A Hybrid Method of BGA and TS for Economic Dispatch of Power Systems

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Abstract: *A Genetic Algorithm (GA) solution to the Network - Constrained Economic Dispatch problem is presented. A hybrid method of the binary genetic algorithm and Tabu Search (TSBGA) for economic dispatch has been implemented to minimize the dispatch cost while satisfying generating unit and branch power flow limits. A real coded Genetic Algorithm (RGA), a binary genetic algorithm (BGA) and Tabu Search (TS) were also developed to provide a means of comparison.*
Numerical results on two test systems consisting of 6 thermal units show that the proposed approach has an ability to find the better solutions than the BGA, the RGA and the TS separately

Keywords: *Economic power dispatch (EPD), Genetic algorithm (GA), Tabu search (TS).*

1. INTRODUCTION

The basic purpose of the economic dispatch function is to schedule the outputs of the online fossil-fuel generating units so to meet the system loast cost. The annual fossil-fuel costs are of the order of several billions of dollars and even a small improvement in the economic dispatch function can lead to significant cost savings.

The factors influencing power generation at minimum cost are operating efficiencies of generators, fuel cost, and transmission losses. The most efficient generator in the system does not guarantee minimum cost as it may be located in an area where fuel cost is high also, if the plant is located far from the load center, transmission losses may be considerably higher and hence the plant may be overly uneconomical. Hence the problem is to determine the generation of different plants such that the total operating cost is minimum.

In analyzing the problem associated with the controlled operation of power systems, there are many possible parameters of interest. Fundamental to the economic operating problem is the set of input-output characteristics of thermal power generation unit. In defining the characteristics of steam turbine units, the following term will be used.

The input to the thermal plant is generally measured in $/h, and the output is measured in MW. A simplified input-output curve of a thermal unit known as heat-rate curve is given in Fig.1.

The input to each unit, shown as Fi, represents the cost rate of the unit. The output of unit P_{Gi} is the electrical power generated by that particular unit. The total cost rate of this system is, of course, the sum of the heats of the individual units (2).

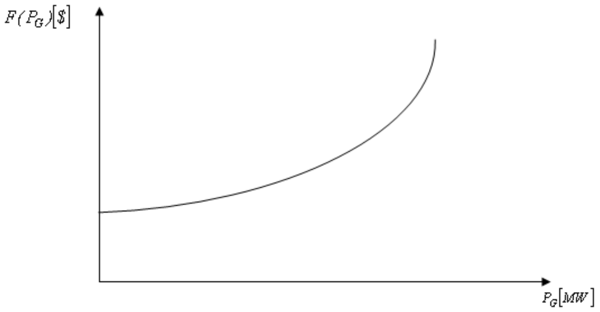

Fig. 1. Production cost as a function of power generated.

In reality, unit incremental heat rate curves do not exhibit the monetarily increasing shape required by traditional dispatch algorithms. Since traditional dispatch algorithms cannot handle monotonically increasing heat rate curves, approximations have been introduced during the estimation of the unit heat rate curves, so that the resulting heat rate curves are monotonically increasing.

In this paper, a hybrid method of BGA and TS (TSBGA) is used for the solution of the economic dispatch problem.

The remainder of the paper is organized as follows. In Section 2, we present the Economic power dispatch (EPD) and the optimization under equality and inequality constraints. This is followed by an explanation of the proposed Tabu Search (TS) in Section 3 and the BGA in section 4. Simulation results are shown and discussed in Section 5. Finally, we conclude in Section 6.

2. ECONOMIC POWER DISPATCH (EPD)

The problem is find the real power generation for each unit such that the objective function (total production cost) as defined by the equation [1, 2].

