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# Unit Commitment and Economic Load Dispatch Using Hybrid Genetic - Particle Swarm Optimization Algorithm

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**Abstract**
Unit commitment and Economic load dispatch is considered one of the most important problems in power systems that optimize the operation cost with respect to the load demands of customers. Several strategies have been proposed to provide quality solutions to these problems and increase the potential saving in the power system operation. These include deterministic and stochastic search algorithms. One of the limitations of deterministic approaches is that they suffer from the curse of dimensionality when dealing with the modern power system with large number of generators. Recently evolutionary based search techniques are popularly applied to these problems which may handle complex non-linear constraints and provide high quality solution. This paper proposes a solution for unit commitment and economic load dispatch problem using hybrid Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). The experimental research shows lower operating cost and execution time when compared to several state-of-the-art techniques. The proposed system was tested on the seven unit Neyveli thermal power station system data. The algorithm was developed and executed using the C++ and MATLAB 7.1 software. The simulations were carried out on a PC with INTEL DUO CORE CPU 1.8 GHz and 512MB RAM.

**Keywords:** economic load dispatch, genetic algorithm, particle swarm optimization, unit commitment.

### 1. Introduction
Unit commitment (UC) in power system involves determining the start-up and shut-down schedule of units to meet the required demand, over a short-term period [1]. Unit commitment decision involves the determination of the generating units to be running during each hour of the planning period, by considering system capacity requirements, reserve, and the constraints on the start-up and shut-down of units. Economic Dispatch (ED) is used to schedule the outputs of available generating units for a particular time that minimizes the total production cost while satisfying equality and inequality constraints [2]. A literature survey on UC methods explores that various numerical optimization techniques have been employed to address the UC problems. Specifically, they are priority list method [3-4], integer programming [5], dynamic programming [7], mixed integer programming [8], branch and bound [9] and Lagrangian relaxation methods [16]. Among these, the priority list method is simple and fast but the quality of final solution is not guaranteed to be good. Dynamic programming methods, which are based on priority lists, are flexible but are computationally expensive. The drawback with the branch and bound method is the exponential growth in the execution time with the increase in size of the UC problem. The integer and mixed-integer methods adopt linear programming technique to solve and check for an integer solution and require major assumptions that limit the solution space. The Lagrangian relaxation method provides a fast solution but suffers from numerical convergence and solution quality problems. The above techniques come under deterministic search approaches.
Recently, a number of computation techniques, for example Simulated Annealing (SA) [10], Genetic Algorithm (GA) [11], Evolutionary Programming (EP) [12], Tabu Search (TS) [13], and Particle Swarm Optimization (PSO) [14, 15] have been applied to solve economic load dispatch problem. Compared to other methods, PSO can solve the problems quickly with high quality solutions and stable convergence characteristics can be easily implemented.

The proposed hybrid GA - PSO algorithm has been extensively compared with the classical approach. The new method is shown to be statistically significant on the test system consisting of seven generating units. The results obtained through the proposed method are compared with those reported in the literature survey.

## 2. Problem Formulation

The main objective of the UC problem is to determine a minimal cost turn-on and turn-off schedule of a set of electrical power generating units to meet a load. The economic load dispatch deals with allocating the power to be generated by each unit that is committed for the particular load demand. In this paper, the equality and inequality constraints indicate the real power balance and limitation of power generation of each unit, respectively. Some of the other constraints including voltage level and security are assumed to be constant. Equation (1) denotes the total fuel cost for a power system which is the summation of the cost functions of all generating units.

$$F = \sum_{i=1}^{N} FiPi \quad (1)$$

Total generation (fuel) cost of a thermal unit is expressed as a second-order function as in (2).

$$F = aiPi^2 + biPi + ci \quad (2)$$

where, $P_i$ is the output power generation of unit i. and $a_i$, $b_i$, $c_i$ are the fuel cost coefficients of unit i.
The output power of each generation unit is bounded between two limitations as shown in (3).

$$P_i\,(min) < P_i < P_i\,(max) \quad (3)$$

where, $P_i$ (min) and $P_i$ (max) denote the minimum and maximum output power generation of unit i.

## 3. Genetic Algorithm

The GA is a stochastic search or optimization procedure based on the mechanics of natural selection and natural genetics. Utilizing GA, many non-linear, large-scale combinatorial optimization problems in power systems have been re-solved. The construction of a Genetic Algorithm for unit commitment problem was separated into four distinct tasks:

i. Choice of the representation of the string;
ii. Selection of the genetic operators;
iii. Determination of the fitness function;
iv. Determination of the probabilities controlling the genetic operators.

The implemented GA consists of input data, binary strings coding, initialization of the population, decoding the commitment schedule by using Economic Status, evaluation of fitness function and application of Selection-Crossover-Mutation of the UC schedules. The steps of the genetic algorithm are described in the flowchart shown in Fig 1.

