

micros because of the specialized architecture and the nature of applications. We will now address issues pertaining to software development with DSPs and also indicate the development tools available.

**Operating System:** DSPs are used for real-time control and data acquisition in motor drive control. Real-time processing requires a fast multi-tasking operating system. Real-time operating systems, such as SPOX, are available for floating-point DSPs. A custom real-time kernel can also be implemented for the chosen processor.

**High-Level Language:** Using a HLL like C can cut development effort substantially. However, HLL compilers for DSPs do not exploit their unique architectural features and instruction-level parallelism. Compiled code is usually two to four times the size of assembly code; this is a high-penalty trade-off for time-critical applications. Therefore, HLLs are used for initialization and nonreal-time code. Due to the general trend towards more usage of HLL, newer DSP architectures are being optimized for HLL.

**Assembly Language:** Assembly language produces the most efficient code in DSPs. Consequently, it is necessary to use assembly language for time-critical operations. Moreover, code for I/O tasks needs to be written almost exclusively in assembly. So, low-level programming expertise is essential when implementing high-speed systems using DSPs. Macro libraries are available for frequently used functions, simplifying application development to a certain extent. Most DSP applications are built using a judicious mix of assembly and HLL.

**Signal Processing Languages:** Signal processing languages provide users with both high-level and low-level instructions. They offer ease of development like HLLs and code efficiency comparable to that of assembly. DSP from dSPACE is one example. However, there is no standard for these languages.

**Code Generation Software:** Code generators produce DSP assembly language code from a mathematical description or block diagram of the algorithm. Such packages allow the designer to focus on design issues instead of assembly language programming problems. DSP-CIT from dSPACE and Hypersignal from Hyperception are examples.

**Programming Techniques:** Programming techniques are slightly different for DSPs than for ordinary processors. DSPs use instruction pipelines and branching breaks the pipeline. Consequently, it makes sense to have straight-line code rather than calling subroutines. Also, it may be faster to compute function values every time instead of using a look-up table. Using nested interrupts in DSPs will cause stack-overflow very quickly. Interrupts also break the instruction pipeline; it is better, therefore, to use synchronous sampling and polling instead of interrupts.

**Discussion:** Programmable DSPs are leading a revolution in signal processing, bringing about the rapid convergence of computers, communication, and consumer electronics. At the same time, advances in DSP chip technology have had a positive impact on the field of motor drives. It is expected that more and more motion control systems will be centered around DSPs in the future.

Developing a DSP-based motor drive requires expertise not only in the underlying motion control, but also in microcomputer system design and software development. Though development environments for DSPs are commercially available, they fall short of meeting the expectations of system designers. DSPs can obviate the need for specialized peripheral devices by capturing the functionality in software. Consequently, it is more cost-effective to build a system using a single-chip DSP for control rather than using a microprocessor with specialized peripheral devices.

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## An Insight into Power Quality Disturbances Using Wavelet Multiresolution Analysis

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**Abstract:** The wavelet transform is beginning to be used widely in power engineering. Its effectiveness for analyzing transients with time localized information is now well known. Multiresolution analysis is especially suitable for feature enhancement of transients and thus makes it possible for power disturbances to be classified. In addition, the wavelet transform works well where the Fourier Transform fails. A graphical insight is demonstrated in this letter.

**Keywords:** Scalogram, MRA, transients.

**Introduction:** Power quality includes problems caused by voltage sags, switching transients, and supply discontinuities. The effects of these faults are generally transitory, i.e., of a short-term duration. The Fourier transform is a powerful tool for harmonic analysis. Wavelets on the other hand, have demonstrated applicability with signals that are nonstationary. Wavelet analysis incorporates the multiresolution technique, an effective way to extract time localization as well as retaining frequency information. The use of wavelets to analyze power disturbances is proposed in [1]. Other works [2-6] demonstrated the ability of wavelets to reconstruct transients with a fraction of the coefficients and the method of multiresolution analysis was used to obtain the specific information of transients on several octave frequency bands. This letter shows how a graphical insight into power quality disturbances can be obtained by examining power transients in the wavelet domain.

