FACTSHEET

Soft starters and harmonics

Summary of facts and the implications for SCR based soft start technology

BENSHAW
Applied Motor Controls

An introduction to harmonics

In the most simple terms, harmonics are integer multiples of some fundamental frequency. In a power systems context, a 50Hz power system has a fundamental or first harmonic of 50Hz, a second harmonic of 100Hz and so on. The first, third, fifth, seventh, etc. harmonics are known as "odd-order" harmonics, while the second, fourth, sixth, eighth, etc. are called "even-order" harmonics. Also possible are what are known as “inter-harmonics”, which are non-integer multiples of the fundamental.

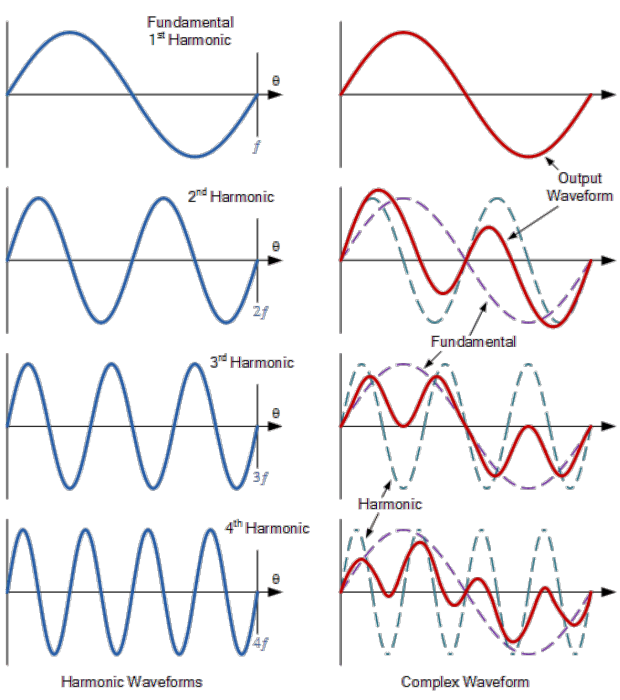

Figure 1: Harmonic Waveforms

Harmonics arise due to distortion created by imperfect circuit elements or other active devices on the network and their interaction with the power system. Such devices act in a non-linear way as the impedance changes as a function of the voltage. Imperfect loads with imperfect sources combine to make harmonics.

It is also worth noting that even the power grid’s voltage is not 100% harmonic free - imperfections in the generators and the transmission system bringing the power to the site also generate harmonics.

Devices such as soft starters, variable speed drives and even computer power supplies effect the system they are getting power from due to how they function. Where and how in the applied voltage waveform the current is drawn by the various systems influences the entire power system.

All other devices who share the same supply experience voltage distortion as the current draw acts though some system impedance, modifying the voltage available to all devices.

Harmonics are unwanted side effects of the operation of loads. As impedance of a power system is a function of frequency, harmonics cause additional current flow which leads to heating effects and reduction in torque produced by motors.

The negative effects of even-order harmonics on the power system are much greater than those caused by odd-order harmonics.

Soft starters and harmonics

When soft starters are being specified, there is often concern over harmonics. This can be perceived as a problem due to confusion with variable speed drives (VSDs) which continuously generate harmonics onto the supply.

Often, specifications for motor control equipment are documented for problems that may arise with the use of VSDs. It is important not to confuse VSD operation and functionality with soft starters.

When a soft starter is starting (or soft stopping) a motor, the voltage supplied to the motor is being altered by switching of the SCRs. The result of varying the conduction angle switching point of the SCRs is a non-sinusoidal voltage waveform being supplied to the motor. Soft starters often use back-to-back SCRs for symmetrical switching. This causes primarily odd-order harmonic currents (mainly 3rd, 5th and 7th) to flow during motor starting (and soft stopping).

