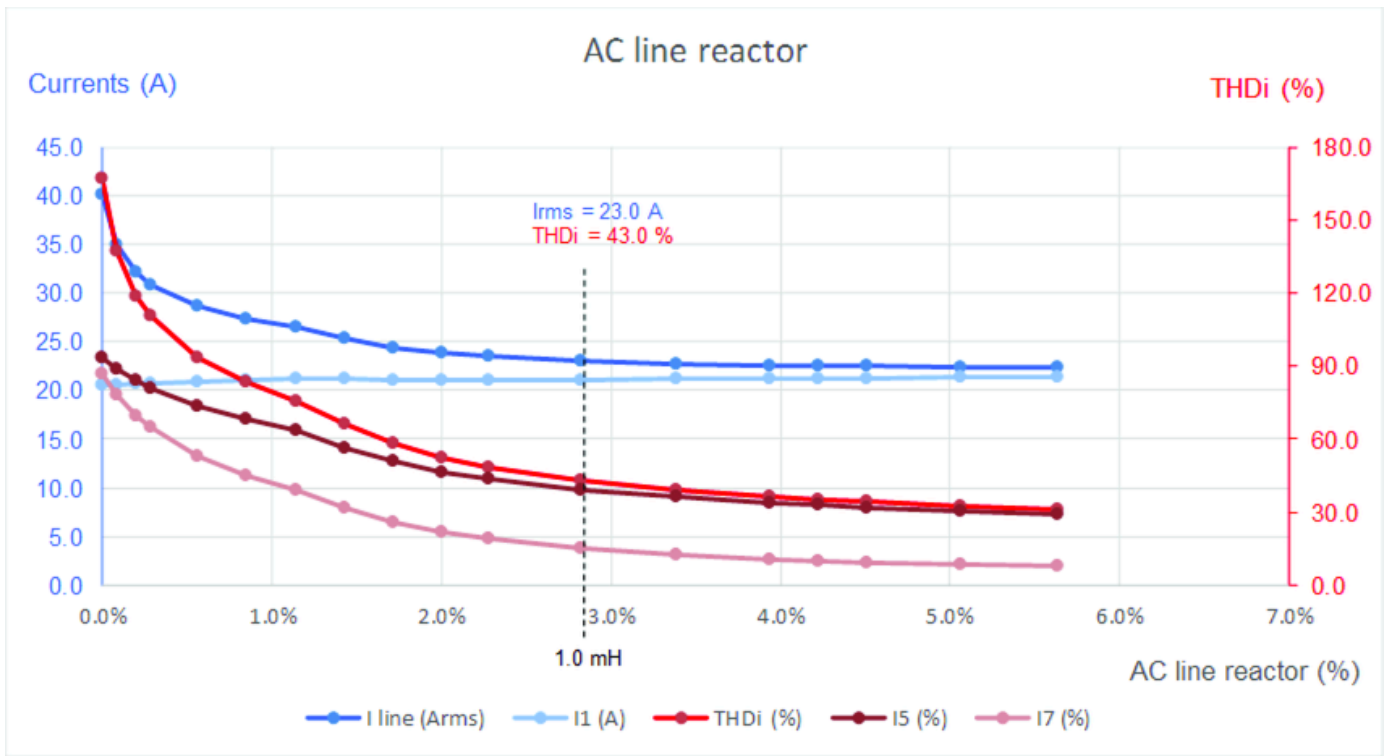
Figure 3 illustrates the result obtained with an internal DC choke value of 1.52 mH, which is a 4.3% impedance at 480 V 60 Hz, taking into account a 20 hp (15 kW) motor with an efficiency of 0.91 and a drive efficiency of 0.95.

Figure 4 shows the result obtained by the same drive without an internal DC choke, but with an external AC line reactor of 1 mH, which is a 2.8% impedance at 480 V 60 Hz and gives the same input current THDi as the DC choke.

DC choke



AC line reactor



Figures 3 and 4 show for impedances from 0–7% of an AC line reactor or a DC choke:

- In blue, the evolution of the total RMS input current and the fundamental part I_1 in A (left Y-axis)
- In red, the THDi and the ratio of the 5th and 7th current harmonics to fundamental in % (right Y-axis)

ATV6xx/ATV9xx drives use an internal DC choke, whose impedance is about 4.0% on average over the full range at 480 V, 60 Hz. The DC choke was designed to reduce the input current THDi in order to meet IEC 61000-3-12 requirements listed in table 4 with $R_{sce} \geq 120$, from which Table 1 is extracted. R_{sce} is the short circuit ratio—the short circuit apparent power divided by the equipment apparent power.