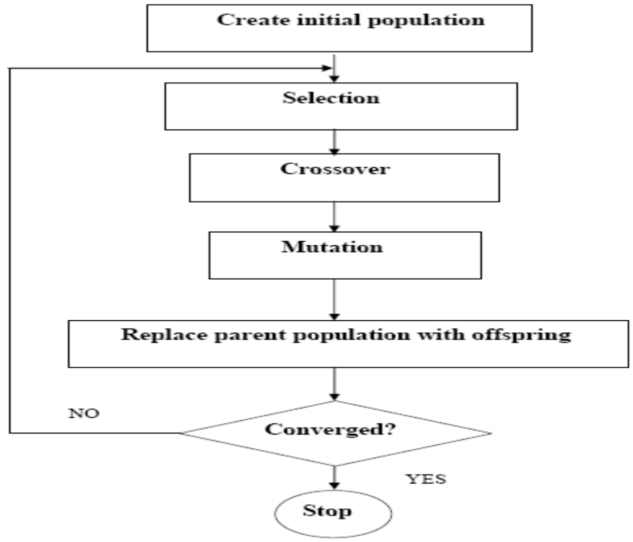


**Fig 1:** GA flowchart

## 4. Particle Swarm Optimization

The PSO algorithm which was first proposed by Kennedy and Eberhart has been inspired by the Social behavior of a simple system (flock of birds). Unlike the mathematical methods for solving optimization problems, this algorithm does not need any gradient information about objective or error function and it can obtain the best solution independently [11].
According to the PSO algorithm, a swarm of particles that have predefined restrictions starts to fly on the search space. The performance of each particle is evaluated by the value of the objective function and considering the minimization problem, in this case, the particle with lower value has more performance. The best experiences for each particle in iterations is stored in its memory and called personal best (Pbest). The best value of Pbest in iterations determines the global best (Gbest). By using the concept of Pbest and Gbest, the velocity of each particle is updated in (4)

$$Vi^{k+1} = w * Vi^k + C1 * r1 * \left(pbest - Pi^k\right) + C2 * r2 * \left(gbest - Pi^k\right) \quad (4)$$

Where,
$Vi^{k+1}$: Particle velocity at current iteration (k+1)
$Vi^k$: Particle velocity at iteration k
r1, r2: random number between [0, 1]
c1, c2: acceleration constant

After this, particles fly to a new position:

$$Pi^{k+1} = P^k + Vi^{k+1} \quad (5)$$

In attempt to increase the rate of convergence of the standard PSO algorithm to global optimum, the inertia weight is proposed in the velocity equation.

$$W = W_{max} - iter * \frac{W_{min} - W_{min}}{iter_{max}} \quad (6)$$

The flowchart of the PSO algorithm for unconstrained optimization is shown in Fig 2. The iterative process will be stopped under the supervision of a change in the production costs value, or when the maximum number of iteration is reached.

**5. Hybrid Ga-Pso Algorithm**

The procedure of the proposed GA-PSO method is as shown below.

1. Initialize randomly the individuals of the population according to the limit of each unit including dimensions, searching points and velocities. This includes the initial schedule of binary bits 0 and 1 analogous to the chromosomes of the randomly generated population.
2. These schedules are tested for solution feasibility (generation > load) using fitness value function where

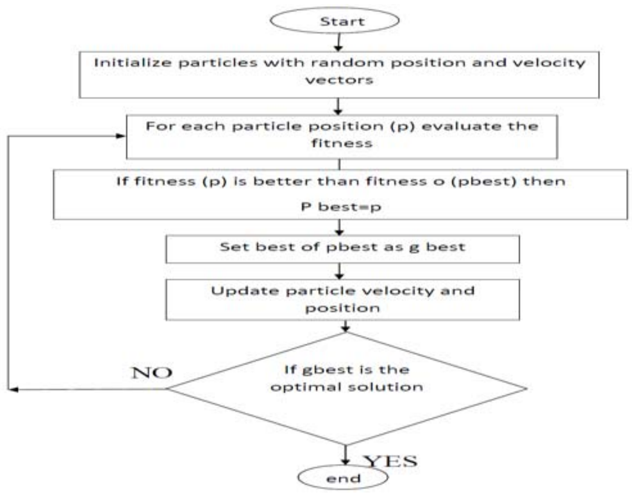


**Fig 2:** PSO flowchart

infeasible strings are eliminated and new random schedules are generated.

3. Genetic operation which involves selection, window crossover and mutation is then performed on the population of chromosomes.
4. The above population is checked for the satisfaction of the feasibility. The hit positions are corrected and the solution will be converted into feasible solution.
5. For the best chromosome, each bit is taken as a particle and the velocity of the particle is randomly initialized.
6. The gbest and pbest values are obtained using fitness function and the velocity is updated.
7. If the maximum iteration number is reached, the process is stopped. Otherwise go to step 3.
8. The gbest value at the end of the algorithm gives the fuel cost for the required demand and the velocity of each particle denotes the power generated by each unit.