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$$F_i\left(P_{Gi}\right) = a_i P_{Gi}^2 + b_i P_{Gi} + c_i \quad (1)$$

$$Min\left\{F_t(P_G) = \sum_{i=1}^{NG} F_i(P_G)\right\} \quad (2)$$

Is minimum subject to constraints [3, 4, 5]

$$\sum_{i=1}^{NG} P_{Gi} = P_D \quad (3)$$

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \quad (4)$$

Where

F_t : Total production cost ($/h)
F_i : Production cost of ith plant ($/h)
a_i , b_i , c_i fuel cost coefficients
P_{Gi} : Real power output of generator i (MW)
P_D : Total demand (MW)
$P_{Gi}^{\min}$, $P_{Gi}^{\max}$ Upper and lower limit of active power generation at bus i
NG : Number of generator

3. TABU SEARCH (TS)

The global iterative optimisation technique Tabu Search (TS) stems from general tenets of intelligent problem solving and is derived from the works of Glover (1977, 1986, 1989, and 1990) [8]. In essence TS is a simple deterministic oriented search procedure that constrains searching and seeks to transcend local optimality by storing the search history in its memory. It forbids (makes tabu) moves in the neighbourhood having certain attributes, with the aim of guiding the search process away from solutions that (based on available information) appear to duplicate or resemble previously achieved solutions. The short term memory function enables "strategic forgetting" by only making the most recent *t* moves tabu. However tabu status of a move is not absolute. The aspiration criterion allows a tabu move to be selected if it attains a determined level of quality [9].

Medium and long term memory functions can also be applied to provide a wider exploration of the search space. Medium term or intermediate strategies are based on modifying choice rules to encourage moves and solutions historically found good where these schemes usually return to attractive parts of the search domain and intensify the search in these regions. Long term methods diversify the search into areas not previously explored. Often they are based on modifying choice rules to incorporate attributes into the solution that are not frequently used. More detailed descriptions are given in Glover and Laguna (1997) [6].

Laguna *et al*. (1991, 1993) present some of the earliest TS approaches in scheduling. They create three tabu search strategies based on simple move definitions. Laguna and Glover (1993)[10] apply target analysis to these two works and indicate the inclusion of job transfers in addition to job swaps improves solution quality, reduces computing time and allows larger problems to be solved.

Barnes and Laguna (1993) [7] suggest six primary components that allow effective production scheduling by TS. They also emphasise the need for medium and long term memory schemes which should be coupled with a restricted tabu search structure [11]. They note that in general insertion rather than swapping procedures are preferred as they provide a higher degree of perturbation and that the superposition of TS with other heuristics provides a fertile domain for future work.

4. GENETIC ALGORITHM

GAs are stochastic optimization techniques founded on the concepts of natural selection and genetics [12]. The algorithm starts with a set of solutions called population. Solutions from a population are used to form a new population. This is motivated by the hope that the new population will be better than the old one. Solutions that will form new solutions are selected according to their fitness: the more suitable they are, the more chances they have to reproduce. This is repeated until some condition (for example, number of generations or improvement of the best solution) is satisfied [13].

Among the advantages of GAs, we can quote that they can optimize with continuous or discrete parameters and do not require information about gradients; the possible discontinuities present on the fitness function have little effect on the overall optimization performance; GAs are resistant to becoming trapped in local optima; they can handle numerically generated data, experimental data or analytical functions; and they can be employed for a wide variety of problems [14].

Real coding is well suited to a large class of programming languages and to problems with a great number of variables [15]. For this reason, modified genetic operators are being developed for a real coded GA aiming an effective exploration of the search space [16]. These modified genetic operators are used in this paper as well as the improvement tools. Fig. 2 is a

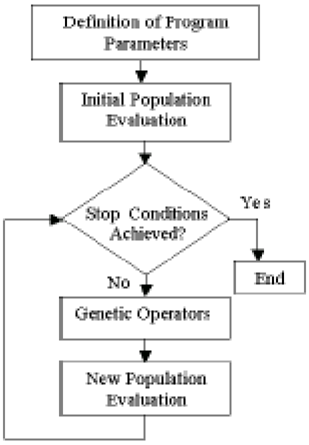

Fig. 2. Optimization procedure.

schematic representation of the parameters identification procedure presented here. The first step is the characterization of the individuals that will form the population.

In real coding, it is not necessary to code the variables in binary representation.