IEC 61000–3–12 Requirements for THDi with $R_{sce} \geq 120$

TDH	15/11	17/11	111/11	113/11
≤ 48%	≤ 40%	≤ 25%	≤ 15%	≤ 10%

The table below shows that at 480 V 60 Hz, the 4.3% DC choke (1.52 mH) is able to reduce the input current THDi to 43.0% at rated load. To get the same input current THDi, an AC line reactor of 1 mH is needed, which is 2.8% impedance.

	I_{rms}	I_1	THDi	15/11	17/11	111/11	113/11
DC choke: 1.52 mH	22.6 A	20.7 A	43.0%	33.5%	21.9%	8.8%	7.6 %
AC line reactor: 1 mH	23.0 A	21.1 A	43.0%	39.2%	14.9%	7.5%	3.6%

At the same value of input current THDi there are differences between the AC line reactor and the DC choke:

- The RMS value of the input current is a little lower with the DC choke.
- The amplitude of the 5th harmonic of the current is lower with a DC choke.
- The amplitudes of the 7th, 11th, and 13th harmonics of the current are lower with an AC line reactor.

The majority of the THDi reduction is reached up to 5% impedance of a DC choke or up to 3% impedance of an AC line reactor. Above these values the THDi reduction is very low.

Both input AC line reactors and integrated DC chokes are valid solutions for reducing harmonics at the drive's input terminals. Typically, installations have certain requirements that dictate which solution is required. For some applications, such as retrofits and applications with size constraints, our integrated DC chokes are ideal. It is important to note that with the use of Altivar Process Drives, the combination of integrated DC chokes with an external 3% input line reactor is acceptable and can achieve lower THDi levels. The advantages and disadvantages when using both an input line reactor and the integrated DC chokes hold true when examining the individual technologies. The following summaries provide the advantages and disadvantages of both types of solutions.

DC bus voltage drop

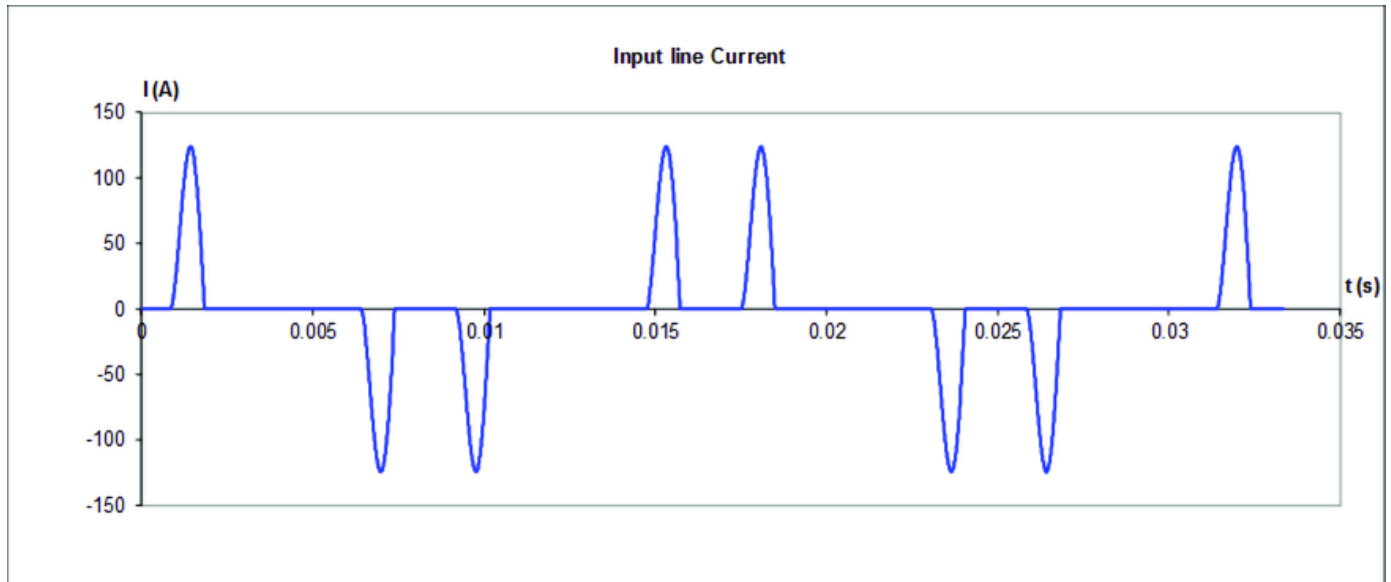
The additional impedance of an AC line reactor or DC choke in the circuit creates a voltage drop on the DC bus. It reduces the maximum voltage available to control the motor at rated speed and torque. If this voltage drop is too high, the motor will not get the full voltage at rated speed and rated load. This may increase the motor current and the motor slip, which can lead to additional losses in the motor.

