An Improved Population-Based Incremental Learning Algorithm

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ABSTRACT
Population-Based Incremental Learning (PBIL) is a relatively new class of Evolutionary Algorithms (EA) that has been recently applied to a range of optimization problems in engineering with promising results. PBIL combines aspects of Genetic Algorithm with competitive learning. The learning rate in the standard PBIL is generally fixed which makes it difficult for the algorithm to explore the search space effectively. In this paper, a PBIL with adapting learning rate is proposed. The Adaptive PBIL (APBIL) is able to thoroughly explore the search space at the start of the run and maintain the diversity consistently during the run longer than the standard PBIL. The proposed algorithm is validated by applying it to power system controller parameters optimization problem. Simulation results show that the Adaptive PBIL based controller performs better than the standard PBIL based controller, in particular under small disturbance.

Keywords: Adaptive Learning Rate, Evolutionary Algorithms, Genetic Algorithm, Low Frequency Oscillations, Population-Based Incremental Learning, Power System Stabilizer

1. INTRODUCTION
Engineering optimization problems arise in varities of engineering applications. These optimizations problems were generally difficult or impossible to solve using conventional optimization methods. In the last three decades or so, there has been a growing interest in applying Evolutionary Algorithm (EA) to engineering optimization problems. The most widely used EA is Genetic Algorithms (GAs) (Goldberg, 1989). Although GAs provide a robust and powerful adaptive search mechanism, they have several drawbacks. Some of these drawbacks include the slow convergence of the algorithm when solving complex problems, the problem of “genetic drift” which prevents GAs from maintaining diversity in the population, and the difficulty to optimally select the genetic operators such as population size, crossover and mutation rates (Davis, 1996; Yao, Kharma, & Grogono, 2010).

In the last few years, Particle Swarm Optimization (PSO) which belongs to the family of Swarm Intelligence has also been proposed as an alternative to GAs (Kennedy et al., 2001; Abido, 2001; Venayagamoorthy, 2005).

Recently, a novel type of Evolutionary Algorithm called Population-Based Incremental Learning (PBIL) which belongs to the family of Estimation of Distribution Algorithms (EDA) has received increasing attention (Baluja, 1994; Baluja & Caruana, 1995; Green, 1996; Folly,
2006, Sheetekela & Folly, 2010; Mitra et al., 2009). PBIL is simpler and more effective than GAs. In addition, PBIL has less overhead than GAs (Baluja & Caruana, 1995; Green, 1996; Gosling, 2004). The main reason for this simplicity is that PBIL, the crossover operator is abstracted away and the role of population is redefined (Baluja, 1994; Baluja & Caruana, 1995). Furthermore, PBIL works with a probability vector (PV) which controls the random bit strings generated by PBIL and is used to create other individuals through learning. Learning in PBIL consists of using the current probability vector (PV) to create $N$ individuals. The best individual is used to update the probability vector, increasing the probability of producing solutions similar to the current best individuals (Baluja & Caruana, 1995; Green, 1996). It has been shown that PBIL outperforms standard GAs approaches on a variety of optimization problems including commonly used benchmark problems (Baluja, 1994; Baluja & Caruana, 1995).

PBIL was also used to optimize the parameters of a power system controller known as power system stabilizer (PSS) and has given promising results (Folly, 2006; Folly & Venayagamoorthy, 2009). The main purpose of PSS is to damp low frequency oscillations. Low frequency oscillations in power systems arise due of several causes. One of these is the transfer of heavy power over long distance. The problem of low frequency oscillations is not new, however, in the last few years, this problem is becoming more and more important due to the economical and environmental considerations and the desire to utilize the available transmission line infrastructure more efficiently. To achieve this, modern power systems are required to operate close to their stability margins. As a result, a small disturbance can easily reduce the damping of the system and drive the system to instability. Another reason for the increase in low frequency oscillations is the deregulation and open access of the power industry. This has led to the transfer of heavy power across different regions, with the devastating consequence of reduced stability margins.

For several years, traditional control methods such phase compensation technique (Hemmati et al., 2010), root locus (Kundur, 1994), pole placement technique (Shalgholian & Faiz, 2010), etc. have been used to design conventional PSSs (CPSS). These methods are widely accepted in the industry because of their simplicity. However, conventional controllers cannot provide adequate damping to the system over a wide range of operating conditions. To cover a wide range of operating conditions, advanced optimization techniques such as Evolutionary Algorithms should be used in combination with multi-power flow conditions.

In (Folly, 2006; Folly, 2007), standard PBIL based power system stabilizers (PSSs) were compared with GA based PSSs and were found to give better results than GA based PSSs. In (Sheetekela, & Folly, 2010), it was shown that standard PBIL-PSS performed as effectively as Breeder Genetic Algorithm (BGA) based PSS. In Mitra et al. (2009), PBIL base PSSs were compared with three other population-based algorithms: Differential Evolution based Particle Swarm Optimization (DEPSO), Modified Clonal Selection Algorithm (MCSA), and Small Population based Particle Swarm Optimization (SPPSO). The paper showed that PBIL based controllers give better results than DEPSO and SPPSO based controllers, and slightly worst results than MCSA based controllers.

Recently, some authors have reported that PBIL suffers from diversity loss making the algorithm converge to local optima (Conzalez et al., 2001a; Gonzalez et al., 2001b; Rastegar et al., 2005; Rastegar et al., 2006). Maintaining the diversity in PBIL’s population is directly linked to the learning rate. However, the learning rate in the standard PBIL is generally fixed to a certain value. Therefore, it becomes difficult for the algorithm to explore and/or exploit the search space in an effective manner. As a result, there is a possibility that the algorithm could converge to local optima.

To cope with the problem of premature convergence, some authors such us (Yang & Richter, 2009) have used hyper-learning for PBIL and investigated its effect in dynamic
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