**Wavelet Transform and Multiresolution:** The ability of the wavelet transform to localize both time and frequency makes it possible to simultaneously determine sharp transitions of the signals and in the localization of their occurrence. In the Wavelet Transform, a set of wavelet functions is chosen as the basis, similar to the sinusoidal function for the Fourier Transform. The set of basis functions is obtained by dilating and shifting a prototype, called a mother wavelet, on different levels. Wavelet coefficients are the projection of the original function onto the basis. The magnitude of the coefficients is an indication of how close the original signal is represented by a particular wavelet.

Multiresolution allows the decomposition of signals into various resolution levels. The level with coarse resolution contains approximate information about lower frequency components and retains the main features of the original signal. The level with finer resolution retains detailed information about the high frequency components.

**Application in Power Disturbances:** Two typical power transients are given in Figure 1. Signal 1 is an autoreclosure signal with an outage of two cycles. Signal 2 is a voltage sag, with a magnitude decrease to 40 percent over 6 cycles. The power spectral density is shown in Figure 1,

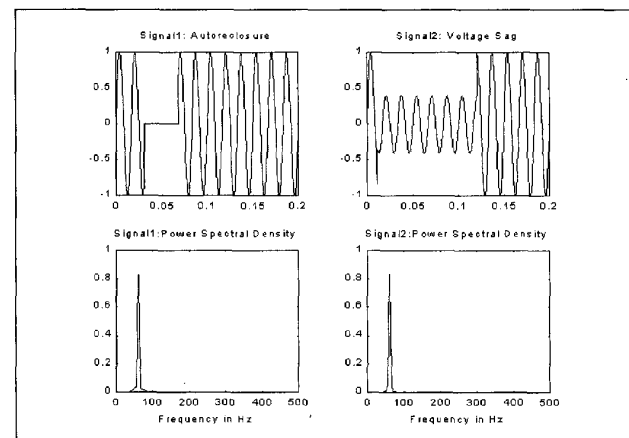


Figure 1. Two signals, autoreclosure and voltage sag, and their power spectral density

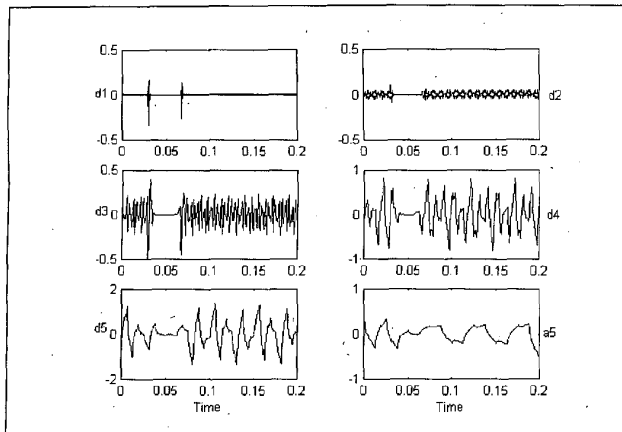


Figure 2. Five level multiresolution decomposition of signal 1, autoreclosure

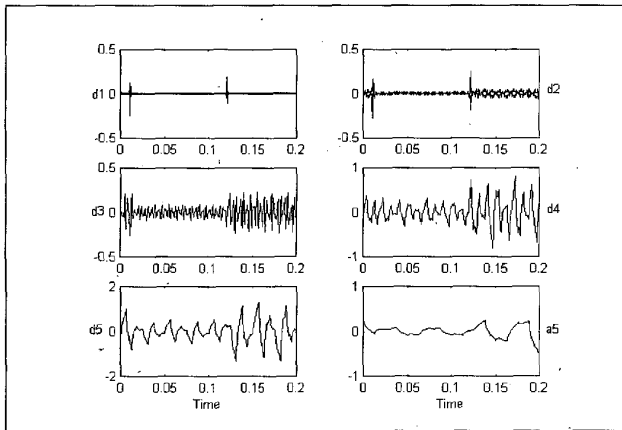


Figure 3. Five level multiresolution decomposition of signal 2, voltage sag

which is the same for these two signals. There is no time information about the instant of the autoreclosure or sag, so it is impossible to distinguish between them using power spectral density.

