Overview

As regulatory authorities impose ever-stricter requirements for power quality, utilities increasingly want to know which customer is imposing harmonics and flicker on the utilities power system. As a result, we are often asked if we can determine the "direction" of harmonic power flow, and what can be done about flicker.

Harmonic Power Flow

Harmonics cause energy flow in power systems, just as fundamental frequencies do. The power at any harmonic is given by:

$$P_h = V_h \bullet I_h \bullet \cos(\theta_h),$$

where V_h and I_h are the rms harmonic voltage and current and θ_h is the phase angle between them. It is often thought that if a customer's load is creating harmonics, then the direction of power flow will be from the customer to the utility. This may not be correct.

Whether this is true or not depends on the phase angle of the utility's line *at the harmonic frequency*. This cannot be overemphasized, because it is quite likely that at these frequencies the impedance is highly reactive. This means that there will be very little active power (it will mostly be VARs), and in the event of an interaction between the line impedance and the customer's load impedance, the active power flow can actually be in the other direction. Due to these large phase shifts (caused by line inductance and leakage inductance of transformers) there will be relatively little active power anyway. Fortunately, there is a better way.

Relative Signal Magnitudes

A more useful means of detecting whether a customer is imposing harmonics on the system is to look at the relative magnitude of the harmonics, as a percentage of the fundamental voltage and current. If the customer is experiencing harmonics imposed upon him by the utility, then the relative magnitudes of the harmonic current will be less than or equal to the relative magnitude of the harmonic voltage. For example, if the third voltage harmonic was 3.1% and the third current harmonic was 2.8%, then we would expect that the harmonic current

was the result of the harmonic voltage on the utility's line. Since the customer's load is likely to have some reactive (inductive) component which will cause the impedance to be higher for harmonics (making his load act somewhat like a lowpass filter), we would expect the current harmonic to be smaller than the voltage harmonic when expressed in percent.

If, however, the reverse is true - the relative magnitude of the current harmonic is greater than that of the voltage harmonic - then the customer's load is probably imposing the harmonic on the utility. This is because the line impedance is likely to be much less than the load impedance, although this effect diminishes at high frequencies as discussed above. Especially at the lower harmonics, this is expected to be true, and it is quite possible, for example, to see a current harmonic of 22% with a voltage harmonic of 3.9%.

Because of resonances, it is possible for occasional harmonics to have exaggerated effects, either reinforcing or challenging the conclusion you would draw about who is imposing harmonics on whom. Therefore, you should always look at the harmonics as a group, with special emphasis placed on the first few harmonics (typically the odd ones, say 3rd through 11th) where line impedance effects are likely less exaggerated.

The Arbiter Systems Model 1133A Power Sentinel™ provides both methods of determining harmonic "direction." You can compare the methods, and draw your own conclusions as to which yields the more useful results.

Direction of Flicker

Flicker is a fundamental-frequency effect. The variations which cause flicker can be expressed as sidebands (modulation) of the "carrier" or fundamental signal. The frequencies of these sidebands are in the vicinity of the carrier, typically 0.5 to 20 Hz removed, unlike harmonics, which may be removed by a factor of 50. This means that the line impedance can be more reliably used to determine the direction of flicker, or more precisely, whether the utility is imposing flicker voltages on the customer or the customer is imposing flicker currents on the utility.

The IEC standards defining flicker, IEC 868 and the newer IEC 61000-4-15, only define flicker as a measurement made on voltage. Te reason may be that the IEC was primarily interested in flicker as an impairment, and the harmful effects of flicker happen because of voltage modulation. The IEC was not apparently interested in the practical question of where is the flicker coming from.

Utilities required to provide power at a certain level of quality are very interested in this question. After all, if they are penalized for poor power quality, then they need to be able to do something to remedy the problem.

For this reason, we have included the flicker measurement in the Model 1133A on both the voltage and current channels. Following similar logic as for harmonics, we would expect that the flicker of current for a customer's load will be less than, or about the same as, that for the voltage if he is experiencing flicker imposed by the utility. Flicker of current will be higher (probably much higher) than that on the voltage if the customer's load is imposing flicker on the utility. Again, this is because the utility's line impedance is generally much less than the customer's load impedance. The ratio of flicker on the voltage to that on the current is proportional to the square of the impedances. It is squared because the IEC definition of flicker says that a voltage variation creates a "flicker perception" that is proportional to the square of the voltage variation. For example, the IEC standard defines a variation of 0.25% peak at 8.8 Hz to represent a level of 1.0 perceptibility unit. If the variation increases to 0.5%, then the flickermeter will measure 4.0 perceptibility units.

Conclusion

The Arbiter Systems® Model 1133A Power Sentinel™ includes a powerful set of analysis tools to investigate power quality issues such as harmonics and flicker. The state of the art is rapidly developing in this area, and having capabilities which exceed that required by the relevant specifications will give the user extra latitude when investigating problems. Some of these methods may even become a part of future standards.