ENGINEERING WHITE PAPER

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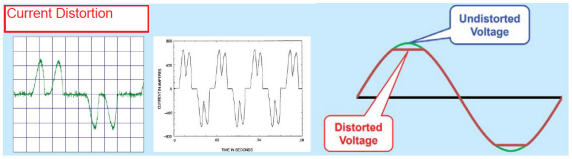
Power Line Harmonics and applying IEEE519 effectively

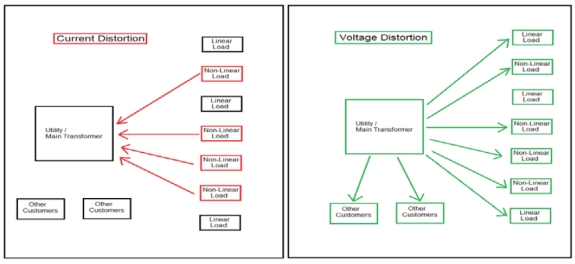
We sell a lot ABB variable frequency drives as well as variable speed compressors on chillers & rtu's. It is not often that we have to deal with the subject of harmonics or IEEE519 compliance in the sale but when it does come up you need to know the basics. Not knowing these basics can prevent you from selling your drives or worse causing a problem with the electrical system and connected components.

What are harmonics and what causes them?

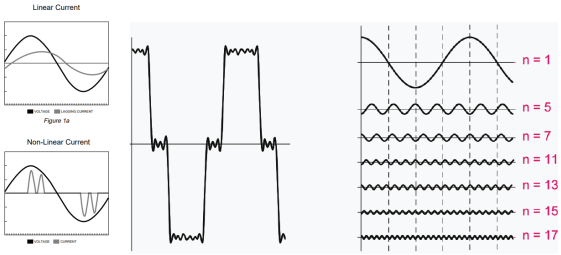
- Harmonics are the integer multipliers of the fundamental power frequency of 60hz. For example, the 2nd harmonic is 120hz while the 3rd harmonic is 180hz.
- For our purposes harmonics are broken down into 2 categories: voltage distortion & current distortion. The waveforms of each distort with voltage at its top & bottom (flattened) and current drawing in short burst (not continuous).



- Non-linear loads cause harmonics because they draw current in a non-linear fashion. In other words, they draw current in "gulps" from the utility. Examples of non-linear loads are: VFDs, lighting ballasts, computer screens, & any electronic devices with a diode rectifier in it (switch mode power supplies).
- Current distortion caused by the electrical consumer's non-linear loads will cause voltage distortion back at the point of common coupling (typically the building's main transformer) that is then shared to all users on that PCC.



These images illustrate linear & non-linear current as well as their harmonic distortion effects on a current waveform



Why do we care about limiting harmonics?

- Harmonics can cause interference to electronics that are sensitive to noise like: medical equipment, airport electronics, security systems, comms, & lab equipment.
- Harmonics can cause interference to electronics that have carrier signals like lighting systems & power meters.
- Generators may have voltage regulator issues when loaded with high harmonic content.
- Harmonics can cause certain hardware to run hot like transformers & motors that are run directly off the line.
- Any users on the same point of common coupling (PCC) like the neighboring buildings served by the same utility substation will be affected by voltage distortion caused by themselves and their neighbor's devices that are causing current distortion (see image below).

What is IEEE 519?

IEEE519 provides requirement for acceptable current harmonic levels (max distortion) but it is good practice to also limit voltage distortion too. Current code is from 2014 and lists maximum harmonic current distortion (TDD) at the point of common coupling (PCC) in percent of maximum demand load current (Isc /IL). A common value for an HVAC job is TDD of 5%.

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Point of Common Coupling (PCC)

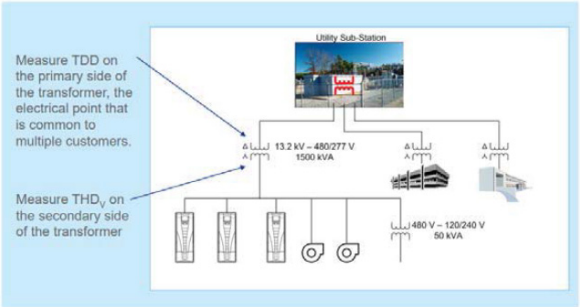

Table 2—Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
$< 20^c$	4.0	2.0	1.5	0.6	0.3	5.0
$20 < 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 < 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 < 1000$	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L

where

I_{sc} = maximum short-circuit current at PCC

I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

Ways to mitigate harmonics and what ABB recommends we do

- There are many methods employed to reduce harmonics such as:
  - Internal impedance like ac line reactors & dc bus chokes
  - Tuned passive harmonic filters
  - Stand alone active filters
  - 12 pulse drives
  - 18 pulse drives
  - Active front end drives
- Determine together (AirReps & the Electrical Engineer) the harmonic mitigation requirements needed for a project. The bare minimum should always be 5% impedance and make sure it is scheduled and specified (in both the mechanical & the electrical specifications).

Who is responsible for mitigating harmonics & when do you do a harmonic analysis?

The electrical engineer is responsible for a proper design but don't presume they have this covered and engage them.

Rules of Thumb

- If VFDs have 5% impedance, and they make up less than 30% of the transformer capacity, then you will likely meet IEEE519.
- In general, if the size of the transformer is large compared to the non-linear loads attached to it, chances are slim there will be an issue at the PCC. It's like throwing a rock in a big lake makes a small ripple no one notices while throwing the same rock in the bathtub makes a big mess.

Information is needed in a harmonic analysis

ABB has a Harmonic Analysis report which is an excel spreadsheet with macros so all you have to do is populate the fields to get an answer (like a wizard). However, much of the input can be hard for those of us not electricians or electrical engineers so refer to our AirReps VFD champions for assistance.

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