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OPTIMIZATION TECHNIQUES FOR THE ECONOMIC DISPATCH PROBLEM IN VARIOUS GENERATION PLANT

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Abstract: The dynamic economic dispatch (DED) occupies important place in a power system's operation and control. It aims to determine the optimal power outputs of on-line generating units in order to meet the load demand and reducing the fuel cost. The nonlinear and non convex characteristics are more common in the DED problem. Therefore, obtaining a optimal solution presents a challenge. In the proposed system, firefly algorithm, Adaptive simulated annealing algorithm, artificial bee colony (ABC) algorithm – a recently introduced population-based technique – is utilized to solve the DED problem. A general formulation of this algorithm is presented together with an analytical mathematical modeling to solve this problem by a single equivalent objective function. The results are compared with those obtained by alternative techniques proposed by the literature in order to show that it is capable of yielding good optimal solutions with proper selection of control parameters.

Introduction

The economic dispatch of generation in power systems is one of the most important optimization problems. The fuel cost component is still the major part of the variable cost of electricity generation directly reflected in the electricity bills. Economic dispatch aims at allocating the electricity load demand to the committed generating units. To obtain the most economic schedule of generation taking into account a number of system limitations, such as the heat rate curves, generation limits or ramping limitations of the generating units, limitations of the transmission lines, or reliability preventive parameters of the system (e.g., the power reserve).Thus, the optimization problem may be stated as a minimization problem, when the objective is to minimize the total cost of supplying the load demand. The ultimate goal of power plants is to meet the required load demand with the lowest operating costs possible while taking into consideration practical equality and inequality constraints algorithms. Optimal operation of electric power system networks is a challenging real-world engineering problem. Those linked optimization problems are the unit commitment, optimal power flow, and economic dispatch scheduling. The recently introduced meta-heuristic methods are the artificial bee colony (ABC) algorithm, adapted simulated annealing algorithm (SA), firefly algorithm(FA). These are a population-based technique and inspired by the intelligent foraging behavior of the honeybee swarm, birds schooling, fish behavior. The DED problem was one of the real-world optimization problems that has benefited from the development of the meta-heuristic algorithms. An evolutionary programming (EP) technique [8] in and is adopted to solve the DED problem. Simulating annealing method (SA), quantum evolutionary algorithm (QEA), and Tabu search approach (TS) have been also designated to solve the DED problem in [12],[13], respectively.

Objective function

The objective function of the DED problem is to minimize the operating fuel's costs of committed generating units to meet the load demand, subject to equality and inequality constraints over a predetermined dispatch period, the result's practical usefulness will be degraded if the units'

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valve-point effects are neglected. Consequently, there are two models to represent the units' valve-point effects in the literature. The first represents the units' valve in terms of prohibited operating zones which are included as inequality constraints. The second form represents the units' valve-point effects as a rectified sinusoid term which is superimposed on the approximate quadratic fuel cost function.The general mathematical form of the DED problem follows:[1]

Minimization of fuel cost :

The problem of an Economic Load Dispatch (ELD) is to find the optimal combination of power generation, which minimizes the total fuel cost, under some constraints [14]. The ELD Problem can be, mathematically, formulated as the following optimization problem:

$$\text{Minimizes } F_{cost} = \sum_{i=1}^{n} (a_i + b_i P_{G_i} + c_i P_{G_i}^2) \tag{1}$$

PGi : the power generated by generator *i* (MW), and

n : the number of generators

Equality constraint:

Integration of a renewable source modifies the equality constraints function to be as follows

$$\sum_{t=1}^{T}\sum_{i=1}^{N} P_i^t = \sum_{t=1}^{T}\left(P_D^t + P_L^t - \sum_{RS=1}^{M} \mu_{RS} P_{RS}^t\right) \tag{2}$$

where p_D^t and p_L^t are the load demand and system's loss at a time *t* respectively. The multiplier μRS is set to a permissible amount of active power injected by *RS*, *PRS.* is the forecasted real power from RS

Inequality Constraint:

The inequality constraints of the DED problem are the units' ramp-rate limits, i.e., upper rate (UR_i) and down rate (*DRi*), are considered as follows:.