The harmonic current level cannot be specified in exact terms. This is determined by many external factors relating to the over all power system, including:

- the "Current Limit" setting of the soft starter
- motor impedance and power pactor (pf)
- motor speed

The harmonic currents being drawn from the supply during motor starting (and soft stopping) will have an effect on the supply voltage waveshape.

The amount of distortion is determined by factors relating to the overall power system, such as:

- the % level of each harmonic current
- the supply impedance at each harmonic frequency
- the % level of each harmonic current in relation to the total load on the supply

The total harmonic distortion (THD) on the supply voltage waveform has various effects on the power system. Some of the more common effects are; extra heating effects on electrical equipment, neutral conductor current flow and malfunction of electronic equipment affected by low frequency supply voltage distortion.

There are two primary considerations when discussing soft starters and harmonics; the generation of harmonics and the starters immunity to any harmonic distrotion on the supply.

Because most soft starters only generate harmonics during motor starting (and soft stopping), harmonic generation is generally a non-issue.

The notable exception to this rule is soft starters that promote an active 'energy saving' feature. Such products produce continuous harmonics in all modes of operation when the 'energy saving' feature is active. With regard to harmonic immunity, all Benshaw soft starters are designed to operate on poor quality power supply systems and have a very high level of immunity to harmonic distortion.