DC bus average voltage reference

To compare an AC line reactor and a DC choke, the voltage drop is defined with a relative value to the average DC bus voltage obtained at rated load with a drive using no chokes or reactors at all. This drive should have 50% more capacitor value to keep the DC bus voltage ripple in an acceptable range. In these conditions, at 480 V, 60 Hz mains power supply and a 20 hp motor load, the DC bus average voltage is 672.5 V. The shape of the input current is shown in Figure 5.

The drive input current is: RMS value = 40.0 A, peak value = 122 A, THDi = 167%.

DC bus average voltage reference



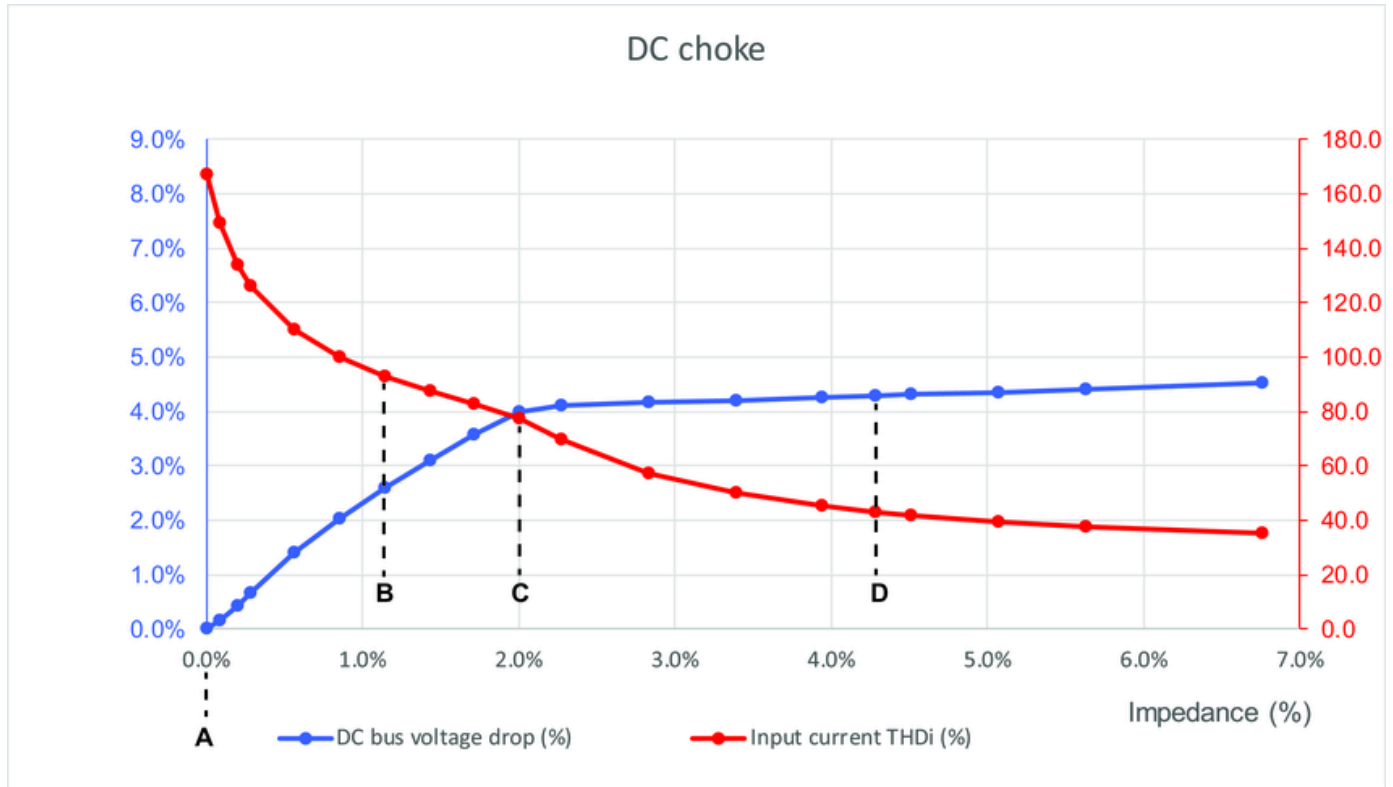
DC choke and voltage drop

The following sections show for an AC line reactor and a DC choke the relative DC bus voltage drop and the input current THDi as a function of the impedance of the chokes.

