Comparative Study of Evolutionary Computing Methods for Parameter Estimation of Power Quality Signals

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ABSTRACT

Recently utilities and end users become more concerned about power quality issues because the load equipments are more sensitive to various power quality disturbances, such as harmonics and voltage fluctuation. Harmonic distortion and voltage flicker are the major causes in growing concern about electric power quality. Power quality disturbance monitoring plays an important role in the deregulated power market scenario due to competitiveness among the utilities. This paper presents an evolutionary algorithm approach based on Adaptive Particle Swarm Optimization (APSO) to determine the amplitude, phase and frequency of a power quality signal. In this APSO algorithm the time varying inertia weight is modified as rank based, and re-initialization is used to increase the diversity. In this paper, to the authors highlight the efficacy of different evolutionary optimization techniques like classical PSO, Constriction based PSO, Clonal Algorithm (CLONALOG), Adaptive Bacterial Foraging (ABF) and the proposed Adaptive Particle Swarm Optimization (APSO) to extract different parameters like amplitude, phase and frequency of harmonic distorted power quality signal and voltage flicker.

Keywords: Bacterial Foraging, Clonal Algorithm, Genetic Algorithm, Particle Swarm Optimization, Power Quality, Voltage Flicker

INTRODUCTION

In recent years, power quality has become a significant issue for both utilities and customers. Power quality issues (Arrillaga, Watson, & Chen, 2000; Bollen, 2000; Dugan, McGranaghan, & Beaty, 2000) and the resulting problems are the consequences of the increasing use of solid state switching devices, non-linear and power electronics switched loads, unbalanced power systems, lighting controls, computer and data processing equipment as...
well as industrial plant rectifiers and inverters. These electronic types of loads cause quasistatic harmonic dynamic voltage distortions, inrush, pulse type current phenomenon with excessive harmonics and high distortion. A power quality (PQ) problem usually involves a variation in the electric service voltage or current, such as voltage dips and fluctuations, momentary interruptions, harmonics and oscillatory transients causing failure or mal-operation of the power service equipment. In order to improve electric power quality, the sources and causes of such disturbances must be known before appropriate mitigating action can be taken. However, in order to determine the causes and sources of disturbances, one must have the ability to detect and localize these disturbances. Estimation of amplitude and phase of fundamental, as well as harmonic signals has been one of the important tasks in measurement, control, relaying protection, distribution automation, and intelligent instrumentation of power system. Accurate power fundamental frequency is a necessity to check the state of health of the power index, and a guarantee for accurate quantitative measurement of power parameters, such as voltages, currents, active power, reactive power, and energy, and so on, in multifunction power meters under steady states. It is more difficult to precisely estimate the fundamental frequency of power systems in presence of harmonics and noises than under sinusoidal condition. It is essential to seek and develop some effective algorithms for accurate estimation of the instantaneous fundamental frequency of power systems under non-sinusoidal conditions.

Several methods employing digital algorithms have been developed for the estimation of parameters like amplitude, phase and frequency of power quality signals. Algorithms based on Fast Fourier Transform (FFT) have been widely used for the purpose (Chen, 1997; IEEE Standard, 1993). The FFT method suffers from the major problem such as resolution, spectrum leakage and picket-fence effects. As the system frequency deviates from the nominal value, the leakage error becomes more (Probabilistic aspects Task Force, 1998). Some of the pitfalls of DFT was suggested in (Girgis & Ham, 1980). The leakage effects of system frequency variation on the measurements of harmonic and flicker have never been accurately determined, so some serious errors might happen in the related measurements. Digital algorithms based on Least Error Square (LES) state estimation technique (Lobos, Kozina, & Koglin, 2001; Sachdev & Giray, 1985; Soliman & El-Hawary, 1999), Least Absolute Value (LAV) estimation (Soliman, Christensen, Kelly, & El-Naggar, 1992) are more common to estimate the parameters of a power quality signal. The above algorithms are not suitable for the non-stationary signals. The other digital algorithm based on Kalman Filtering is a stochastic dynamic filtering algorithm, mostly suitable for non-stationary signals. This method leads to fast and accurate estimation of power system signal amplitude and phase. This method has been applied for finding the parameters of the voltage flicker signal, harmonic signals and has been reported in (Dash, Jena, Panda, & Routray, 2000; Routray, Pradhan, & Rao, 2002). However the algorithm requires an accurate guess of system frequency. The use of Fourier Linear Combiner for harmonic estimation in distorted power signals is reported in (Dash, Swain, Liew, & Rahman, 1996; Dash, Pradhan, & Salama, 2002). Another method based on sample count and interpolation estimation technique is reported in (Aghazadeh, Lesani, Sanaye-Pasand, & Ganji, 2005) for frequency and amplitude estimation of power system signals. Besides the above digital techniques, some of the intelligent techniques like Artificial Neural Network (ANN), Expert system (ES) has been applied for amplitude, phase and frequency estimation of distorted power signals (Kandil, Sood, Khorasani, & Patel, 1992; Martins, Oliveira, & Goncalves, 2000; Mori, 1992; Osowski, 1992). Soft computing techniques like Genetic Algorithm (GA) (El-Naggar & AL-Hasawi, 2006; El-Zonkoly, 2005), Simulated Annealing (SA) (Soliman, Mantaway, & El-Hawary, 2004) have also been applied for power quality analysis. A new algo-
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