ER-0097
A Discussion of Reduced Voltage Soft Starter Harmonics

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Abstract:

The generation of harmonics by SCR based reduced voltage soft starters and what the harmonic spectrum depends on is discussed. Some example harmonic spectrums are given that can be used for approximate calculations.

Discussion:

Calculating harmonics distortion with reduced voltage soft-starters is a very complicated situation; it is much more difficult than with Variable Frequency Drives (VFDs). In the case of VFDs, they have essentially a passive rectifier front-end that produce input current waveforms that are consistent and repeatable. Because of the repeatability of the input current waveform, it is easy to calculate the harmonic spectrum of the VFDs input current. Unfortunately reduced voltage soft starters are a completely different story. Unlike VFDs, soft-starters only produce harmonics during acceleration and deceleration ramping, essentially anytime the SCR devices are phased back (i.e. not full on). The current harmonics that a starter generates are highly dependent on the phase angle of the SCRs during ramping and also the power factor (PF) of the motor. The actual SCR phase angle depends on many factors: the incoming line voltage level (which changes due to line drop during starting and in the long run changes day-to-day or depending on what other equipment is running), the starting ramp profile, the motor's speed/torque/current starting profile and the external loading of the motor. The starting PF of the motor also changes the form factor of the current, which changes the harmonic spectrum of the current.

Because in certain cases harmonic distortion can cause significant problems, there is an industry standard defining the limits on harmonic production. The standard is IEEE-519-1992. IEEE-519-1992 is a very commonly quoted specification for electrical installations. IEEE-519-1992 is also one of the most misunderstood specifications. IEEE-519-1992 sets limits for the overall harmonic current present at the point of common coupling (PCC) of a facility. This point is usually the metering point of the building/facility. The harmonic limits are also dependent on the source capability of the utility supply and can range from a maximum Total Harmonic Distortion (THD) of 20% down to only 5%. Some customers/consultants specify that IEEE-519-1992 must be met at the drive/starter input rather than at the PCC. Technically, application of IEEE-519-1992 limits right at the equipment's input rather than at the PCC is not the intent of IEEE-519-1992. However this is sometimes specified by customers and consultants when drives and other harmonic loads make up a large share of a facility overall electrical load. Because the harmonic generation by a soft-starter is short term (only during ramping), the IEEE519 requirements are double what they would be for something like a VFD that

produces continuous harmonics. As with any piece of equipment and depending on what IEEE519 levels required, a soft starter may already meet the requirements depending on the situation. However since the harmonic generation of a starter is very application specific it is impossible to state that any soft starter complies with IEEE519 without extensive analysis requiring precise source data (one-line with all the transformer data etc), precise motor data (i.e. Complete Speed/Torque/Current/PF profile when starting), development of an exact ramp profile given a certain load profile and an exact incoming line voltage.

Calculations:

Even though the actual harmonic spectrum of a soft-starter in a particular installation is very difficult to calculate many times an approximate calculation of the harmonics is all that is necessary. Some rough/"generic" values for the harmonic current distortion produced by a soft-starter during starting are presented below.

Assuming a constant 0.22PF for the motor power factor during starting, a 300% full load amps (FLA) motor starting current, and assuming no voltage drop in the starter, bus, or wiring.

It is found that the only significant current harmonics are the 5th, 7th, and 11th harmonics. The harmonic current magnitudes shown below are percent (%) of total current drawn which in this case the harmonic magnitudes are % of 300% FLA current. Note if the specification requires current harmonics to be calculated based on %FLA then triple the distortion values below.

SCR delay angle	5^{th} Harm %I	7^{th} Harm %I	11th Harm. %I	Current THD%
85	3.00%	2.00%	1.10%	3.77%
90	5.30%	3.50%	1.50%	6.53%
95	8.00%	4.70%	1.20%	9.36%
100	10.00%	5.40%	0.20%	11.37%

In general during starting (acceleration ramp), the firing delay angle of the SCRs hovers between 85-100 degrees (usually between 90 and 95 for a typical NEMA B motor) but as stated above the exact SCR firing angle depends on motor load, line voltage, etc. As can be seen, a small change in SCR firing angle makes a significant difference in the current harmonic magnitudes. In practice, the motor PF will not be constant during starting and will also vary depending on external loading, the line voltage will tend to drop and the starting current profile will not necessarily be 300% FLA. Also if the motor is ever changed to a different type/brand motor, the ramp profile is changed, or the motor loading is changed the harmonic spectrum may also change.

Conclusion:

A brief discussion of reduced voltage soft starter harmonic production has been covered above. It can be concluded that, unlike VFDs, determining the exact magnitude and spectrum of current harmonics for a soft starter can be very complicated. However an estimate of the harmonic spectrum of a typical soft-starter has been given above so that, if needed, rough calculations of the effects of the current harmonics can be performed.