BENSHAW Inc.

SOLID STATE MOTOR CONTROL

TECHNICAL NOTES

Technical Notes TN0020-01

Harmonic Generation in Solid State AC Motor Controls

The subject of harmonic generation often comes up when solid state AC motor controls are being considered. Harmonics can cause motor heating and also lead to interference with other electronic equipment. This application note is intended to explain these effects so that an informed decision can be made regarding the use of different methods of solid state AC motor control.

Since any periodic wave-form can be expressed mathematically as the sum of a sine wave at the fundamental frequency and more sine waves at multiples of that frequency, (h “harmonics” of the fundamental frequency) the term “harmonics” has come to be used to describe the wave-form distortion of an otherwise pure sine wave of AC voltage or current. “even” harmonics are distortion components that can be represented as sine waves at frequencies that are even multiples of the fundamental frequency, while “odd” harmonics are at odd multiples of the fundamental frequency. High frequency harmonics are at high multiples of the fundamental, and low frequency harmonics are at low multiples. High frequency harmonics are generated by the fast transitions in the wave-form, and low frequency harmonics are generated by slower changes to the fundamental sine wave.

The effects of harmonic generation can be divided into two categories: the first is the low frequency (less than 10K Hz) deformation of the sinusoidal current wave-forms. Inverters generate significant line harmonics due to the input rectifier present on all types, and this leads to increased power distribution capacity requirements. SCR type inverters also generate significant harmonics in the motor currents. These harmonics are present whenever the motor is being run, and cause increased heat generation during operation. Transistor-type (PWM) inverters do not generate these low frequency harmonics in the motor currents.

Reduced voltage motor starters also generate line ad motor current harmonics, but they only do so while the motor is being started. Once up-to-speed, the motor starter is basically a short circuit from the line to the load, and the sinusoidal current waveforms are not distorted.

During startup, however, there are significant differences in the harmonic generation of different types of motor starters. The three-diode, three-SCR starter generates an asymmetrical current waveform which contains large amounts of even harmonics, as well as significant odd harmonic distortion. The six-SCR starter, such as Benshaw’s, generates not even harmonic, and fewer odd harmonics, as well. Figure 1 shows the relative content of the two largest harmonics in the six-SCR starter. Because of these differences, the six-SCR starter draws as low as half of the current required by the three-diode, three-SCR starter, giving a longer motor life and increasing the allowable starts-per-hour.

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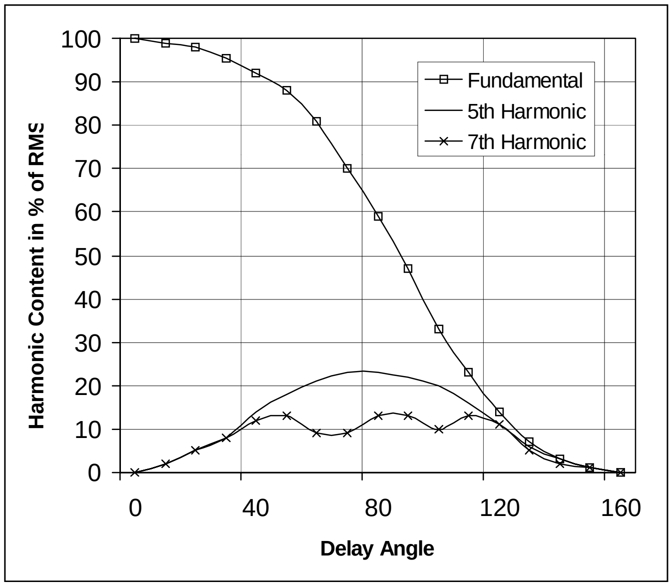

Figure 1: Six SCR Converter with Resistive Load

Another fact to consider concerning reduced voltage motor starters is that the harmonics are generated at reduced voltage levels, and as the voltage is increased, the harmonic content is reduced. Thus, when the most critical period of a motor is reached, the harmonic content is very low.

Higher frequency effects (greater than 10K Hz) of harmonic generation are generally not noticed in power distribution equipment or in motors, but can cause interference with computer, communication, and instrumentation systems. These high frequency harmonics are caused by the turn-off of the switching devices used in the motor control. The phase control SCRs used in reduced voltage starters are relatively slow to turn on, and are naturally commutated off. In comparison, inverter grade SCRs used in inverters have a much faster turn-on time, and are forced into turn-off. Transistor type (PWM) inverters are the worst offenders of all when it comes to high frequency interference since their turn-on and turn-off cycle is repeated at a frequency much greater than the line frequency. Also, as with the low-frequency harmonics, the higher frequency harmonics are generated only during startup with a reduced-voltage starter, but are generated continuously with an inverter.

One last fact to consider deals with filtering the harmonic to prevent interference. The power handling capacity of an interference filter is related to the price of the filter, so except for a few specialized installations, it is usually more economical to filter the affected equipment than it is to filter the motor starter.