Each individual of this population is evaluated using the fitness between calculated and experimental results. and also on a maximum allowed number of generations.

If convergence is not attained, genetic operators (selection, crossover, mutation and improvements techniques) are applied. The selection procedure is responsible for forming the pairs that will be submitted to the other genetic operators. Selection is a mechanism related to individual fitness.

The “roulette wheel” method was used as selection procedure [17]. Crossover and mutation are mechanisms used to change the genetic materials of the individuals. They are the main tools for the success of the optimization process and must be implemented in order to allow an effective exploration of the search space. We use an efficient scheme for crossover and mutation for a real coded GA, proposed in [15]. The improvement techniques presented in are also used here: global elitism (which avoids loss of good solutions during the process), dynamic adaptation of crossover and mutation probabilities (variation of the probabilities values according to the population behaviour) and reduction of the variables spaces (reduction of the variables ranges to increase the results precision and to facilitate the search toward the global minimum). The new individuals created by the genetic operators described above will be evaluated and the iterative process will be repeated until one of convergence criteria is reached.

The optimization procedure was executed several times. The algorithm found practically the same best individual. This demonstrates the convergence of the applied methodology. For a stochastic optimization method, the final solution can only be considered optimal by repetition of the results [18].

A non-uniform arithmetic crossover operator was introduced into the RGA [15].

We used a non-uniform arithmetic crossover operator produces a complimentary pair of linear combinations produced from random proportions of the parents. The heuristic crossover operator produces a child that is a linear extrapolation away from the better parent along the direction of the vector joining the two parents. Two chromosomes, selected randomly for crossover,

$$C_{i,gen+1} = \beta \cdot C_{i,gen} + \left(1-\beta\right) \cdot C_{j,gen} \tag{5}$$

$$C_{j,gen+1} = \left(1-\beta\right) C_{i,gen} + \beta C_{j,gen} \tag{6}$$

Where β is a random number in range of [0, 1].

The non-uniform mutation operator is used to inject new genetic material into the population and it is applied to each new structure individually. A given mutation involves randomly altering each gene with a small probability.

5. SIMULATION RESULTS

The proposed algorithm in this paper is been compared to the GA and the ST by applying to tested for the 6-generator system. This system has a single quadratic cost function for each generator. As a sample system, IEEE 30-bus system [14], which has 6-generator, is chosen. Total power demand D is set to 189.2 MW.

Equations for the 6 generators are:

$$F_1\left(P_1\right) = 0.01P_1^2 + 0.301P_1 + 0.20$$

$$F_2\left(P_2\right) = 0.01P_2^2 + 0.301P_2 + 0.20$$

$$F_3\left(P_3\right) = 0.01P_3^2 + 0.301P_3 + 0.20$$

$$F_4\left(P_4\right) = 0.01P_4^2 + 0.301P_4 + 0.20$$

$$F_5\left(P_5\right) = 0.01P_5^2 + 0.301P_5 + 0.20$$

$$\mathrm{F}_6\left(\mathrm{P}_6\right) = 0.01\mathrm{P}_6^2 + 0.301\mathrm{P}_6 + 0.20$$

And the constraints are:

$$0 \le P_1 \le 575.88$$

$$0 \le \mathrm{P}_2 \le 100$$

$$0 \le P_3 \le 140$$

$$0 \le P_4 \le 100$$

$$0 \le P_5 \le 550$$

$$0 \le P_6 \le 410$$

This test was designed for the comparison of STBGA, BGA, RGA, and ST.

Various tests were made with a varying Percentage of the maximum power as demand.

