The Datawave® Magnetic Synthesizer as a Solution to Harmonics Problems

SUMMARY

The Datawave® magnetic synthesizer has earned its reputation as a superior power conditioner in over 10,000 installations around the world. It provides comprehensive protection from all power disturbances except frequency deviations and complete outages. It's input voltage regulation range is unmatched at greater than ± 40%. Power studies have documented its ability to protect against very deep power sags (greater than -70%). the synthesizer generates a new output voltage waveform, free of any input transients, notches, or waveform distortion. More recently, the Datawave has found increased application because of its excellent harmonic isolation capabilities. The Datawave isolates the load from any harmonics that may be present in the power system, and it isolates the power system from the harmonics of the nonlinear loads.

The increased use of nonlinear loads has prompted an increased concern about harmonics and their effects on the power system. Harmonics are voltages and currents which have frequencies that are whole number multiples of the fundamental power system frequency. The major sources of harmonics are static power converters used in most modern electronic equipment including battery chargers, UPSs (uninterruptible power supplies), adjustable speed motor drives, electronic ballast's, and computer power supplies.

Harmonic currents generated by nonlinear loads flow through the power system impedance's, causing voltage drops at the harmonic currents' frequencies. These higher frequency voltage drops add to or subtract from the generated fundamental sinusoidal to cause voltage distortion. Distorted voltages applied to certain power system components such as capacitors, motors, and transformers cause additional heating and can cause misoperation of certain sensitive loads. Notching is a special form of voltage distortion. It is typically caused by the normal commutation overlap in an SCR converter when two SCRs are conducting at the same time, producing a momentary short circuit. The resulting voltage waveform has sharp deviations from the sine wave (notches) which can affect the operation of sensitive electronic loads.

Harmonic currents flowing through the power system components cause additional losses beyond the normal I^2R losses due to the higher frequencies of the harmonic currents. For some components, such as transformers, the deratings for harmonic currents can be quite substantial, e.g., 30-40%. Further, harmonic current flows in the power system primarily as reactive power (VARs), which decreases the system power factor and adds to the apparent power demand (VA). In certain circumstances, particularly where capacitors are used for voltage regulation or power factor correction, harmonic currents can excite system resonance's with their associated high component stresses and voltage waveform distortion.

As more and more users of electronic equipment become aware of harmonics and their detrimental effects on the power system, they are actively pursuing ways to reduce harmonics. The best solution is to not generate them in the first place. Standards such as IEEE 519 and IEC 555 are being formulated to encourage the development of computers and other electronic loads that do not generate harmonics. However, until these efforts have time to take effect, harmonic problems will increase, and remedial-dial solutions will be required.

Currently, passive harmonic filters are on of the most popular methods of reducing harmonic currents, but they require careful application, are large and expensive, and may produce unwanted side effects. Active filters, which consist of electronics designed to produce harmonics of opposite polarity to cancel the unwanted harmonics, are beginning to become available, but they are also relatively large and expensive.

Transformers have been used over the years to help control harmonic currents. Standard delta-wye transformers provide cancellation of the balanced triplen harmonic load currents (3rd, 9th, 15th...). Specially constructed transformers with the capability to tolerate the added heating effects of harmonic currents have recently been developed and are known as K-factor transformers. Neither of these solve the problems because they merely pass harmonic currents on to the upstream power system and pass power system voltage distortion on to the loads.

More elaborate multi-phase transformers have been used for quite some time, particularly with large rectifiers, to reduce input current distortion. Six-phase, twelve-phase, and other transformer configurations have been used to provide phase-shifted voltages to multiple, balanced rectifier loads to cancel specific harmonic current pairs. For example, a six-phase transformer is used with a twelve-pulse rectifier to provide two three-phase voltages with a 30° phase shift and cancel the 5th, 7th, 17th, 19th... harmonic currents. Recently, these techniques have been applied to computers and other electronic loads. While providing some level of harmonic current reduction, they require similar and balanced loads to cancel specific harmonic currents, and they do not address other harmonic problems such as voltage distortion or notching.

