A Hybrid Evolutionary Programming Technique with Applications to Electric Power Generation System

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1. Introduction

Several heuristic techniques have been applied to solve optimization problems that were previously difficult or impossible to solve. These techniques include Genetic Algorithm (GA), Evolutionary Programming (EP), Simulated Annealing (SA), Tabu search, Particle Swarm etc. These methods have been given much attention by many researchers due to their ability to seek for the near global optimal solution. Moreover, they use just only objective function information to find the solution. Therefore, they can be applied to solve a complex problem, which lacks gradient information. Recently, these new heuristic tools have been combined among themselves as well as with more traditional approaches to solve extremely challenging problem. These combined methods provide the major advantage that a better solution can be obtained within shorter time. This paper presents two applications of the hybrid EP techniques to an electric power generation system. Firstly, a hybrid method between EP and Sequential Quadratic Programming (SQ) is applied to solve the Dynamic Economic Dispatch (DED) problem. This method employs the property of EP, which can provide a near global search region at the beginning, then the local search SQP is applied to find the final optimal solution. Secondly, a combined method between EP and Lagrange Relaxation (LR) method is applied to the Unit Commitment (UC) problem. This method uses the advantage of LR, which can solve a mix-integer optimization problem within a short time, combines with EP, which can provide a near global solution. With this method, a high quality solution can be obtained within a reasonable time.

2. A Hybrid EP and SQP for Dynamic Economic Dispatch problem

The DED is a problem to schedule the online generator outputs with the predicted load demands over a certain period of time so as to operate an electric power system most economically. This problem can be formulated as follows:
The objective function:

$$Min \quad F=\sum_{t=1}^{T}\sum_{i=1}^{n}F_{it}(P_{it})$$

Constraints:

$$\sum_{i=1}^{N}P_{it}-P_{Dt}=0 \quad , \quad t=1,\ldots,T$$

$$P_{i\min}\le P_i\le P_{i\max} \quad , \quad i=1,\ldots,N$$

$$P_{it}-P_{i(t-1)}\le UR_i \quad , \quad i=1,\ldots,N$$

$$P_{i(t-1)}-P_{it}\le DR_i \quad , \quad i=1,\ldots,N$$

Where P_{it} is the power output of unit i at time t, F is the fuel cost function, N is the number of units, T is the number of hours in the time horizon, P_{Dt} is the demand at time t, $P_{i\min}$ and $P_{i\max}$ are the minimum and maximum power outputs of unit i respectively, UR_i and DR_i are the ramp-up and ramp-down rate limits of unit i respectively.

Although EP can provide a high quality solution, it takes long computation time. On the other hand, a gradient-based method can provide a faster solution but the solution obtained from this method is just a local optimum. To obtain an optimal solution within a short time, a two parts method has been proposed in this paper. In the first part, EP is applied to avoid getting stuck in the local optimum. Then SQP is applied in the second part using the solution from EP as a starting point to climbs the hill and gets the final optimal solution. Ten-unit test system [1] is simulated and comparison of results is shown in Table 1.

Table 1. Comparison of simulation results

Method	Cost ($)	Time (min)
SQP	1051163	1.19
EP	1048638	42.49
Hybrid	1035748	20.51

3. Unit Commitment using EP combines with LR method

The UC is a problem to determine generating units to be in service (on/off) economically during each interval of the schedule periods to meet system demand and reserve requirement. The purpose of UC is to minimize the cost of operation subject to attainment of a certain level of security and reliability. It is a mix-integer optimization problem and can be formulated as follows:
The objective function:

$$Min \quad TC(X_{ih}, P_{ih}) = \sum_{h=1}^{H}\sum_{i=1}^{N}[F_i(P_{ih}) + ST_i(1 - X_{i(h-1)})] \cdot X_{ih}$$

Constraints:

$$\sum_{i=1}^{N} P_{ih}X_{ih} - D_h = 0 \quad , \quad h = 1,\ldots,H$$

$$\sum_{i=1}^{N} P_{i\max}X_{ih} - D_h - R_h \geq 0 \quad , \quad h = 1,\ldots,H$$

$$P_{i\min} \leq P_i \leq P_{i\max} \quad , \quad i = 1,\ldots,N$$

and minimum up and down constraints.
P_{ih} is the power output of unit i at hour h, X_{ih} is the on/off status of unit i at hour h, ST is the start up cost, F is fuel cost function, TC is the total production cost, N is the number of units, H is the number of hours, D_h is the demand at hour h, R_h is the spinning reserve at hour h, $P_{i\min}$ and $P_{i\max}$ are the minimum and maximum power output of unit i respectively.

Since UC was introduced, several optimization techniques have been applied to solve this problem. Among these methods, LR method seems to be the most suitable one. The LR method solves a mix-integer optimization problem by relaxing or ignoring the coupling constraints, then solving the problem through a dual optimization procedure. This method provides a fast solution but sometime it suffers from numerical convergence problem especially when the problem is non-convex. Besides, this method strongly depends on the technique used to update Lagrange multipliers. Most of researches dealing with LR use gradient method to achieve this task. However, solution obtained from gradient-based method suffers from convergence problem and always get stuck into a local optimum. On the other hand, EP can provide a near global solution but take long time to compute. To get a high quality solution within a reasonable time, a combined method between EP and LR are proposed here. The proposed algorithm is developed in such a way that an EP is used to update Lagrange multipliers in order to overcome the convergence problem and improve performance of the LR method. Simulation result is shown in Table 2 compared with those obtained from other methods [2]

Table 2. Simulation results

Method	Cost ($)
LR	565825
GA	565825
EP	564551
Proposed method	564049

4. References

[1] P. Attaviriyanupap, H. Kita, E. Tanaka and J. Hasegawa, "A Hybrid EP and SQP for Dynamic Economic Dispatch with Non-Smooth Fuel Cost Function", to be published in IEEE Trans. Power Systems.

[2] P. Attaviriyanupap, H. Kita, E. Tanaka and J. Hasegawa, "A Hybrid Evolutionary Programming for Solving Thermal Unit Commitment Problem", in 12th Annual Conference of Power & Energy Society, IEE of Japan.