**6. Results and Discussions**

The proposed algorithm is applied to the test data which consists of seven units from Neyveli thermal power station system. The algorithm was developed and executed in Matlab simulink environment. PSO toolbox, developed by Kennedy and Eberhart was used to develop the algorithm.

The parameters of GA and PSO algorithm are set as shown in Table1 and Table 2 respectively. The selection of population size for GA and PSO is very important. If the population size is too small, then an insufficient number of particles are produced and the algorithm may not give the best possible solution since some of the best positions are missed. If the population size is too large, the algorithm is very slow and inefficient. As shown in the table1 and table2, the population size for GA and PSO is 28 and 24 respectively.

The best range for changing the linear descending function value of inertia weight in PSO for convergence and obtaining the best possible solution is between 0.9 and 0.4.

**Table 1:** GA Parameters

| S. No | PARAMETER | VALUE |
|---|---|---|
| 1 | Maximum number of generations | 2000 |
| 2 | Population Size | 28 |
| 3 | Selection method | Roulette wheel |
| 4 | Crossover rate | 0.6 |
| 5 | Mutation rate | 0.001 |

**Table 2:** PSO parameters

| S. No | PARAMETER | VALUE |
|---|---|---|
| 1 | Population size | 24 |
| 2 | Maximum inertia weight | 0.9 |
| 3 | Minimum inertia weight | 0.4 |
| 4 | Initial velocity | 0 |
| 5 | Initial position | Random |
| 6 | Cognitive factor (c1) | 2 |
| 7 | Social factor (c2) | 2 |
| 8 | Error gradient | 1e-25 |
| 9 | Maximum number of iterations | 2000 |

The unit characteristics of the test data are shown in Table 3. The test data includes the minimum and maximum power generation limit of each unit and their fuel cost coefficients. The load demand in MW for 24 hours time is shown in Table 4. The unit commitment and economic load dispatch results are obtained successfully and the cost of generation for 24 hours and the time taken to execute the algorithm are tabulated.

**Table 3:** NTPS Test System

| Unit | Max Power (MW) | Min Power (MW) | A (Rs/W-$h^2$) | B (Rs/W-h) | C (Rs) |
|---|---|---|---|---|---|
| 1 | 60 | 15 | 0.255 | 70 | 750 |
| 2 | 80 | 20 | 0.198 | 75 | 1250 |
| 3 | 100 | 30 | 0.198 | 70 | 2000 |
| 4 | 120 | 25 | 0.191 | 70 | 1600 |
| 5 | 150 | 50 | 0.106 | 75 | 1450 |
| 6 | 150 | 50 | 0.0675 | 65 | 4950 |
| 7 | 200 | 75 | 0.074 | 60 | 4100 |

**Table 4:** Load Demand Data

| Hour | Demand (MW) | Hour | Demand (MW) |
|---|---|---|---|
| 1 | 840 | 13 | 545 |
| 2 | 757 | 14 | 538 |
| 3 | 775 | 15 | 535 |
| 4 | 773 | 16 | 466 |
| 5 | 770 | 17 | 449 |
| 6 | 778 | 18 | 439 |
| 7 | 757 | 19 | 466 |
| 8 | 778 | 20 | 463 |
| 9 | 770 | 21 | 460 |
| 10 | 764 | 22 | 434 |
| 11 | 598 | 23 | 530 |
| 12 | 595 | 24 | 840 |

