Public Service Commission of Wisconsin

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September 7, 1999

TO THE PERSON ADDRESSED

Re: Power Quality Guidelines

Many people have contacted the Public Service Commission (PSC) with concerns about the issue of earth currents, especially those at the third harmonic of the power frequency – namely 180 Hertz (Hz). As the issue of harmonics is addressed by the general document IEEE-519, we would like to point out several key provisions and some guideline numbers for use in any evaluation of data associated with this harmonic. First of all, harmonics are not generated by utilities. They are load-specific. Non-linear loads can and do generate harmonic currents and any subsequent harmonic voltages. Mitigation methods are most effective at the source site of the harmonics – namely the customer's wiring. Only in the rarest case, with large amounts of triplen harmonics existing on a three-phase neutral in a heavily industrialized area, would primary side mitigation methods be considered. There is no specification for the amount of harmonic currents that can exist at any point in the earth alone. All voltage and current measurements are made relative to the phase and neutral conductors and are not made to remote reference.

The PSC has, over a period of many years, comprehensively investigated the effects of traditional stray voltage on farm animals. It has considered the extensive available research about the effects of electricity, including harmonics, on farm animals but not on humans. Recent research by Drs. Aneshansley and Gorewit of Cornell Univ. recorded the most sensitive Holstein cow in their research to react to 8.48 milliamps peak to peak of 180 Hz current through the animal while the average for 16 animals was 24.8 milliamps peak to peak. When combined with the fundamental (60 Hz) frequency at zero degrees phase shift, the most sensitive cow reacted to 8.1 milliamps peak to peak. These are all above the 2 milliamp rms (5.7 milliamp peak to peak) 60 Hz, steady state 'level of concern.' The experiments are somewhat academic as the levels of harmonics selected in the research are well above those found in the real world. In all normal power systems, the harmonic content of the power supply is generally a small percentage of the fundamental, not at parity with the 60 Hz level.

The PSC must rely on the expertise of other government agencies regarding human health questions because we do not have in-house professionals to research these subjects. It was the Wisconsin Department of Agriculture, Trade and Consumer Protections' concerns about stray voltage that prompted the PSC to create the Stray Voltage Program. The Wisconsin Department

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of Health and Family Services has not reported any similar concerns about harmonics in electricity having an adverse effect on human health.

The IEEE 519 document stresses some cautions about data acquisition techniques using a high input impedance device, such as an oscilloscope, to measure harmonic content on a power line. It states:

> "Coaxial cable is suitable for relatively short leads. If one is forced to measure at a distance of tens to hundreds of meters, or if the sensor is near high voltage, the use of a voltage-to-frequency converter on the receiving end is very helpful for avoiding spurious signal pickup as well as for providing a safety barrier."

This requirement is not always followed by individuals untrained in proper data acquisition techniques. On a similar theme, utilities making measurements shall not parallel the input leads of more than one data acquisition instrument at a time. This is because one can experience data integrity problems from loading, interference, crosstalk, interaction of power supplies, etc.

As to the recommended limits of harmonic levels and the interpretation of those limits, IEEE 519 states:

> "The harmonic voltage distortion on the system will be a function of the total injected harmonic current and the system impedance at each of the harmonic frequencies. The total injected harmonic current will depend on the number of individual customers injecting harmonic currents and the size of each customer."
> "Accordingly, good engineering judgments are required on a case-by-case basis, and this recommendation (IEEE 519) in no way overrides such judgment."

Harmonics may be measured in both AC currents and AC voltages. The IEEE 519 document recommends individual customer site (secondary side) current limits. The data needed to derive the limit is: customer maximum load current, customer short circuit current limit and harmonic number. For a 10,000 amp Isc farm with a 400-amp service, the limit of 3rd harmonic current is 7% of the maximum load current or 28 amps. This number applies equally to both phase and neutral current. The neutral current must flow back to its source, which is the farm transformer. A 3rd harmonic current will exist in the primary phase and neutral conductors as a result of the common coupling (transformer) of the farm to the distribution system. For a typical 7,200-volt system with a 30:1 voltage transformer, this would result in a 0.93 amp phase current or neutral current that would also flow back to its source via the neutral conductor and the earth. This limit would be applied equally to each load on a rural distribution feeder. If, for example, there were 35 loads on a typical rural feeder, a total of over 32 amps of third harmonic would be the limit to flow back to its source point (substation or single-phase/three-phase interconnection point) via the neutral conductor/ earth pathway.

Third harmonic voltage limits for utility distribution lines are as follows: (the THD limit is for Total Harmonic Distortion, which is the sum of all harmonic voltages from the 2nd through the 50th). The voltages are measured phase to neutral.

Distribution voltage	3rd harmonic limit	THD limit
7,200 v AC rms	3 % = 216 volts AC rms	5 % = 360 volts AC rms
14,400 v AC rms	3 % = 432 volts AC rms	5 % = 720 volts AC rms

For selected transmission lines, the voltage limits would be as follows (measured phase to phase):

Transmission voltage	3rd harmonic limit	THD limit
69,000 v AC rms	3% = 2070 volts AC rms	5 % = 3450 volts AC rms
138,000 v AC rms	1.5% = 2070 volts AC rms	2.5 % = 3450 volts AC rms
345,000 v AC rms	1 % = 3450 volts AC rms	1.5 % = 5175 volts AC rms

In the latest version of the power quality section of Ch. PSC 113, which should be published early next year, the IEEE 519 document will be proposed as the standard of reference for harmonic concerns. If any third harmonic levels are found in excess of these limits, the utility should inform the customer generating the harmonics and it is that customer's responsibility to reduce their contribution to below the limit. As to other power quality concerns, Ch.PSC113 states that the limit of voltage in a steady state condition at the point of common coupling shall not vary by more than 5% above or below the nominal level. Any modifications made to customer wiring or devices on customer premises that create deviations greater than the limits referred to above must be dealt with by that customer.

If there are any questions about the above analysis, please contact Dick Reines at 6082670406.

Sincerely,

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