An analysis of Benshaw soft starters

HARMONIC MAGNITUDES

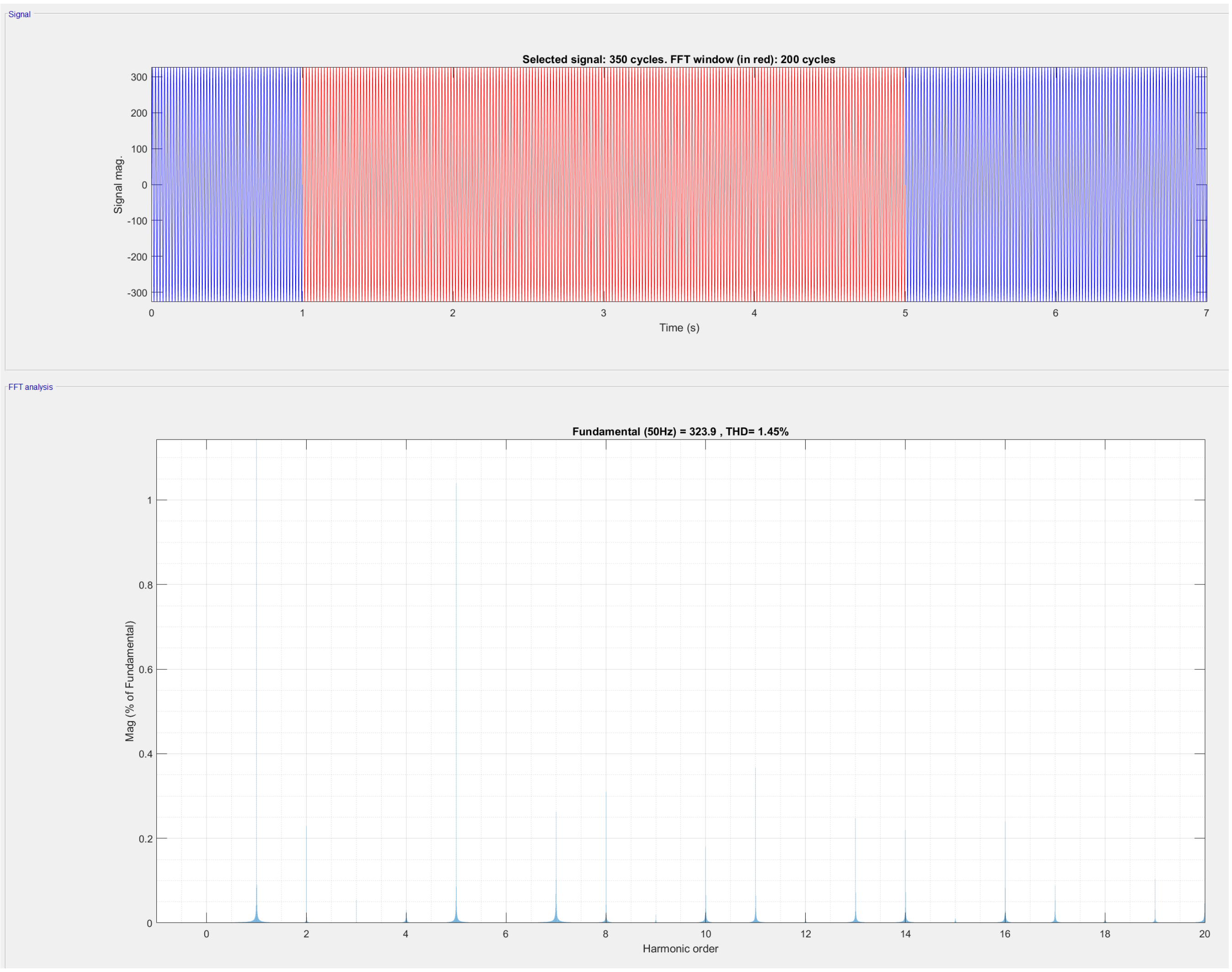

Figure 2: Harmonics generated during start as a percentage of the fundamental frequency.

The magnitude of each harmonic order generated by an Benshaw soft starter during motor starting is shown in figure 2 above. Not only is the period of harmonic generation short (generally a matter of seconds during start/soft stop only), but these magnitudes and the total harmonic distortion are relatively low. Use of back-to-back SCRs allows for symmetrical switching, which largely eliminates damaging even-order harmonics.