**Table 5:** Power generated per unit per hour - 24 hour generator power schedule

| HOURS (h) | Power generated / unit (MW) | | | | | | |
|---|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 | P6 | P7 |
| 1 1 | 60 | 80 | 98.2005 | 101.7995 | 150 | 150 | 200 |
| 2 2 | 60 | 65.5072 | 78.1334 | 80.9970 | 122.3624 | 150 | 200 |
| 3 3 | 60 | 69.1772 | 81.8035 | 84.8015 | 129.2178 | 150 | 200 |
| 4 4 | 60 | 68.7694 | 81.3957 | 84.3788 | 128.4561 | 150 | 200 |
| 5 5 | 60 | 68.1578 | 80.7840 | 83.7447 | 127.3135 | 150 | 200 |
| 6 6 | 60 | 69.7889 | 82.4151 | 85.4356 | 130.3604 | 150 | 200 |
| 7 7 | 60 | 65.5072 | 78.1334 | 80.9970 | 122.3624 | 150 | 200 |
| 8 8 | 60 | 69.7889 | 82.4151 | 85.4356 | 130.3604 | 150 | 200 |
| 9 9 | 60 | 68.1578 | 80.7840 | 83.7447 | 127.3135 | 150 | 200 |
| 10 10 | 60 | 66.9344 | 79.5607 | 82.4765 | 125.0284 | 150 | 200 |
| 11 11 | 60 | 80 | 0 | 108.0000 | 150 | 0 | 200 |
| 12 12 | 60 | 80 | 0 | 105.0000 | 150 | 0 | 200 |
| 13 13 | 60 | 69.6391 | 0 | 85.2803 | 130.0806 | 0 | 200 |
| 14 14 | 60 | 67.8463 | 0 | 83.4218 | 126.7318 | 0 | 200 |
| 15 15 | 60 | 67.0780 | 0 | 82.6254 | 125.2966 | 0 | 200 |
| 16 16 | 60 | 0 | 0 | 81.9394 | 124.0606 | 0 | 200 |
| 17 17 | 57.4984 | 0 | 0 | 76.7694 | 114.7367 | 0 | 200 |
| 18 18 | 55.3890 | 0 | 0 | 73.9487 | 109.6623 | 0 | 200 |
| 19 19 | 60 | 0 | 0 | 81.9394 | 124.0606 | 0 | 200 |
| 20 20 | 60 | 0 | 0 | 80.8687 | 122.1313 | 0 | 200 |
| 21 21 | 59.8187 | 0 | 0 | 79.8627 | 120.3186 | 0 | 200 |
| 22 22 | 54.3343 | 0 | 0 | 72.5406 | 107.1251 | 0 | 200 |
| 23 23 | 60 | 65.7974 | 0 | 81.2979 | 122.9047 | 0 | 200 |
| 24 24 | 60 | 80 | 98.2005 | 101.7995 | 150 | 150 | 200 |

The unit commitment and economic load dispatch outputs for the test system are tabulated in table 5. The table displays the power generated by the seven units for each hour. Unit commitment results are obtained using GA. The zero power in the table implies that the unit is in off state. The power in MW contributed by the seven units for each day is displayed in figure 3. It can be seen that the contribution of each unit per day varies from the other units. Units 5 and 6, contribute different power demands per day, 5800 MW and 2500 MW respectively, though they have the same power rating of 150 MW. This is due to the difference in the cost coefficient values of the two units. The results of the proposed algorithm are validated by comparing the obtained results with other algorithms and shown in Table 6. It is clear from the comparative analysis that the proposed algorithm is better in terms of fuel cost and time.

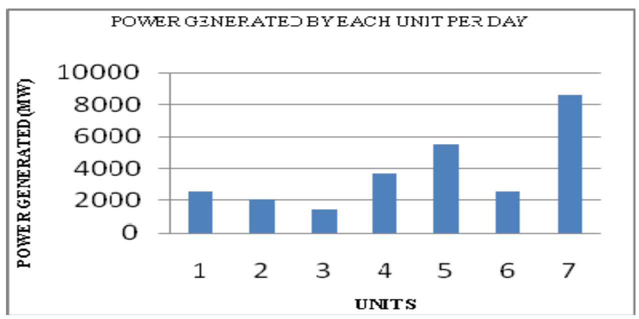


Fig 3: Power generated by each unit per day

**Table 6:** Comparison of GA-PSO with other algorithms

| ALGORITHM | TOTAL COST (MW) | TOTAL COST (p.u) | CPU TIME (s) |
|---|---|---|---|
| Tabu search [17] | 1573093 | 1 | 80 |
| Dynamic programming [19] | 1552926 | 0.9872 | 180 |
| Lagrangian relaxation [17] | 1548742 | 0.9845 | 169 |
| Fuzzy dynamic programming [18] | 1547340 | 0.9836 | 158 |
| Hybrid GA-PSO | 1528301 | 0.9715 | 62 |

The fuel cost of tabu search algorithm, if taken as 1 p.u, then the fuel cost of the proposed algorithm is 0.9715 p.u. Also, the time taken to execute the algorithm is lesser when compared to other algorithms. From this case it can be clearly proved that the GA-PSO optimal solution technique in unit commitment and economic load dispatch problem leads to remarkable cost saving and increase in the profit of power generation. Also, there is no mathematical complexity in the proposed algorithm since it has a simpler structure than other traditional methods. To conclude, both the solution quality and stability of the hybrid GA-PSO algorithm is good to solve the unit commitment and economic load dispatch problem.

## 7. Conclusion

The paper has presented a hybrid Genetic and PSO algorithm for determination of optimal solution for UC and ELD problem with the generator constraints. The presented scheme attempts to make a judicious use of exploration and exploitation abilities of the search space and therefore likely to avoid false and premature convergence. The feasibility of the proposed method was demonstrated with seven unit sample system. The test results reveal that the unit commitment and economic dispatch solution obtained through the GA-PSO lead to less operating cost and execution time than the other methods stated in the literature.

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