Table 1. EPD results for various loads (30 bus)

Demand	TS cost ($)	BGA cost ($)	RGA cost ($)	TSBGA cost ($)
P	589.841	574.154	561.838	553.633
95% *P*	533.694	529.169	521.290	518.429
90% *P*	500.022	497.190	486.767	483.778
80% *P*	443.394	438.395	422.378	416.616
70% *P*	372.233	367.954	356.957	350.618

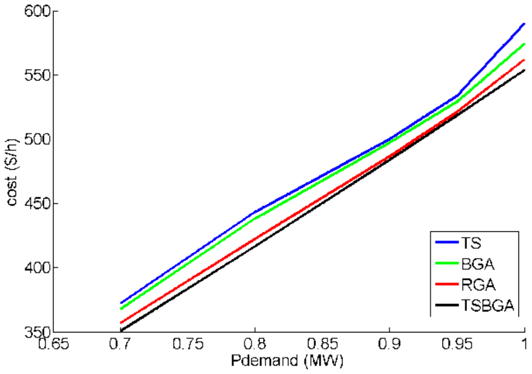

Fig. 3. EPD results for various loads.

Table 2. EPD results for load 189.2 (30 bus).

	TS	BGA	RGA	TSBGA
P_{G1}	65.010627	44.839351	50.0012	43.8139
P_{G2}	19.957552	70.894148	39.9898	57.1967
P_{G3}	23.444470	12.426175	25.0067	21.7218
P_{G4}	40.818984	21.038463	36.3094	29.8614
P_{G5}	11.124227	2.104106	17.5255	14.9448
P_{G6}	22.813034	30.062627	9.99999	15.5570
P_D	189.2	189.2	189.2	189.2
Cost ($/h)	589.841591	574.154619	561.838	553.633

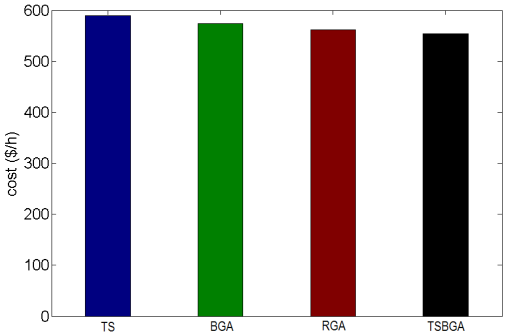

Fig. 4. EPD results for load189.2.

Table 3. EPD results for load 179.7400 (30 bus).

	TS	BGA	RGA	TSBGA
P_{G1}	19.99998	47.50137	36.249385	42.47279
P_{G2}	64.89596	39.99465	55.697506	54.91763
P_{G3}	25.00339	31.25015	18.740936	21.45526
P_{G4}	34.37308	24.73953	37.938920	27.51008
P_{G5}	7.499009	14.94385	9.370986	13.51175
P_{G6}	21.45299	15.35654	15.416584	13.88761
P_D	179.7400	179.7400	179.7400	179.7400
Cost ($/h)	533.6944	529.1699	521.290975	518.4293

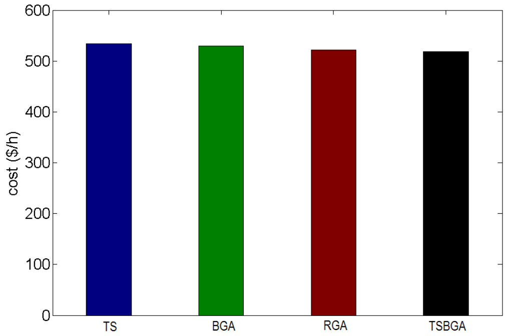

Fig. 5. EPD results for load 179.7400.

Table 4. EPD results for load 170.28 (30 bus).

	TS	BGA	RGA	TSBGA
P_{G1}	60.083250	29.818673	38.73844	41.090998
P_{G2}	45.449217	34.999783	55.11977	54.134978
P_{G3}	25.053069	24.655947	21.00737	21.061786
P_{G4}	3.434101	42.749193	17.17630	22.112629
P_{G5}	7.449305	16.933910	22.50196	13.371398
P_{G6}	23.131288	15.802301	9.999540	12.567523
P_D	170.28	170.28	170.28	170.28
Cost ($/h)	500.02299	497.19046	486.7675	483.7784

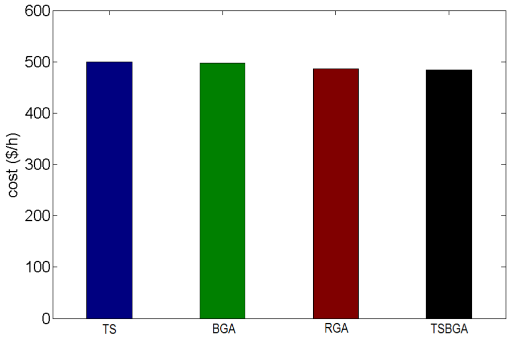

Fig. 6. EPD results for load 170.28.

