



Profit based unit commitment for GENCOs using parallel NACO in a distributed cluster

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ABSTRACT

Deregulation process has created an intense competition with the participation of many generating companies (GENCOs) in a power market. Wholesale transactions (bids and offer) have to be cleared and settled in a shorter duration. Therefore, this necessitates for the system operator to quick and smarter decisions. In this problem formulation, profit based unit commitment (PBUC) problem aims in maximizing the profit of GENCOs. However demand satisfaction is not an obligation. Here, parallel nodal ant colony optimization (PNACO) approach mimicking ant's intelligence is used in the decision on committing generating units. The sub problem economic dispatch (ED) is carried out using parallel artificial bee colony (PABC) approach mimicking foraging behavior of bees. Profit based unit commitment (PBUC) must be obtained in less time even though there is a possible increase in generating units. Nowadays, as computing resources are available in plenty, effective utilization will be advantageous for reducing the time complexity for a large scale power system solution. The proposed approach uses a cluster of computers performing parallel operations in a distributed environment for obtaining the PBUC solution. The time complexity and the solution quality with respect to the number of processors in the cluster are thoroughly investigated. The effectiveness of the proposed approach for PBUC is first validated on a standard 10 unit system available in the literature and then analysis for computational efficiency using 1000 generating units, which is a duplicate form of standard 10 unit system.

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1. Introduction

In the deregulated electricity power market, optimal economic operation and planning of electric power generation has always occupied an important position. The traditional unit commitment problem (UCP) generally focuses on committing the ON/OFF status of the generating units and optimally allocates the generation of power for the ON generating units [1,2]. The optimal allocation is obtained by solving the economic dispatch (ED) problem, which can be categorized as a sub problem of the UCP. This operation is to minimize total generation cost in a specified time zone (usually 24 h) [3,4]. However, the profit based unit commitment (PBUC) problem is generally solved by the GENCOs in a deregulated power market. The operation involves maximizing solely the GENCOs profit, where demand satisfaction is not an obligation.

In deregulated markets, generation companies (GENCOs) are usually entities owning generation resources and participating in the market without concern of the system unless there is an

incentive for it. Hence, GENCOs consider generation planning for a period of, say 24 h in advance, based on the price forecast, generation unit characteristics, unit availability etc., and thereby determine the bidding strategy for each bidding period of the next day. To excel in the competition, GENCOs will acquire additional generating units with flexible operating capability which allows a timely response to the continuous changes in power system conditions. In the deregulated market, independent system operator (ISO) forecasts the demand and the price for the next day/hour. The GENCOs will send its bidding to the ISO, depending upon the demand and its generator coefficients. The ISO will accept and select the bidder whose price is less than or equal to its forecasted price. If the bidder's price is more than the forecasted one, then ISO will fix the forecasted price as the market clearing price (MCP). If any of the GENCOs fix the price below the forecasted price, the ISO will fix the lowest price as MCP.

1.1. Literature survey for solution techniques

The profit based unit commitment (PBUC) problem is a mixed integer and continuous nonlinear optimization problem, which is very complex to solve because of its enormous dimensions, nonlinearity and large number of constraints. Eric H. Allen first