In Figure 2, the multiresolution decomposition of signal 1 is presented. It is decomposed into five detailed and one approximate component. From the detailed components, in level 1, the time instant when the outage begins and ends is clearly obtained. By examining levels d1 and d2, the magnitude of the components during the outage are very small or approximately zero, thus indicating an autoreclosure. a5 is the approximate component on the fifth level. Figure 3 provides the multiresolution decomposition of signal 2 on five levels. From d1, the time localization for the beginning and end of the sag is provided. From d2, the magnitude of the coefficients during the sag is nonzero, thus allowing discrimination between these two signals.

Figure 4 gives the scalogram of signal 1. The wavelet coefficients are presented in a two dimensional time-frequency relationship. All the rectangles are shaded in proportion to the magnitude of the wavelet coefficients. The darkest one represents the highest magnitude of the coefficients. The frequency axis has a dyadic bandwidth. As the frequency increases, the frequency resolution decreases while the time resolution gets better. This makes it possible for the detection of the short-time fast changing transients. The autoreclosure results in a blank area with negligible coefficients during the power outage. The two narrow rectangles that exist between 250 and 500 Hz give the time localization of the beginning and end of the outage. In Figure 5, the scalogram of the signal 2 is given. It presents graphically the same information as in the multiresolution display in Figure 3. Compared to Figure 4 the coefficients during the sag are larger than for the case with the autoreclosure. The period between 125 and 250 Hz shows that the magnitude of the coefficients are quite small, thus it gives the time localization of the beginning and end of the voltage sag.

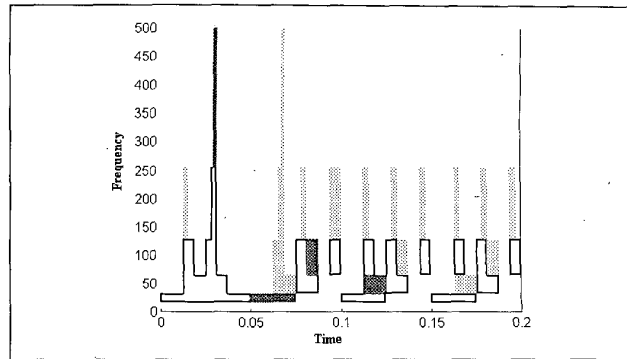


Figure 4. Scalogram of signal 1, autoreclosure

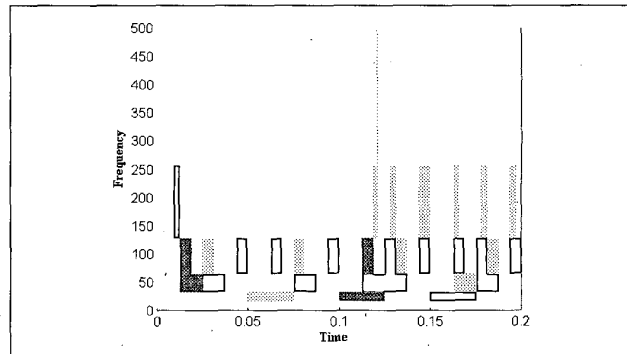


Figure 5. Scalogram of signal 2, voltage sag

**Conclusion:** With wavelet transform and multiresolution analysis, power transient signals that have the same Fourier power density show obvious difference in the wavelet domain. In this domain, it is possible to obtain time and frequency information simultaneously. The scalogram demonstrates the effectiveness of the wavelet transform for power system disturbance classification, as an example.

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