Table 5. EPD results for load 151.36 (30 bus).

	TS	BGA	RGA	TSBGA
P_{G1}	60.002939	50.00511	34.961680	37.501890
P_{G2}	19.999896	19.99869	43.748343	55.000616
P_{G3}	20.313582	18.74210	19.629237	19.140519
P_{G4}	27.500007	23.40936	27.500638	12.919189
P_{G5}	7.381009	13.24510	2.793588	11.251697
P_{G6}	10.475922	20.00986	20.000316	10.002767
P_D	151.36	151.36	151.36	151.36
Cost ($/h)	443.39479	438.3951	422.37818	416.61673

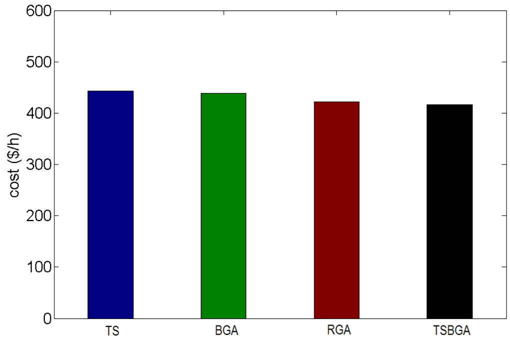

Fig. 7. EPD results for load 151.36.

Table 6. EPD results for load 132.44 (30 bus).

	TS	BGA	RGA	TSBGA
P_{G1}	50.004149	19.9996	29.998607	34.995418
P_{G2}	19.999653	43.6327	39.999483	47.030327
P_{G3}	21.884457	18.7693	20.718272	18.715208
P_{G4}	27.502677	3.45523	3.435426	9.431222
P_{G5}	5.153214	11.2512	11.248033	8.598667
P_{G6}	2.499490	30.0003	20.011205	8.114831
P_D	132.44	132.44	132.44	132.44
Cost ($/h)	372.2334	367.954	356.957073	350.6186

For the 30 bus system, the ranges of parameters used, a Population size of 60, a Number of generations 100, a Crossover probability of 0.5 and Mutation probability of 0.05 provide more or less the minimum augmented cost.

The tests were carried out on a Pentium III at 450MHz with 128Mb ram.

After different tests we can see that the hybrid method (TSBGA) is very efficient, and the optimal

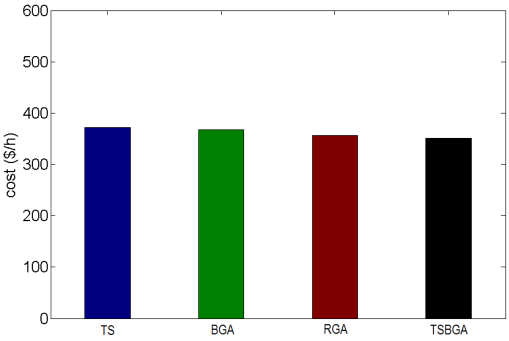

Fig. 8. EPD results for load 132.44.

solution found by this method is better than the best solution obtained by other methods (BGA, RGA and ST).

In all cases considered (with the variation of the load) confirm the advantage of the hybrid method (TSBGA) compared to the other methods BGA, RGA and ST.

6. CONCLUSION

This paper presents a methodology for solving the Economic Dispatch problem with network constraints. Including active power dispatches using BGA and TS. The method employs advantage of the GA which can provide a near global solution at the beginning.

Then TS which can tune the control variables to obtain the global solution is applied. Results of the study demonstrate that the proposed method give a better solution than GA or TS alone.

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