Expert Systems with Applications 37 (2010) 3352–3357

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Optimal gamma based fixed head hydrothermal scheduling using genetic algorithm

J. Sasikala [a,*], M. Ramaswamy [b]

[a] Computer Science and Engineering, Annamalai University, Annamalainagar, Tamil Nadu 608 002, India
[b] Electrical Engineering, Annamalai University, Annamalainagar, Tamil Nadu 608 002, India

ARTICLE INFO

Keywords:
Genetic algorithm
Hydrothermal scheduling

ABSTRACT

The short-term hydrothermal scheduling is a daily planning proposition in power system operation, a task which is usually more complex than the scheduling of all-thermal generation system. The traditional methods have become inadequate to handle large scheduling problems and tend to be ineffective in terms of their computational speed, robustness and accuracy. Alternative strategies have thus become an imminent necessity and intelligent techniques appear to suit the complex scheduling problems. This paper presents a novel optimal gamma based scheduling algorithm for fixed head hydrothermal problems using genetic algorithm. It includes the simulation results of four test cases with a view to highlight its superior performance and suitability for easy implementation, irrespective of the problem size.

1. Introduction

Hydrothermal scheduling (HTS) plays an important role in maintaining a high degree of economy and reliability in power system operational planning. It is mainly concerned with both hydro unit scheduling and thermal unit dispatching, and rather difficult than the scheduling of all-thermal system. However due to insignificant operating cost of hydro plants, the scheduling problem essentially reduces to minimizing the fuel cost of thermal plants constrained by generation limits, available water and the energy balance equivalence over a scheduling horizon. It is basically a non-linear programming problem involving a non-linear objective function and a mixture of linear and non-linear constraints (Wood & Woolenberg, 1996).

It is accomplished by hierarchical chains of long, mid and short-range models. Mid/long-range models are concerned with optimal hydrothermal co-ordination for one or more years on a weekly or monthly basis. The final output is the amount of water to be discharged at each hydroelectric plant throughout the coming week. Short-range operational planning, on the other hand, is concerned with distributing the generation among the available units over a day or week, usually on an hourly basis, satisfying the operational constraints, as well as reservoir release targets determined by mid/long-range planning models. In short-range scheduling problem, fixed water head is assumed frequently and the net head variation can be ignored for relatively large reservoirs, in which case the power generation is solely dependent on the water discharge (Basu, 2003, 2005; El-Hawary & Landrigan, 1982; Farid Zaghlool & Trutt, 1988; Rashid & Nor, 1991).

The short-range HTS problem has been the subject of intensive research work during the past few decades. Several researchers have suggested many methods such as dynamic programming (Yang & Chen, 1989), network flow programming (Heredia & Nabona, 1995), mixed integer programming (Chang et al., 2001) and Lagrangian relaxation (Salam, Nor, & Hamdan, 1998) to solve this difficult optimisation problem. Dynamic programming among these approaches has been found to tackle the complex constraints directly but suffers from the curse of dimensionality. The other methods have necessitated simplifications in order to easily solve the original model, which may lead to sub-optimal solutions with a great loss of revenue.

In recent years, heuristic optimisation techniques have aroused intense interest due to their flexibility, versatility and robustness in seeking global optimal solution. These evolutionary approaches such as genetic algorithms (Chang & Chen, 1998; Kumar & Naresh, 2007; Orero & Irving, 1998; Wong & Wong, 1996; Wu, Ho, & Wang, 2000), simulated annealing (Basu, 2005), evolutionary strategy (Lakshmnarasimman & Subramanian, 2008; Mandal & Chakraborty, 2008; Sinha, Chakrabarti, & Chattopadhyay, 2003), particle swarm optimisation (Mandal, Basu, & Chakraborty, 2008; Yu, Yuan, & Wang, 2007) and peak shaving (Simopoulos, Kavatza, & Vournas, 2007) involve large number of problem variables, which not only depend on the number of generating plants but also the number of intervals considered in the planning horizon and thus are highly ineffective. Therefore, a genetic algorithm (GA) based efficient approach that involves minimum number of GA variables, which are independent of the number of intervals in the scheduling period, is developed for fixed head HTS in this paper and the results are presented.

* Corresponding author. Tel.: +91 4144 237360.
E-mail address: sasikala_07@rediffmail.com (J. Sasikala).