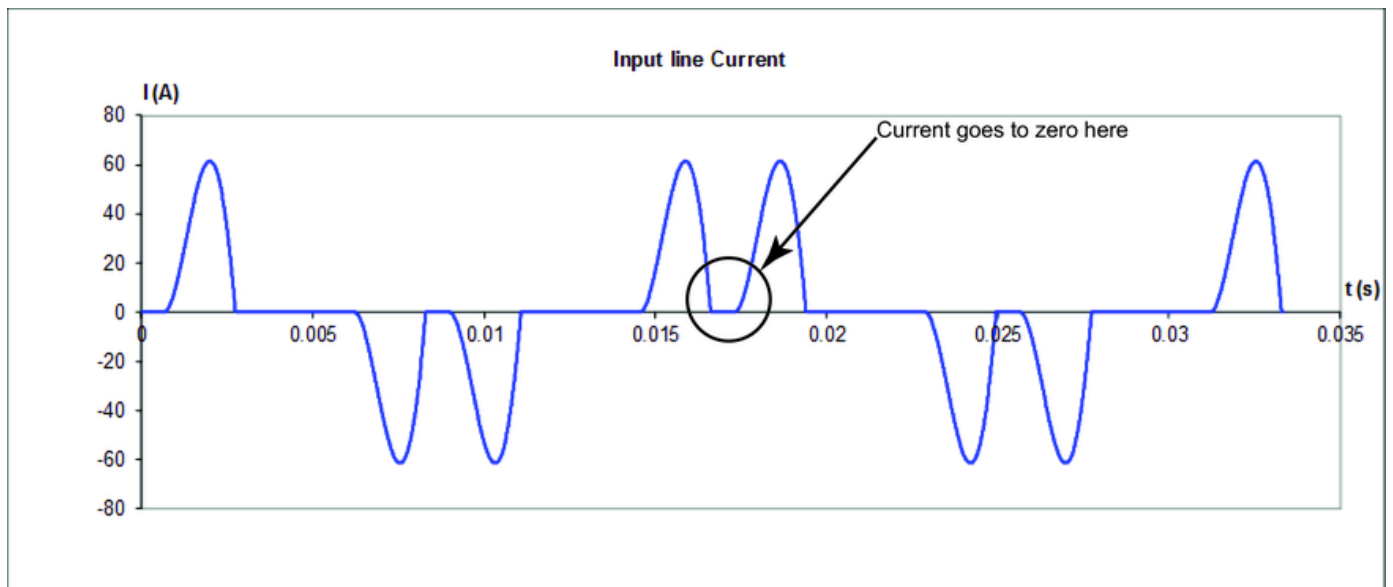
There are specific points on the graphics corresponding to different situations:

- Point A is the drive with increased capacitors and no chokes: this is the reference of the average DC bus voltage.
- At point B, there is an AC or DC choke with discontinuous conduction on the input rectifier.
- At point C the input current in the drive's input stage changes from discontinuous conduction to continuous conduction. This creates the slope change in the DC bus voltage drop.
- Point D is the drives' design point with the DC choke, to be compared with an AC choke which gives the same THDi.