$$P_i^t - P_i^{t-1} \le UR_i$$

$$P_i^{t-1} - P_i^t \le DR_i \tag{3}$$

Additional inequality constraints are the minimum and maximum power output of each unit:

$$P_{i,min} \le P_i \le P_{i,max} \tag{4}$$

Firefly algorithm

The development of FA is based on flashing behavior of fireflies.There are about two thousand firefly species where the flashes often unique for a particular species. The flashing light is produced by a process of bioluminescence where the exact functions of such signaling systems are still on debating. Nevertheless, two fundamental functions of such flashes are to attract mating partners (communication) and to attract potential prey. For simplicity, the following three ideal rules are introduced in FA development [7]: 1) all fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex, 2) attractiveness is proportional to their brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one, 3) the brightness of a firefly is affected by the landscape of the objective function. For maximization problem, the brightness can simply be proportional to the value of the objective or fitness function.

Artificial bee colony

In the ABC model, the colony consists of three groups of bees: employed bees, onlookers and scouts. It is assumed that there is onl one artificial employed bee for each food source. In other words, the number of employed bees in the colony is equal to the number of food sources around the hive. Employed bees go to their food source and come back to hive and dance on this area. The

employed bee whose food source has been abandoned becomes a scout and starts to search for finding a new food source. Onlookers watch the dances of employed bees and choose food sources depending on dances.

It is clear that the ABC algorithm has the following control parameters: 1) the *CS* that onlooker bees (*Ob*), 2) the *limit* value, which is the number of trials for a food-source position to be abandoned, and 3) the maximum cycle number (*MCN*.) Although the ABC algorithm has three parameters to be tuned, once the *CS* parameter has been determined by the practitioner, the *limit* value can be calculated easily as half of the *CS* multiplied by the problem's dimension. Therefore, technically speaking, the ABC algorithm has only two parameters to be adjusted: *CS* and the *MCN* values. Updating these two parameters towards the most effective values has a higher likelihood of success than in other competing meta-heuristic methods.

ABC algorithm

1. Initialize the population.
2. Modify positions.
3. Apply selection criterion.
4. Repeat (cycle.)
5. Allow the employed bees to share the food information with onlooker bees.
6. Allow the onlooker bees to choose the best food source based on the probability calculation.
7. Apply selection criterion.
8. Check for an abundant solution, and (if exists) initiate a new food-source position. Otherwise, follow the next step.
9. Retain best solution so far.
10. Until stopping rule.

Simulated Annealing Method

Simulated Annealing (SA) is a stochastic optimization technique which is based on the principles of statistical engineering. The search for a global minimum of a multidimensional cost function is a quite complex problem especially when a big number of local minimums correspond to the respective function. Following its introduction from Kirkpatrick et al [8], simulated annealing is mainly applied to large-scale combinatorial optimization problems.

The process of annealing in Thermodynamics

At high temperatures, the metal is in liquid phase. The molecules of liquidated metal, move freely with respect to each other. By gradually cooling (thermodynamic process of annealing) thermal mobility is lost. The atoms start to get arranged and finally form crystals, having the minimum energy which depends on the cooling rate. If the temperature is reduced at a very fast rate, the crystalline state transforms to an amorphous structure, a meta-stable state that corresponds to a local minimum of energy.

To conclude, the main point of the process is slow cooling, that leads to a crystallized solid state, which is a stable state, corresponding to a minimum energy. There are similarities between the thermodynamic simulation annealing process and a combinatorial optimization problem.

The annealing process of metal influences SA algorithm.

If the system is at a thermal balance for given temperature T, then the probability $P_T(s)$ that it has a configuration s depends on the energy of the corresponding configuration $E(s)$, and is subject to the Boltzmann distribution:

$$P_T(s) = \frac{e^{-E(s)/\kappa T}}{\sum_W e^{-E(w)/\kappa T}} \tag{6}$$

Where κ is the Boltzmann constant and the sum Σ_W includes all possible states W.

Metropolis et al [9] were the first to suggest a method for calculating a distribution of a system of elementary particles (molecules) at the thermal balance state.

Let's suppose that the system has a configuration *g*, which corresponds to energy *E(g)*. When one of the molecules of the system is displaced from its starting position, a new state σ occurs which corresponds to energy *E(σ)*. The new configuration is compared with the old one. If $E(\sigma) \leq E(g)$, then the new state is accepted. If $E(\sigma) > E(g)$, then the new state is accepted with probability :

$$e^{-(E(\sigma)-E(g))/\kappa T} \tag{7}$$

Here κ is the Boltzmann constant.