An analysis of Benshaw soft starters

TOTAL HARMONIC DISTORTION (THD) DURING START

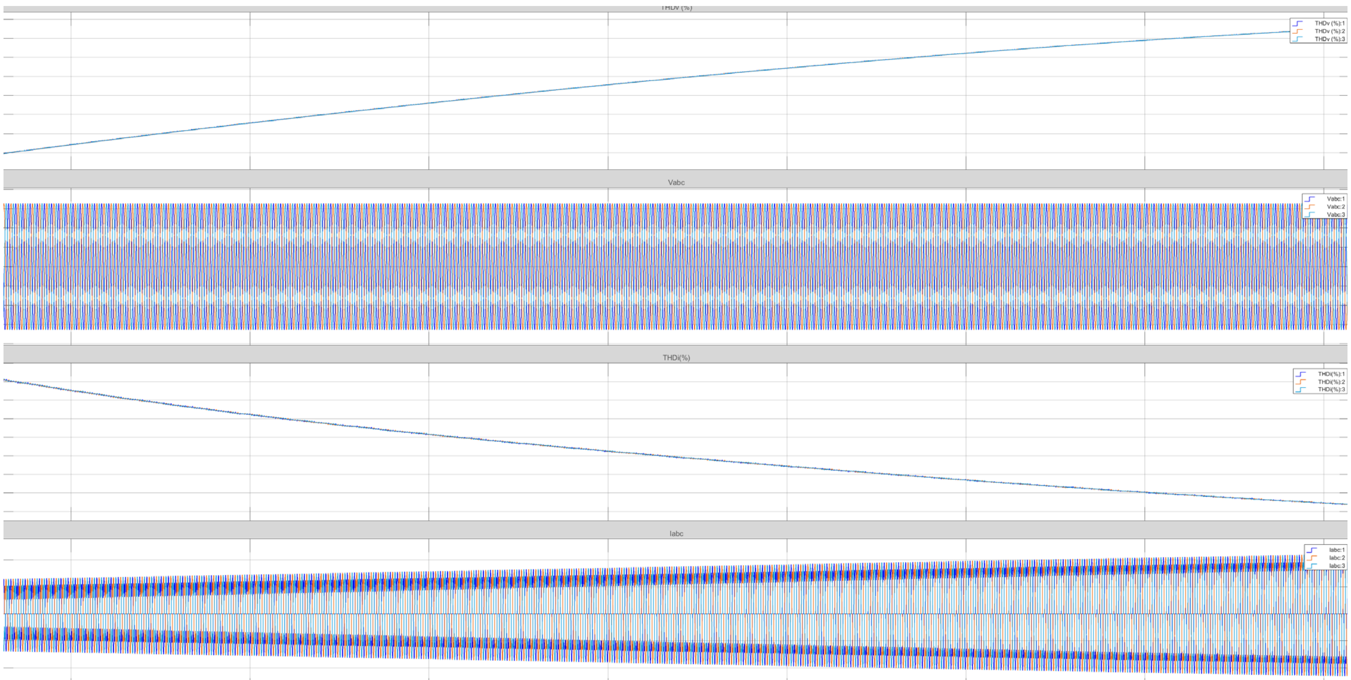

Figure 3: THD as a function of time during soft starting with an Benshaw starter.

Total harmonic distortion (THD) resulting from motor starting with an Benshaw start is shown in figure 3. This THD is the aggregate sum of the harmonics represented in figure 1, and displays their level as a function of time.

As can be seen, THD decreases steadily throughout the start to very low levels. Harmonic distortion is eliminated completely once the bypass contactor is engaged and the SCRs are removed from circuit, and as such the soft starter has no harmonic impact at all during run.

Conclusion

Harmonics are a reality of all power systems - even the voltage from the power grid is not 100% harmonic free due to imperfections in generators and transmition equipment.

Operation of electronic motor control devices such as variable speed drives and soft starters results in generation of harmonics by nature of the way these devices operate. Becuase harmonics cause additional heating and can interfere with the operation of sensitive electronic equipment it is important to understand the basic principles involved and ensure that total harmonic distortion (THD) on any given power system is kept to acceptable levels.

Because the SCR switching devices used by soft starters are only operating during the relatively short period of motor starting (and soft stopping), the harmonics generated by soft starters are generally of no concern.

Furthermore, back-to-back SCR arrangements allow for symmetrical switching which all but eliminates even-order harmonic generation.

Benshaw products have been tested and certified to the IEC60947-4-2 standard for low voltage AC semiconductor soft starters relating to electromagnetic compatibility (EMC). Harmonic tests are not a requirementof these standards.

Standards relating to harmonics (eg. IEEE 519) specify acceptable levels of harmonic generation over long term operational periods. As Benshaw soft starters only generate harmonics during motor starting (and soft stopping) we do not violate any such standards. Hypothetically speaking, if soft starters were within the scope of such standards Benshaw products would be compliant.

In contrast to Benshaw soft starters (and most other soft starter products in general), variable speed drives generate harmonics onto the supply continuously during operation as their switching devices must operate continuously to provide speed control functionality.

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Notes

24/7 Technical Support

Benshaw is dedicated to providing comprehensive 24-hour-a-day, 7-day-a-week phone support. Benshaw provides repair, spare parts, field engineering, retrofit and training services, when and where you need us. You can count on our experienced team, backed by the latest diagnostics and repair tools and an extensive part inventory to support your operations.

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- Overnight parts shipment
- 24-hour service dispatch
- Coordination of all service capabilities

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Repairs are made on Benshaw equipment by trained, experienced personnel, using the latest diagnostic and test equipment.

Field Services are performed on-site by skilled technicians, engineers or complete team if needed, including:

- Start-up commissioning
- Field repairs
- Field analysis/data collection
- Preventative maintenance
- Retrofits

The Benshaw Product Line

A wide range of motor controls and drives is available.

- Solid-state starters fractional up to 30,000HP at 15kV
- LV AC drives to 2,000HP, MV AC drives to 10,000HP
- Electromechanical controls to 800A

Benshaw express is a 24/7 online inventory and order entry system for authorized Benshaw distributors:

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