DC voltage drop and input current THDi versus impedance

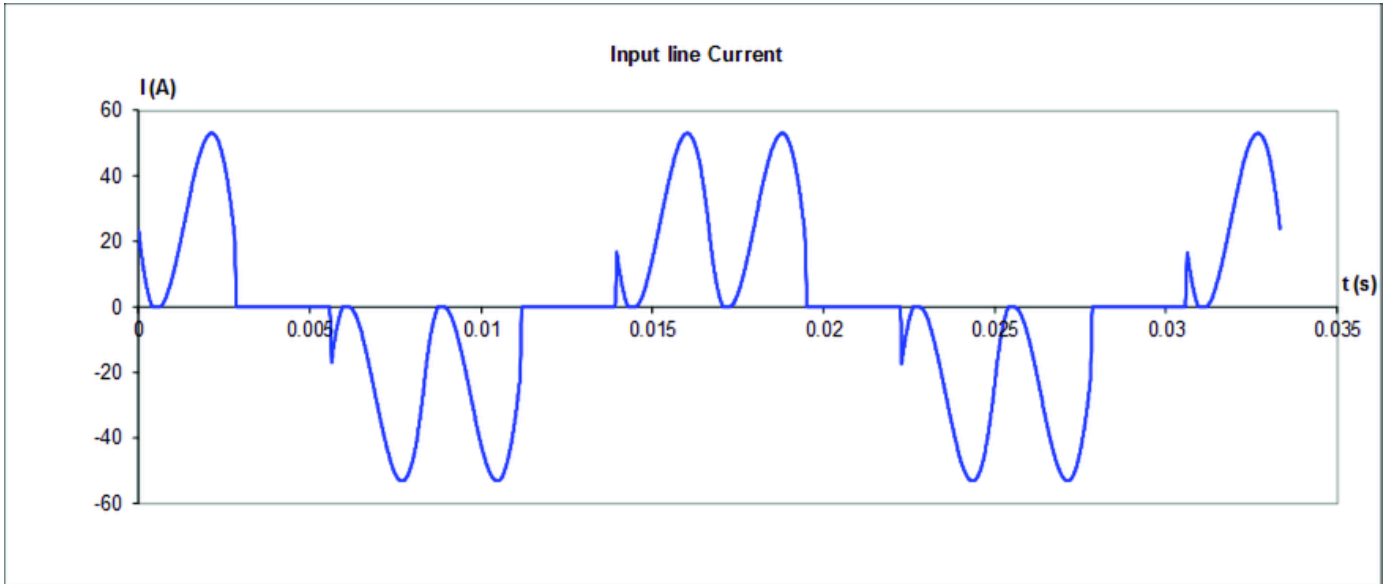


Input current with input rectifier in discontinuous conduction mode



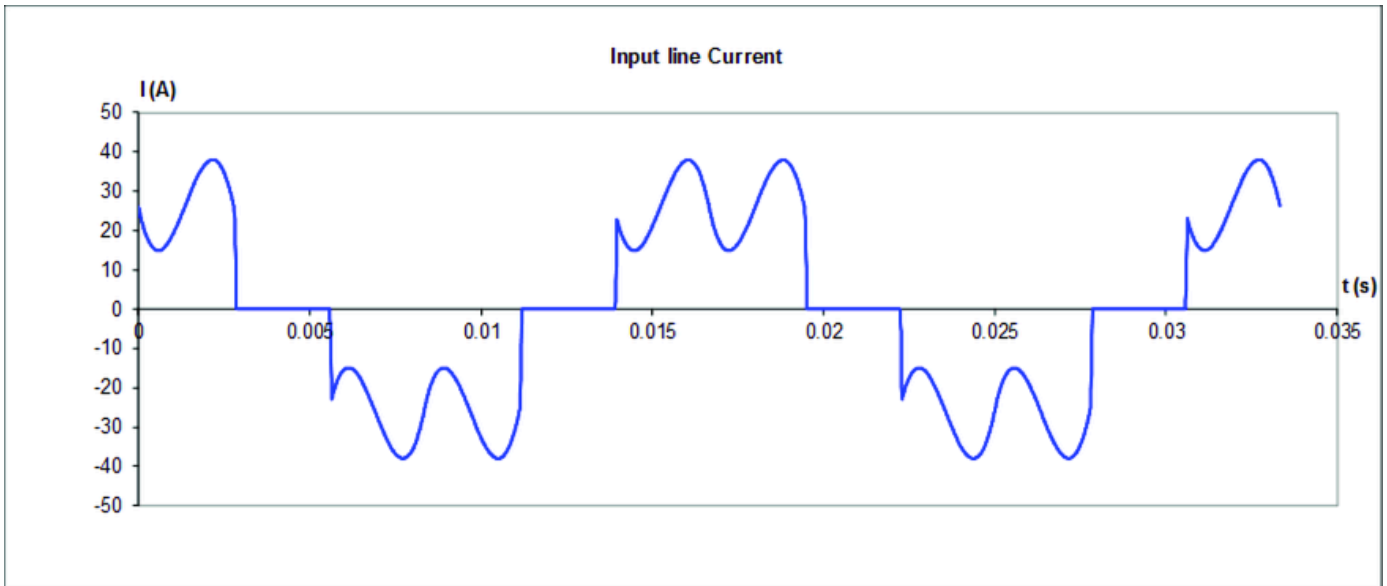
- Input current waveform at point B for DC choke: $L = 0.4\text{ mH}$, $Z\% = 1.1\%$.
- Drive input current RMS value = 28.6.4 A, peak value = 61.5 A, THDi = 93.0%

Input current with input rectifier at transition from discontinuous to continuous conduction mode



- Input current waveform at point C for DC choke: $L = 0.7\text{ mH}$, $Z\% = 2.0\%$
- With this impedance value of the DC choke, the system is at the transition between continuous and discontinuous current in the input rectifier.
- Drive input current RMS value = 26.7 A, peak value = 53.1 A, THDi = 77.5%

Input current with input rectifier in continuous conduction mode



- Input current waveform at point D for DC choke: $L = 1.52\text{ mH}$, $Z\% = 4.3\%$. This is the design point of the drive taken as reference.
- Drive input current RMS value 22.7 A, peak value = 38.0 A, THDi = 43.0%

The other drives of the range have the following impedance at 480 V, 60 Hz for the internal DC choke and the corresponding THDi of the input current at rated output load.