The Datawave™ magnetic synthesizer made by Liebert Corporation is a unique three-phase power conditioning product that provides a more complete solution to harmonic problems. The Datawave uses the input as a source of power and timing to generate the output. The basic block diagram for a Datawave magnetic synthesizer is shown in Figure 1.

Figure 1: Datawave Magnetic Synthesizer

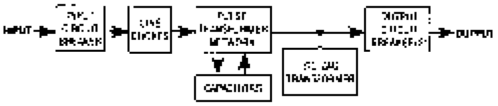


Figure 2: Synthesized Output Voltages
by combining the six transformer probes

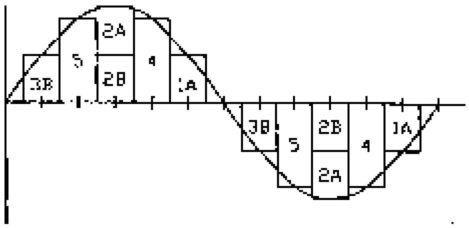
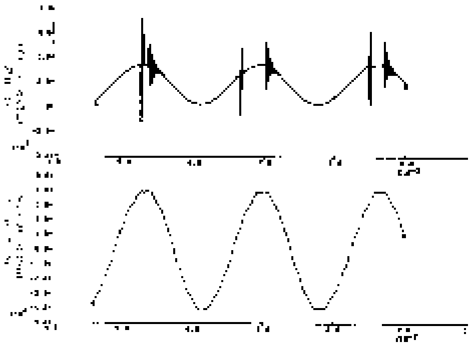


Figure 3: Datawave Eliminates Sever Notching and Ringing Transients



The output voltage waveform is generated by combining the pulses from six interconnected saturating pulse transformers in a manner similar to a step-wave inverter, but without using semiconductors or electric controls. Energy oscillates between the main capacitor banks and the pulse transformer cores. This ferroresonance ensures that the transformer cores saturate and produces the desired voltage pulses. The pulse of each transformer is determined by the physical construction of the transformer (core geometry and windings) which limits the available volt-seconds of the pulse and results in a very controlled and stable output waveform.

Figure 2 shows how the six pulse transformer outputs are combined to produce sinusoidal output voltage. The resulting output voltage distortion is less than 4% THD (total harmonic distortion), independent of the input voltage distortion. Therefore, the Datawave isolates sensitive loads from any power system voltage distortion or notching. Further, the Datawave is not sensitive to input voltage distortion and can accommodate highly distorted input voltages (> 30% THD) without affecting its operation. Figure 3 is an example of sensitive loads isolated by the Datawave from very severe notching and ringing power system transients.

Nonlinear line chokes are used to isolate the synthesizing network with its regulated output voltage from the input voltage source. The variable impedance of the line chokes allows the pulse transformers to operate at a constant voltage even though the input voltage varies. In effect, the line chokes convert the input power source into a current source which supplies the energy required by the output synthesizing network. The input current waveform of the Datawave is a function of the way the synthesizing network draws energy from the supply rather than a function of the load current waveform. Therefore, the Datawave is very effective in isolating the power system from the harmonic current distortion of nonlinear loads. The Datawave's input current distortion remains less than 8% THD regardless of the load current distortion. This harmonic current isolation is also not dependent on the similarity or balance of the nonlinear loads.

When supplying nonlinear loads, the power source should provide a low enough impedance at the harmonic current frequencies to prevent excessive output voltage distortion due to harmonic currents flowing through the internal impedance of the power source (transformer, power conditioner...). Figure 4 shows two different nonlinear loads connected to the same size isolation transformer and Datawave, and the resulting output voltage and input current distortions. The Datawave is better able to supply the nonlinear load's harmonic currents because it has a lower output impedance at the harmonic frequencies than an isolation transformer. Further, the Datawave's input current remains linear and prevents the nonlinear load's harmonic currents from affecting the rest of the power system.

