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Experimental evaluation of envelope tracking techniques for voltage disturbances

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ABSTRACT

In this paper a digital signal processor (DSP) based real time voltage envelope tracking system is developed and examined. The ADAptive LINEar neuron (ADALINE) and the Recursive Least Square (RLS) algorithms are adopted for envelope tracking. The proposed ADALINE and RLS algorithms give accurate results even under rapid dynamic changes. The paper investigates the effects of different parameters on the performance of the ADALINE algorithm and that of the RLS algorithm. The experimental system is cantered around a Texas Instrument 16 bit fixed-point arithmetic (TMS320LF2407A) evaluation board. Both the ADALINE and the RLS tracking algorithms are developed using the DSP-assembly language. A simple voltage flicker generator is implemented to produce various voltage disturbances. Extensive tests of the proposed envelope tracking algorithms are conducted to evaluate their dynamic performance.

1. Introduction

Not only is envelope tracking a crucial task for assessing the voltage quality and evaluating the flicker severity, but it also can be applied to mitigate voltage disturbances. Many techniques have been proposed in the literature for tracking the flicker envelope: Fast Fourier Transform [1], Kalman Filter [2], Least Absolute Value [3], and Wavelet Transform [4]. To overcome drawbacks of the aforementioned techniques, the authors introduced the ADALINE [5] and the RLS [6] techniques for the on-line tracking and mitigation of voltage flicker. Theoretical study of both the ADALINE and the RLS algorithms and their tuning factors are conducted in [7].

The ADALINE algorithm is characterized by simple calculations which lead to a fast execution time of the algorithm, a property which is essential for an on-line application. For fast convergence, the RLS algorithm outdoes the ADALINE algorithm. The robustness of the RLS algorithm results because it diminishes the effect of the initial conditions more quickly than the ADALINE algorithm. While the RLS algorithm offers a precise envelope tracking with a lower error value than the ADALINE algorithm, the ADALINE algorithm has lower calculation demands than the RLS one. However, both the ADALINE and the RLS algorithms are characterized by an adaptive tuning nature that leads to a precise envelope tracking.

This paper details the digital implementation of the proposed algorithms for envelope tracking using Texas Instrument 16 bit fixed-point arithmetic DSP (TMS320LF2407A) evaluation board. A power electronic switching circuit is implemented to emulate the operation of resistance welder by generating a square wave flicker shape. Connecting more switching circuits together generates more complicated envelope waveforms. Extensive experimental studies of both the ADALINE and the RLS tracking algorithms are carried out with emphasizing on the effects of their tuning factors on the tracking performance.

2. Implementations of envelope tracking techniques

The disturbed voltage waveform in distribution systems can be modeled as a variable amplitude sinusoidal waveform such as $v(t) = A(t)\sin(\omega_1 t + \phi_1)$ where $A(t)$ is the magnitude of the disturbance voltage, ω_1 is the supply angular frequency and ϕ_1 is the angle of the fundamental component. The shape of $A(t)$ depends on the load that produces the disturbance. The shape can be a step function to represent the switching of heavy loads, or it can be a square wave to model resistance welders or a sinusoidal modulating function to represent the arc furnace. Writing $v(t)$ in vector form yields

$$v(t) = [\sin\,\omega_1 t\ \cos\,\omega_1 t]\begin{bmatrix} A(t)\cos\,\phi_1 \\ A(t)\sin\,\phi_1 \end{bmatrix} = X(t)^{\mathrm{T}} W(t) \qquad (1)$$

where $W(t) = \begin{bmatrix} w_1 \\ w_2 \end{bmatrix}$ w_1 and w_2 are equal to $A(t)\cos\phi_1$ and $A(t)\sin\phi_1$, respectively. The superscript 'T' is the transpose operation. If the elements of the vector $W(k)$ are known, the envelope

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