ATV630•••N4	U07	U15	U22	U40	U55	U75	D11	D15	D18	D22	D30
Power rating (hp)	1	2	3	5	7.5	10	15	20	25	30	40
DC choke value (mH)	21.6	11.5	8.10	4.55	3.40	2.90	2.25	1.52	1.18	1.00	0.76

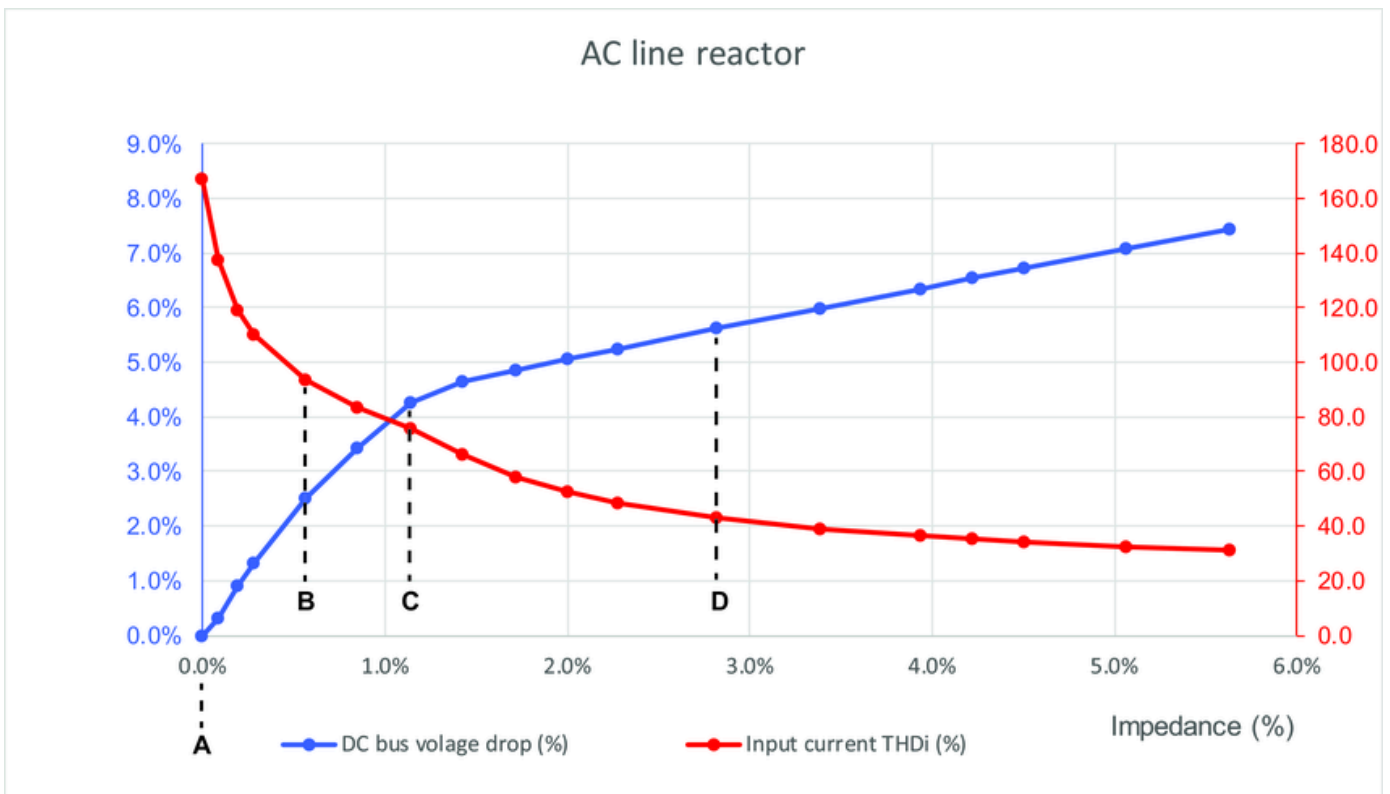
Impedance (%)	3.4	3.5	3.6	3.3	3.7	4.2	4.8	4.3	4.2	4.2	4.2
THDi (%)	48.3	48.3	48.2	50.8	47.9	43.4	40.7	43.0	44.2	44.4	43.4
Voltage drop (%)	4.0	3.5	2.9	3.0	2.8	3.9	3.3	4.0	3.7	3.4	3.9

ATV630...N4	D37	D45	D55	D75	D90	C11	C13	C16	C22	C25	C31
Power rating (hp)	50	60	75	100	125	150	200	250	350	400	500
DC choke value (mH)	0.59	0.49	0.37	0.31	0.23	0.16	0.16	0.16	0.105	0.095	0.069
Impedance (%)	4.0	4.1	3.8	4.2	3.8	3.2	4.3	5.3	5.0	5.2	4.7
THDi (%)	45.1	44.6	45.2	42.4	44.6	47.9	41.0	37.4	37.3	36.7	36.9
Voltage drop (%)	3.8	3.8	3.6	3.5	3.3	3.1	3.0	2.9	2.1	1.9	1.2