Simulation result

The six unit generating units considered are having different characteristic. Their cost function characteristics are given by following equations.

Table1: Fuel Cost Coefficient For 6 Unit System (ABC ALGORITHM)

Fuel cost function	a(p^2)	b(p)	c(Rs/hr)	p_{min}(MW)	p_{max}(MW)
F1	0.1524	38.539	756	10	125
F2	0.1058	46.159	451	10	150
F3	0.0280	40.396	1049	35	225
F4	0.0354	38.305	1243.	35	210
F5	0.0211	36.327	1658	130	325
F6	0.0179	38.270	1356	125	315

The B_{mn} loss coefficient matrix is given by

0.17	1.4	0.15	0.19	0.26	0.22
0.6	0.17	0.13	0.16	0.15	0.20
0.13	0.15	0.65	0.17	0.24	0.19
0.16	0.19	0.17	0.71	0.30	0.25
0.15	0.26	0.24	0.30	0.64	0.32
0.20	0.22	0.19	0.25	0.32	0.85

This is the example we have taken for the testing this novel coding scheme on the six unit system.
Simulation Result – Solution of ED Problem(using ABC algorithm)

The solution of ED problem of the six unit system considered here is given below.the total demand taken here is about 700 MW.Power demand=700MW

Table 2: Simulation Result For 6 Unit System(700 MW)

S. no	Algo-Rithm	P1	P2	P3	P4	P5	P6	Total power	Fuel cost
1	FA	30.26	20	120.78	125.74	225.69	256.48	778.97	3.4569E+004*
2	ABC	28.29	10	118.96	118.68	230.75	212.73	719.43	3.6912E+004
3	SA	27.62	9.6	98.58	125.36	225.78	230.06	717.00	3.9545E+004

*- Lowest Cost Of FA Compare Than Other Methods

The ten unit generating units considered are having different characteristic. Their cost function characteristics are given by following equations.

TABLE 3:FUEL COST COEFFICIENT FOR 10 UNIT SYSTEM(PD=1200MW)

Fuel cost	$a(p^2)$	b(p)	c(Rs/hr)	p_{min}(MW)	p_{max}(MW)
F1	0.0051	2.2034	15	12	73
F2	0.0040	1.9104	25	26	93
F3	0.0039	1.8518	40	42	143
F4	0.0038	1.6966	32	18	700
F5	0.0021	1.8015	29	30	93
F6	0.0026	1.5354	72	100	350
F7	0.0029	1.2643	49	100	248
F8	0.0015	1.2130	82	40	190
F9	0.0013	1.1954	105	70	590
F10	0.0014	1.1285	1000	40	113

Simulation Result – Solution of ED Problem (using firefly algorithm) POWER DEMAND=1200 MW

TABLE4: Result For 10 Unit System (PD=1200 MW)

S .no	Algorithm	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total power	Fuel cost
1	FA	79.6	86.7	89.8	96.3	107.2	119.0	139.1	142.5	152.8	163.7	1176.7	1.59E+ 004

Comparison between ABC and firefly algorithm

TABLE5: Comparison Result

S.No	UNIT	POWER DEMAND(MW)	ALGORITHM	FUEL COST(RS/HR)	TOTAL POWER(MW)
1	3	300	FA	1.32E+004	329
			ABC	1.57E+004	325
2	6	700	FA	3.2153E+004	725.8721
			ABC	3.6912E+004	719.4354
3	10	1200	FA	1.59945E+004	1176.7
			ABC	1.9624E+004	1021.9

Conclusion

This project presents a new approach to the solution of ED using ABC and firefly has been proposed. Through the proposed coding scheme, constraints of ED problems can be effectively released during the search process, therefore, the solution quality, as well as the calculation time, is greatly improved. The proposed approach has been demonstrated by six unit system and proven. including high quality solutions, stable convergence characteristics, and good computational efficiency. By comparing results, the fuel cost and calculation time for firefly algorithm is better than ABC. The encouraging simulation results showed that the proposed method is capable of obtaining more efficient, higher quality solutions for ED problems.

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