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Nomenclature

AvgP	average of maximum profit (\$) obtained in 10 simulations	TC	total cost (\$)
D_t	total system demand at time t	W	processor or worker
E	all states that are eligible at time t	W_h	number of processors in cluster
EW_h	efficiency of a cluster	W_t	execution time of one processor
fit_p	fitness value of the solution p	W_{ht}	execution time of a cluster
L_{gb}	maximum total profit incurred till the current tour	$X^{on}(i,t)$	“on” duration of i th generator unit till time t
N	total number of generating units	$X^{off}(i,t)$	“off” duration of i th generator unit till time t
n	number of units in each node	x_{qmin} and x_{qmax}	the minimum and maximum limits of the parameter to be optimized.
i	index for generator unit	C_i	production cost (\$) $C_i(P_{(i,t)}) = a + b \times P_{(i,t)} + c \times P_{(i,t)}^2$
N_{ants}	total number of ants	a	cost co-efficient of i th generator unit (\$/h)
N_e	number of food sources which is equal to the number of employed bees n_e	b	cost co-efficient of i th generator unit (\$/MW h)
$P_{(i,t)}$	power level of i th generator unit at t th hour (MW)	c	cost co-efficient of i th generator unit(\$/MW ² h)
$I_{(i,t)}$	commitment state of i th unit at t th hour	A	relative importance pheromone trail intensity
maxiter	maximum number of iterations	B	relative importance of heuristic function
$P_{i,min}$	minimum power output of i th generator unit (MW)	C	constant
$P_{i,max}$	maximum power output of i th generator unit (MW)	ρ	evaporation factor
PF	total profit (\$)	σ_g	forecasted market price for energy at time t
$Pr_{rs}^k(st)$	transition probability of k th ant from state r to s	σ_n	forecasted market price for non-spinning reserve at time t
RV	total revenue (\$)	σ_r	forecasted market price for spinning reserve at time t
ST_t	startup cost (\$)	$\tau_{rs}(st)$	pheromone trail intensity of state (st) r to s
SW_h	speedup factor for a cluster	η_{rs}	(st) Heuristic function of state (st) r to s
TS	total number of states	$\Delta\tau_{rs}$	change in pheromone deposition
t	index for time	ϕ_{pq}	random number between $[-1, 1]$
$T^{on}(i)$	minimum up-time of i th generator unit	LC	limit count
$T^{off}(i)$	minimum down-time of i th generator unit	HC_i	hot cost of the i th generator (\$/h)
T	dispatch period in hours	CC_i	cool cost of the i th generator (\$/h)
		T^{cold}	permissible cool hour of the i th generator (h)
		Ini-state	initial status of the i th generator

proposed the price based decision mechanism for GENCOs to schedule their reserve based on spot market power [5]. The Lagrange Relaxation method can provide a fast solution by properly adjusting the Lagrangian multiplier [6,7]. But if the problem is a non-convex, then it suffers from numerical convergence. In LR gradient method this problem is eliminated. However, the solution obtained from gradient-based method suffers from getting local optimum solutions. In order to overcome these complex mathematical problems, there are other methods of computational methodologies shared by popular intelligent systems such as genetic algorithm and evolutionary programming. Charles W. Richter et al. presented a PBUC formulation using genetic algorithm (GA) which considers the softer demand constraints and allocates fixed and transitional costs to the scheduled hours [8].

Pathom Attaviriyapap et al. proposed a Hybrid LR-EP to solve profit based unit commitment for scheduling both power and reserve simultaneously [9]. However, the reserve is scheduled based on reserve probability value. Here, evolutionary programming (EP) is used for the proper adjustment of lagrangian multiplier. H.Y. Yamin et al. proposed an auxiliary hybrid model using LR and GA to solve UC [10]. Here, GA is used to update the Lagrangian multiplier. T.A.A. Victoire et al. proposed Tabu-search based heuristic technique to solve PBUCP involving both energy and reserve schedule [11]. Here, for different values of reserve probability, the variations of energy and reserve schedules are observed in terms of profit. A mixed integer programming method which provided better solution than LR method is proposed by Tao Li and et al. [12]. This approach took higher computation time for convergence.

In [13], Chandram et al. proposed an Improved Pre-prepared Power Demand (IPPD) table and the Muller's method as a means

of solving the Profit Based Unit Commitment (PBUC) problem. Here, the PBUC problem is solved by the proposed approach in two stages. Initially, information concerning committed units is obtained by the IPPD table and then the sub problem of Economic Dispatch (ED) is solved using the Muller's method. In [14], variable neighborhood Tabu search parallel enhanced particle swarm optimization with island model (VTS-PEPSO) is used to solve the PBUC problem. Christopher et al. implemented parallel artificial bee colony algorithm (PABC) for solving PBUC problem using parallel computation [15]. Though the computational time taken has reduced, the accuracy of the solution could have been improved. They had also applied nodal ant colony optimization (NACO) for solving PBUC [16] and found that the convergence of getting near optimal solution is encouraging. However, the inherent limitation is the computation time. Therefore, considering the strength and weakness of ACO [16–21] and ABC [3,15,22–24], this paper focuses on suitably combining both ACO and ABC solving PBUC in the parallel environment. Here, ACO is used to get the discrete status of the generating units and ABC is used to solve economic dispatch sub problem producing the optimal dispatch of the committed generating units.

2. Proposed work

ACO is an intelligent optimization algorithm that searches the optimal solution mimicking real ants [17,18]. Existing literatures [16–21] prove ant colony optimization (ACO) techniques are found to be competent in solving combinatorial optimization problems. It is on this basis that ACO is suitable for PBUC which is also hard combinatorial in nature. An analogy can be drawn between ants finding the shortest path from source (nest) to its

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