0957-4174/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2009.10.015

Nomenclature

GA	genetic algorithm
HTS	hydrothermal scheduling
CLGM	classical lambda gamma iterative method
EGA	existing GA based HTS
L	number of binary bits in the sub-string
B	loss coefficients
HP	hydel plant
TP	thermal plant
NET	normalised execution time
PS	population size
PM	proposed method
FIT_i	fitness function of *i*th chromosome
ng	number of generating plants
nt	number of thermal plants
nh	number of hydro plants
$K_{\max}$	number of intervals
$a_i b_i c_i$	cost coefficients of *i*th thermal plant
$d_i e_i f_i$	water discharge rate coefficients of *i*th hydro plant
D_i	equivalent decimal value of *i*th sub-string
t_k	duration of interval-*k*
P_{Tik}	generation at *i*th thermal plant at interval-k
P_{Hik}	generation at *i*th hydro plant at interval-*k*
$P_{T_i}^{\min}$ and $P_{T_i}^{\max}$	minimum and maximum power limits of *i*th thermal plant respectively
$P_{H_i}^{\min}$ and $P_{H_i}^{\max}$	minimum and maximum power limits of *i*th hydro plant respectively
P_{Dk}	total power demand at interval-*k*
P_{Lk}	system losses at interval-*k*
V_i^{avl}	available water for *i*th hydro plant over the scheduling period
$F_{ik}(P_{Tik})$	fuel cost function of *i*th thermal plant at interval-k
$Y_{ik}(P_{Hik})$	water discharge rate of *i*th hydro plant at interval-*k*
Φ	objective function to be minimized
Φ_T	augmented objective function to be minimized
γ_i	fictitious cost of water at *i*th hydro plant
$\gamma_i^{\min}$ and $\gamma_i^{\max}$	minimum and maximum values of γ_i respectively
λ_k	incremental cost of received power at interval-*k*

2. Problem formulation

The main objective of HTS problem is to determine of the optimal schedule of both hydro and thermal plants of a power system in order to minimize the total system operating cost, represented by the fuel cost required for the system's thermal generation. It is intended to meet the forecasted load demand over the scheduling period, while satisfying various system and unit constraints. The HTS problem is formulated as

$$\text{Minimize} \quad \Phi = \sum_{k=1}^{k\max} \sum_{i=1}^{nt} t_k \cdot F_{ik}(P_{Tik}) \tag{1}$$

subject to the power balance constraint

$$\sum_{i=1}^{nt} P_{Tik} + \sum_{j=1}^{nh} P_{Hjk} - P_{Dk} - P_{Lk} = 0; \quad k = 1,\ 2,\ \ldots,\ K_{\max} \tag{2}$$

and to the water availability constraint

$$\sum_{k=1}^{K\max} t_k \cdot Y_{ik}(P_{H_{ik}}) = V_i^{avl}; \quad i = 1,2,3,\ldots,nh \tag{3}$$

with

$$\begin{aligned} P_{T_i}^{\min} &\le P_{T_{ik}} \le P_{T_i}^{\max}; \quad i = 1,2,\ldots,nt \\ P_{H_i}^{\min} &\le P_{H_{ik}} \le P_{H_i}^{max}; \quad i = 1,2,\ldots,nh \end{aligned} \tag{4}$$

where

$$F_{ik}(P_{Tik}) = a_i \cdot P_{Tik}^2 + b_i \cdot P_{Tik} + c_i \quad \$/\text{h} \tag{5}$$

$$Y_{ik}(P_{Hik}) = d_i \cdot P_{Hik}^2 + e_i \cdot P_{Hik} + f_i \quad \text{m}^3/\text{h} \tag{6}$$

2.1. Classical $\lambda - \gamma$ iteration method (Wood & Woolenberg, 1996)

The augmented lagrangian function for the HTS problem can be written as

$$\Phi_T = \sum_{k=1}^{k\max}\left[\sum_{i=1}^{nt} t_k \cdot F_{ik}(P_{Tik}) - \lambda_k\left(\sum_{i=1}^{nt} P_{Tik} + \sum_{j=1}^{nh} P_{Hjk} - P_{Dk} - P_{Lk}\right)\right] + \sum_{i=1}^{nh}\gamma_i\left[\sum_{k=1}^{K\max} t_k \cdot Y_{ik}(P_{H_{ik}}) - V_i^{avl}\right] \tag{7}$$

The co-ordination equation from the above function can be obtained as

$$t_k \cdot \frac{dF_{ik}(P_{Tik})}{dP_{Tik}} + \lambda_k \frac{dP_{Lk}}{dP_{Tik}} = \lambda_k \tag{8}$$

$$\gamma_i \cdot t_k \cdot \frac{dY_{ik}(P_{Hik})}{dP_{Hik}} + \lambda_k \frac{dP_{Lk}}{dP_{Hik}} = \lambda_k \tag{9}$$

The above co-ordination equations along with constraint Eqs. (2)–(4) can be iteratively solved to obtain optimal HTS.

3. Proposed methodology

The GA is essentially a search process based on the mechanics of natural selection and natural genetics to obtain a global optimal solution of a combinatorial optimisation problem. The power of this algorithm accrues from its ability to exploit historical information structures from the previous solution guesses in an attempt to enhance the performance of future solution structures (Goldberg, 2000).

The execution of GA involves initialisation of population of chromosomes and generation of new chromosomes based on fitness values. The process of generation of new chromosomes and the selection of those with better fitness values are continued until the desired conditions are satisfied. The process can be terminated after a fixed number of generations or when any significant improvement in the solution ceases to occur.

In the existing GA based HTS approaches (EGA), each chromosome consists of generation of both thermal and hydel generating plants at all intervals of the scheduling horizon (Chang and Chen, 1998; Wong and Wong, 1996). These methods involve a large number of GA variables, which is the product of the number of generating plants and the number of intervals over the scheduling