The Datawave is designed to be compatible with nonlinear loads without derating, including single-phase, switched-mode power supplies. The internal components of the Datawave are designed to withstand the effects of harmonic currents without over heating. This includes having neutral components of 2087/120 volt systems sized to accommodate currents up to at least 1.73 times the rated full-load output current.

Often it is desired to improve the power factor to reduce system losses and avoid penalties imposed by some utilities. Power factor is the ratio of real power (kW) used by the load to the apparent power (kVA) drawn by the load. With nonlinear loads, the power factor has two components, displacement power factor and harmonic power factor. The displacement power factor is the cosine of the phase angle between the fundamental voltage and current. Harmonic power factor is due to the reactive power (kVAR) flows of the harmonic currents. Displacement power factor can be corrected by adding power factor correction capacitors, but they will have no beneficial effect on the harmonic power factor. Indeed, adding power factor capacitors in the presence of nonlinear loads may result in over compensation or harmonic resonance. The Datawave corrects for both the displacement and harmonic power factor.

The input power factor of the Datawave is better than 0.95 for any load condition, quarter load to full load, independent of load power factor.

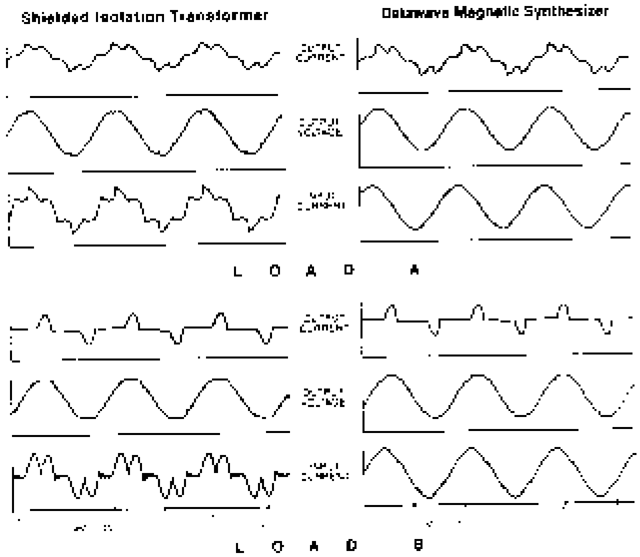
Another concern is the load balance. Three-phase power sources supplying single-phase loads often experience unbalanced load conditions. This can cause voltage unbalance and additional heating in three-phase components. The Datawave can accommodate unbalanced loading, even 100% load imbalance (full load on one phase, no load on another). Additionally, because the Datawave uses the input as a source of energy, the Datawave draws balanced input current from the input power source regardless of the load current balance.

The Datawave is a superior power conditioner besides being an excellent harmonic isolator that presents an ideal load for the power system (balanced, linear load with near unity power factor). The input voltage regulation range is greater than ± 40%. Power studies have documented the ability of the Datawave to protect against very deep voltage sags (greater than -70%). The synthesizing action of the Datawave blocks any input voltage surges and ringing transients from appearing on the output voltage. In fact, the only power disturbances not correctable by the Datawave are frequency deviations and complete interruptions (outstages), both of which require a UPS to correct.

The Datawave is very rugged and reliable, based on dry-type transformers and self-healing, long life capacitors. It is field-proven in over 10,000 installations around the world. The Datawave is particularly attractive where outages are unlikely or where more expensive UPS systems can not be justified. Ideal applications include installation in major urban areas where utility networks or loops of power are fed from multiple substations providing very reliable but otherwise dirty power.

The Datawave has always provided exceptional features as a power conditioner. Today, as more and more users of electronic equipment become concerned about harmonics, the Datawave is finding increased applications as a solution to harmonic problems. Because of its basic operation, the Datawave isolates its input from its output. The Datawave isolates the load from the effects of harmonics present in the power system, and it isolates the power system from the harmonics of the loads, thereby providing a complete solution to harmonic problems with the added benefits of power conditioning for sensitive loads.

Figure 4: Nonlinear Load Performance Comparisons



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