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ONLINE SELECTIVE EVOLUTIONARY HYPERHEURISTIC FOR LARGE SCALE ECONOMIC LOAD DISPATCH PROBLEM

***Digest of paper*[1]**

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Abstract: The economic load dispatch (ELD) problem is known as a hard optimization problem in the field of power system planning and control. Evolutionary algorithms (EAs) have demonstrated high performance in solving ELD problems with the number of power generator up to 40, but they lose their efficiency with high dimensionalities. In this study, we have proposed and have estimated the performance of a selective hyperheuristic for the online synthesis of an optimization algorithm based on large-scale optimization approaches. In the paper, the experimental results for benchmark problems and a real-world ELD problem are presented and discussed.

Key words: large scale global optimization, evolutionary algorithms, hyperheuristics, ELD problem.

1. INTRODUCTION

ELD is an important task in the field of power system planning and control. The ELD problem can be stated as an optimization problem, where the objective is to minimize the total cost of generating energy by many distributed units (generators). The existed ELD models are too complex for comprehensive analysis, thus the ELD optimization problem can be viewed as a “black-box” (BB) optimization problem. Evolutionary and other nature-inspired techniques have been applied for solving ELD problems. The standard EAs lose their efficiency for ELD optimization problems with

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[1] The full paper is proposed for including in the IEEE Xplore Digital Library

more than 100 units. Hard BB global optimization problems with many objective variables (usually many hundreds or thousands) are called large-scale global optimization (LSGO) problems.

In the study, we have proposed a new selective hyperheuristic for the online synthesis of an optimization algorithm for solving the real-world ELD problem with 140 generating units. The hyperheuristic selects and combines basic LSGO heuristics for grouping variables into the problem subcomponents of smaller size. The approach has demonstrated the high performance and has outperformed some previously obtained results.

2. THE PROPOSED APPROACH

We will solve the optimization problem proposed and formalized in [1]. The model contains a nonlinear objective function and a set of constraints for balancing total system generation and total system loads and losses, for limiting the power output for generators, for modeling ramp rate limits, and for presenting physical limitations by setting prohibited operating zones. In the study, we have chosen the 140 generators real-world ELD problem. All data for evaluating the model are taken from [2].

A novel hyperheuristic approach is proposed for solving the ELD optimization problem (denoted as HH-LSGO). We have chosen the following set of basic LSGO heuristics [3]: random dynamic grouping, differential grouping, delta grouping. We have also included in the set two advanced approaches: a combination of the estimation of distribution algorithm and the genetic algorithm (EDA-GA) [4] and the adaptive variable-size random grouping algorithm (AVS-RG) [5]. Each basic heuristic uses its own variables grouping and cooperative coevolution is applied for each decomposition independently. The proposed hyperheuristic is based on the island model concept, in which every island run an EA with one of the basic heuristics. Online selection of heuristics is done by evaluating the performance of each island and increasing the population size of the most efficient island.

LSGO problems are usually computationally costly. One of the benefits of applying the proposing method is the capability of the method parallelization.

First, we will estimate the performance of the proposed hyperheuristic using the IEEE CEC LSGO 2013 benchmark. All settings for HH-LSGO are the same as in the rules of the IEEE CEC competition on LSGO. We have also compared the experiential results with some state-of-the-art LSGO methods. Next, we will apply HH-LSGO for solving the real-world ELD problem. We have estimated the mean, best, and worst objective function values obtained over 25 independent runs. The maximum number of function evaluations in the run is 150000. HH-LSGO uses 5 islands, total population (sum of populations from all island) is 250, the adaptation period is 50 generations.

3. THE EXPERIMENTAL RESULTS

3.1. Benchmark problems

First, we have estimated the performance of HH-LSGO and each of basic heuristics on the benchmark. The proposed approach outperforms its component heuristics. Thus, HH-LSGO is able to efficiently select and combine basic heuristics during the optimization process.

We have also compared the results of applying HH-LSGO on the benchmark problems with some state-of-the-art techniques, including Covariance Matrix Adaptation Evolution Strategy Using Cooperative Coevolution (CC-CMA-ES), Surrogate Model Assisted Cooperative Coevolution (SACC), Multiple Offspring Sampling (MOS), Variable Mesh Optimization Differential Evolution (VMO-DE), Multilevel Cooperative Coevolution (MLCC), Cooperative Coevolution Particle Swarm Algorithm (CCPSO2) and Cooperative Coevolution of Differential Evolution with Random Grouping (DECC-G).

There are some methods that outperform HH-LSGO, but their performance may vary for different problems. For BB optimization problem, a researcher is not able to choose an efficient algorithm for the given problem beforehand. Thus, we have compared the performance of HH-LSGO with the performance of the random choice from the list of state-of-the-art algorithms. The performance of the random choice can be estimated by the average by all algorithms. The results have shown that HH-LSGO outperforms the random choice on 12 from 15 problems. Thus we can conclude that the propose HH-LSGO is more preferable for random and ill-studied BB problems.

3.2. Real-world ELD problem

We have run HH-LSGO for 25 times for collecting some statistical data on its performance. The variance in the results is not too large, the results are stable. We have applied the visual analysis of the distribution of population sizes over islands to see how the hyperheuristic selects different LSGO approaches. There is no heuristic that is the most preferable on each adaptation period.

Finally, we have compared the results with some previously obtained results by Genetic Algorithm with Multi-parent Crossover (GA-MPC) [6] and Self-Adaptive Multi-Operator Differential Evolution (SAMODE) [7]. The results of the comparison by the best-found and the average solutions are presented in Table 1. GA-MPC and SAMODE outperform HH-LSGO by the best-found solution in 25 runs, but HH-LSGO is better in the average value.

Table 1. The Experimental Results on the ELD Problems

	GA-MPC	*SAMODE*	*HH-LSGO*
Best-found	*1920263.30*	*1919252.50*	*1922300.12*
Average	*1953321.70*	*1977088.30*	*1932151.59*

As we can see from Table 1, GA-MPC and SAMODE outperform HH-LSGO by the best-found solution in 25 runs, but HH-LSGO is better in the average value. Thus, HH-LSGO is able to provide more stable results in a single run.

5. CONCLUSION

In this study, we have proposed a new approach for solving a hard ELD optimization problem. The proposed approach can efficiently deal with complex BB LSGO problems. The experimental results on the LSGO benchmark and the real-world ELD optimization problem show that HH-LSGO outperforms some state-of-the-art techniques by the average performance, but may yield by the best-found in a random run.

According to the well-known NFL theorem, there exists the best algorithm for every specific optimization problem that will be not efficient for other problems. In a case of BB problems, we are not able to choose the best approach, thus applying a hyperheuristic that can synthesize an efficient optimization algorithm during the problem solving is more preferable.

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