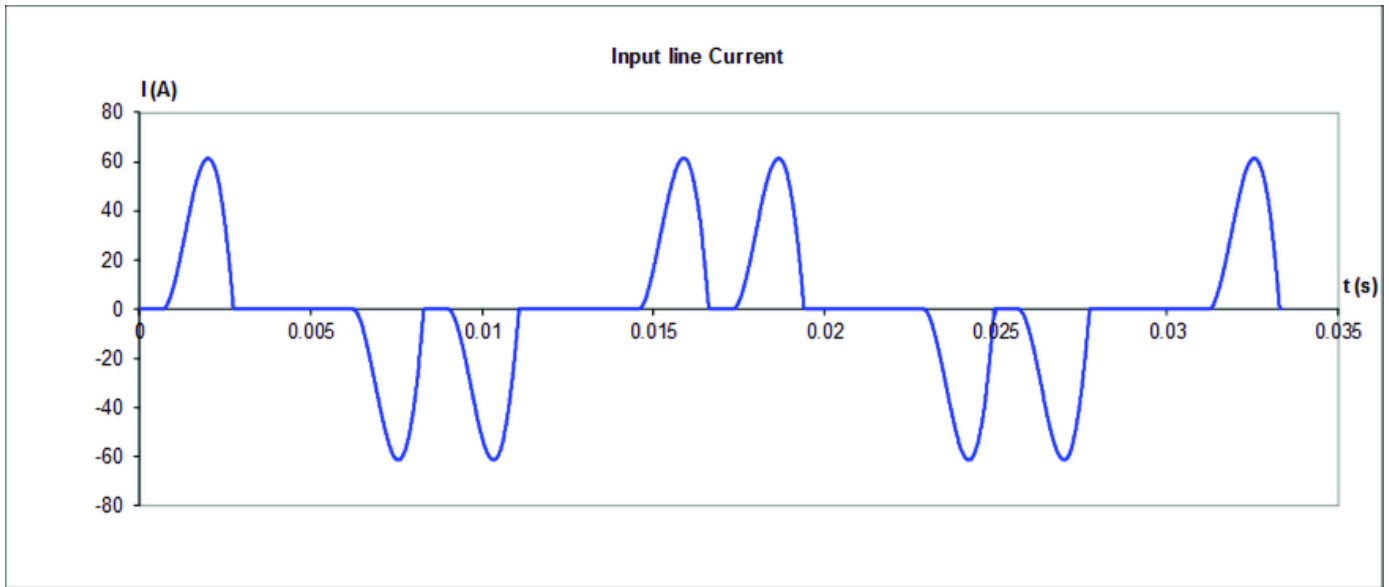
AC line reactor and voltage drop

The same variable speed drive operating a 20 hp, 480 V, 60 Hz, 3-phase induction motor without the internal DC choke but with a 3-phase AC line reactor is used to perform the same simulations to compare the behavior of AC line reactors to DC chokes. The DC bus voltage drop and input current THDi are displayed as functions of the impedance. The input current waveforms are also displayed for different values of the impedance in the same way as for the DC choke.

