Informational Document from Harmonics Limited IDHL-16

Subject: UPS Input-Generator Harmonic Filtering

Interactions Between UPS Systems and Emergency Generators

The Problem:

Large facilities containing numerous critical computer loads cannot afford to sustain any downtime. To ensure continuous operation during power outages such facilities are often powered through a UPS sized to carry the entire facility load for a number of minutes. Long-term backup is provided by an emergency generator which will pick up the load if the outage lasts any significant time. Such generators usually come on line in under a minute after utility power is lost.

When utility power is restored an automatic transfer switch senses both the utility and generator power, waits until the voltage waveforms are synchronized, and reconnects the load to the utility. The generator then shuts down. The load, which receives continuous power, is unaffected by the outage. There are two problems with operation of such a system. Both are caused by high harmonic currents drawn by the UPS load.

A large UPS is a 3-phase non-linear load. Most units contain 6-pulse rectifiers, which draw harmonics currents. The input current to the UPS contains primarily 5th and 7th harmonics. Total harmonic current distortion can reach over 50% of the fundamental, and the 5th harmonic, the largest, can be as much as 40%. These harmonic currents are drawn through the impedance of the supply circuit, resulting in the production of harmonic voltage distortion. Voltage distortion can have detrimental effects on generator operation.

Voltage distortion is present when the UPS operates on utility power. Due to the relatively low impedance of the utility transformer, voltage distortion is seldom a problem. The generator, however, has a much higher impedance than the same rated utility transformer. For example, a 500 kVA 480 volt 5% impedance transformer has a source impedance of about 0.025 ohms. A generator to power a 100 kVA load might be rated at 200 kW, 0.8 pf, and would have a sub transient reactance of 18%. This would result in a source impedance of about 0.17 ohms, a factor of almost 7 greater than the transformer impedance. Thus harmonic currents that would result in 1.5% voltage distortion when the transformer is supplying the power (not unusual for the system described) would result in over 10% voltage distortion when the generator is on line.

While this amount of voltage distortion is not necessarily harmful, in the case of generators, it can be extremely troublesome.

The first effect of voltage distortion is to mislead the generator voltage regulator into thinking that the voltage is higher than it should be. The regulator responds by decreasing the field on the generator, thus lowering apparent voltage. But this lowers the 60 Hz voltage and causes the UPS to draw more current. Again the apparent voltage increases and again the regulator decreases the field. This feed-back loop usually results in the generator crashing as it fails to support the load. Fortunately, recent advances in the design of voltage regulators for generators have resulted in regulators sensitive only to the 60 Hz portion of the voltage, and this mechanism of generator failure can be avoided.

Perhaps more serious is the effect the distorted voltage has on the system when utility power is restored. Upon restoration of utility power the UPS load transfer switch, that reconnects the load to the utility, electronically looks for synchronization between the utility and generator voltage waveforms and, when synchronization is obtained, reconnects the UPS load to the utility. Then the generator is shut down. Unfortunately, if the generator voltage waveform is so distorted that it no longer resembles a sine wave or has multiple zero crossings, the transfer switch will not be able to synchronize generator and utility voltages and the load will never be returned to utility power.

The Solution:

One way to avoid synchronization problems is to increase the size of the generator. This has the effect of lowering sub-transient reactance, thus reducing the magnitude of the harmonic voltage distortion. If the generator has a low enough impedance the voltage waveform will be close enough to a sine wave to allow synchronization with the utility power. This is a very expensive solution which results in wasted generator capacity, wasted floor space, wasted fuel, and higher-than-necessary maintenance costs on the oversized generating system.

A better way to solve this problem is to apply harmonic filters to remove harmonic currents before they reach the generator. Some UPS manufacturers offer “filters” for their units which consist primarily of capacitors without any tuning. Such filters do not really remove harmonic currents, and can cause leading power factor if the UPS is lightly loaded. Harmonic shunt filters tuned to absorb the 5th harmonic have proved successful in ensuring correct operation of generators powering non-linear UPS loads. If harmonic currents do not flow in the generator, harmonic voltages will be reduced and a sinusoidal voltage waveform can be maintained.

5th harmonic filters are normally sized to compensate for harmonic currents drawn by a UPS under quarter to full load conditions. Under very light loading, there may be some concern that the capacitance in the filter will cause the power factor to become leading, resulting in generator instability. In such cases the filter can be connected to a controller that will disconnect it if the power factor temporarily becomes leading, and will reconnect it when the filtering is again needed.

If parallel redundant UPS units are on line with only one at a time being used to power loads, a single filter, sized for one UPS, can be placed on the bus feeding all the UPS units. If multiple UPS units are paralleled to feed a load that varies widely, a single multi-step filter can be placed on the bus with a controller switching filter steps in an out as the load changes. In any case, the use of parallel shunt filter technology can ensure that harmonic voltages are kept to a low enough level to permit proper utility-generator synchronizing under changing load conditions.

Such filters are much more cost effective than generator over sizing in ensuring proper operation of generators powering large UPS units.

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