DC voltage drop and input current THDi versus impedance

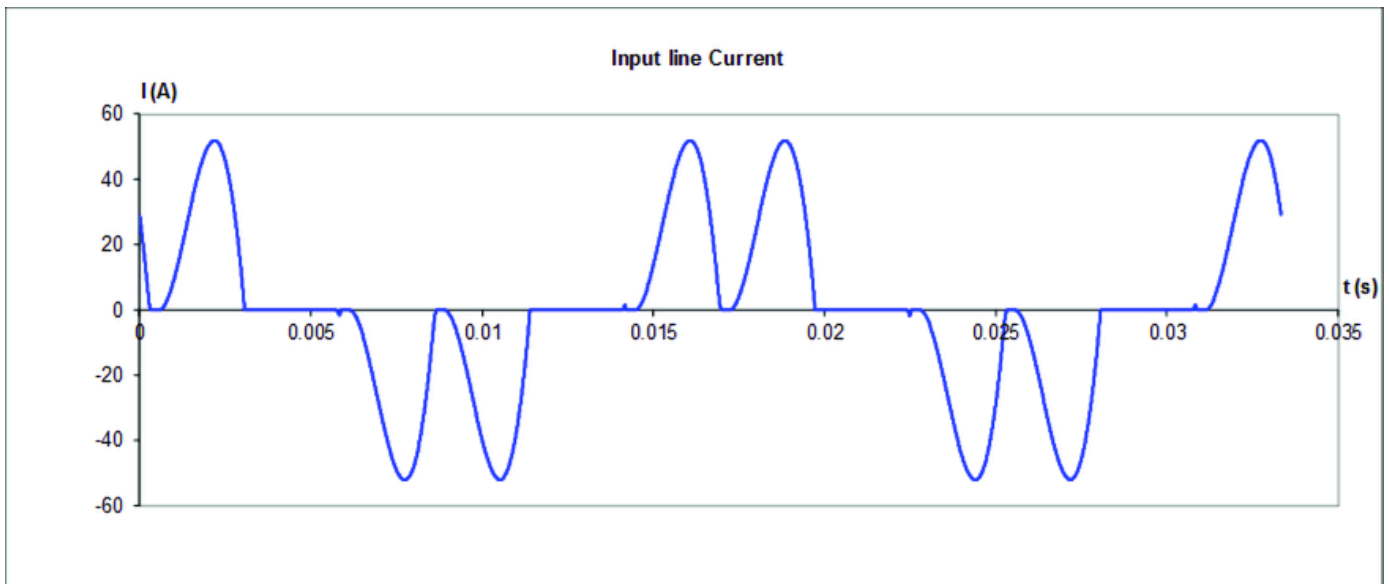


Input current with input rectifier in discontinuous conduction mode



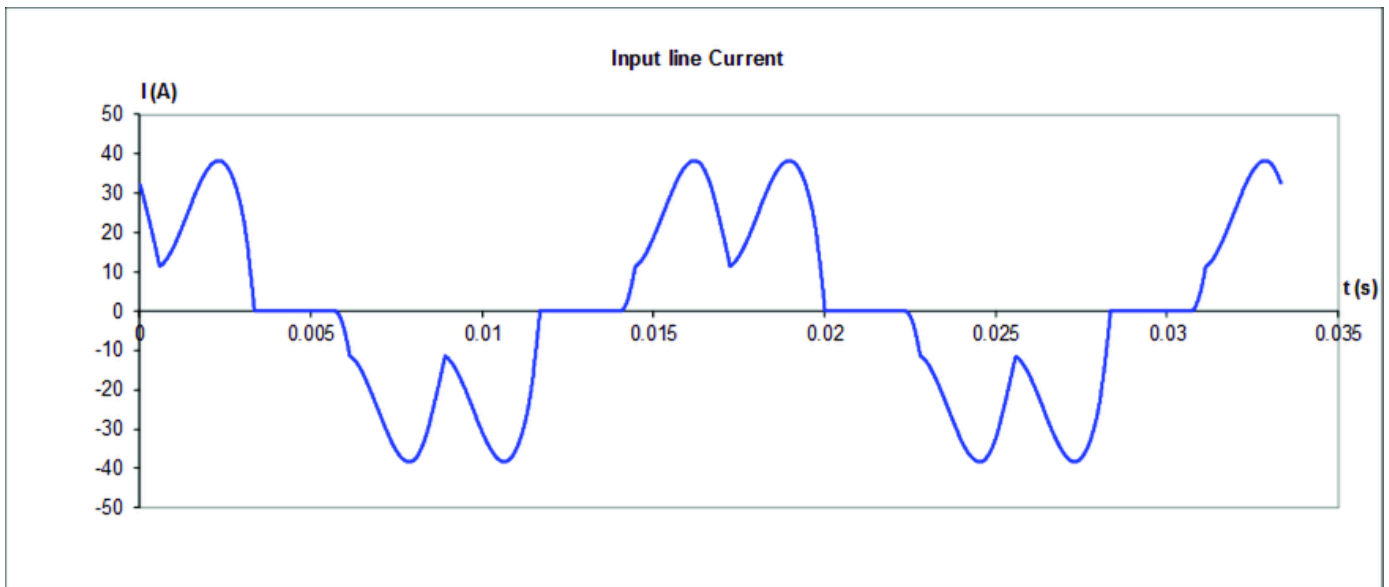
- Input current waveform at point B for AC line reactor: $L = 0.2 \text{ mH}$, $Z\% = 0.6\%$.
- RMS value = 28.6 A, peak value = 61.4 A, THDi = 93.4 %.

Input current with input rectifier at transition from discontinuous to continuous conduction mode



- Input current waveform at point C for AC line reactor: $L = 0.4 \text{ mH}$, $Z\% = 1.4\%$
- RMS value 26.6 A, peak value = 52.0 A, THDi = 75.7%

Input current with input rectifier in continuous conduction mode



- Input current waveform at point D for AC line reactor: $L = 1 \text{ mH}$, $Z\% = 2.8\%$
- This value is selected to get the same THDi as at point D on the curve with the DC choke.
- RMS value 23.0 A, THDi = 43.0%, peak current 38.3 A

Conclusions

- Both DC Chokes and AC Line Reactors are effective methods to mitigate line harmonics.
- It is acceptable to use both DC Chokes and AC Line Reactors in order to achieve higher overall impedance, thus increasing the ability to mitigate harmonics.
- At the same level of input current THDi, the DC bus voltage drop created by the DC choke is less than with an AC line reactor.
- At 43% THDi—which is reached with a 4.3% impedance DC choke or a 2.8% impedance AC line reactor at 480 V, 60 Hz—the difference is about 30% more DC bus voltage drop with an AC line reactor.
- To increase DC choke or AC line reactor impedances over 4.5% or 3% respectively does not provide significant THDi and RMS input current reductions.

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