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DETAILED LITERATURE SURVEY ON DIFFERENT METHODOLOGIES OF UNIT COMMITMENT

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ABSTRACT

This Paper explores the existing methodologies for the solution of unit commitment problem of large size power system. The survey covers exhaustive review of literature available over the past five decades published by the Pioneers, Experts & Researchers working in this field. It includes publications in standard international journals like IEEE, IEE, ELSEVIER etc, and proceedings of prominent international conferences. The various methods employed to solve the unit commitment problem can be broadly grouped as Conventional and Intelligent. The conventional methodologies include the well known techniques like Priority List, Dynamic Programming, Lagrange Relaxation, Branch-and-Bound , Integer and Mixed-Integer methods. Intelligent methodologies include the recently developed and popular methods like Genetic Algorithm, simulated annealing, ant colony, Particle swarm optimization, Fuzzy Logic and Neural Networks. This paper summarizes salient features, merits and demerits of, as well as contributions made by research scholars and experts on each of the unit commitment method based on detailed review and critical examination of various methods, The contents of this paper provide ready-to-refer and ready to use information for the researchers working in the field of unit commitment.

Keywords: *Priority List, Dynamic Programming, Lagrange Relaxation, Integer And Mixed Integer Methods, Genetic Algorithm, Particle Swarm Optimization, Ant Colony, Simulated Annealing*

1. INTRODUCTION

The problem of Unit Commitment (UC) is generally stated as the allocation of given load amongst the generating units in operation in such a manner that, the overall cost of generation is minimum. Basically the problem of UC is an optimization problem. Regardless of objective function of the problem, the problem of UC should be solved so that the entire set of equality and inequality constraints, all the necessary and sufficient conditions of control parameters etc. must be satisfied thoroughly. The area of unit commitment has warranted a great deal of attention from operating and planning engineers.

A comprehensive study regarding the problem of unit commitment was done by R.H.Kerr et al[1]. The detailed analysis of UC was carried out and the results were presented. P.G.Lowery[2] demonstrated the feasibility of using Dynamic Programming to solve the unit commitment problem. He showed that simple, straight forward constraints were adequate to produce a usable optimum operating policy. A method for determing the most economical generating unit commitment policy and loading schedule for a days operation of an electric utility system was proposed by J.D.Guy[3]. Huge amount of research has been done on the problem of unit commitment by various researchers over the years[4-6]. The solution methodologies can be broadly grouped into two namely:

1. Conventional (classical) methods
2. Intelligent methods.

The further sub classification of each methodology is given below as per the Tree diagram shown in Fig.1. To meet the requirements of different objective functions, types of application and nature of constraints, the popular conventional methods is further sub divided into the following

(a) Priority List Method [7,8,9]
(b) Dynamic Programming Method [2,10-15]
(c) Lagrange Relaxation Method [16-21]
(d) Branch and Bound Method [22]
(e) Integer and Mixed Integer method [23,24]

Even though, excellent advancements have been made in classical methods, they suffer with the following disadvantages: In most cases, mathematical formulations have to be simplified to get the solutions because of the extremely limited

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capability to solve real-world large-scale power system problems. They are weak in handling qualitative constraints. They have poor convergence, may get stuck at local optimum, they can find only a single optimized solution in a single simulation run, they become too slow if number of variables are large and they are computationally expensive for solution of a large system

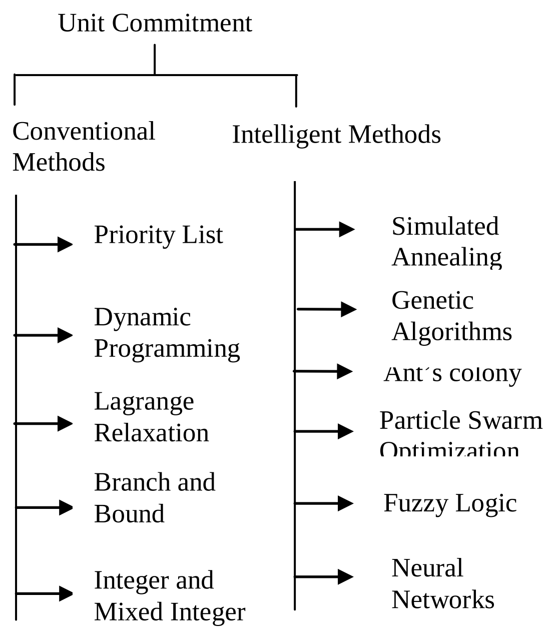

Figure 1: Tree Structure Indicating UC Methodologies

To overcome the limitations and difficulties in analytical methods, intelligent methods based on Artificial Intelligence (AI) techniques have been developed in the recent past. These methods can be classified or divided into the following,
a)Simulated annealing
b) Genetic Algorithms (GA) [28,29,30,31]
c) Ant colony
d) Particle Swarm Optimization (PSO) [21,32,33]
e) Fuzzy Logic [34-37]
f) Artificial Neural Networks (ANN) [25,26,27]

The major advantage of the intelligent methods is that they are relatively versatile for handling various qualitative constraints. These methods can find multiple optimal solutions in single simulation run. So they are quite suitable in solving multi objective optimization problems. In most cases, they can find the global optimum solution. The main advantages of intelligent methods are: Possesses learning ability, fast, appropriate for non-linear modeling, etc. whereas, large dimensionality and the choice of training methodology are some disadvantages of intelligent methods

Detailed description on important aspects like Merits & Demerits and Researchers' contribution on each of the methodology as referred above is presented in the coming sections. A detailed review of different papers have also been presented in detail explaining the work done in the area of unit commitment.

2. CONVENTIONAL METHODS

Fig 1 shows the representation of conventional methods employed in the solution of unit commitment.

2.1 Priority List Method

The Generalized priority list is applied to the Unit commitment problem [7] with the main motivation being the existence of the concept of the tabu search to be employed along with the priority list techniques. With the availability of good optimization techniques, the information needed is provided.

2.1.1 Significant Contributions

In the recent past, researchers have applied this method for UC solution. Salient features and significant contributions made by them are furnished below:

1. [38] Raymond R.Shoults, Show Kang Chang, Steve Helmick and W.Mack Grady, "A practical approach to unit commitment, economic dispatch and savings allocation for multiple area pool operation with import/export constraints", IEEE transactions on Power Apparatus and Systems, Vol., PAS-99, No 2, April 1980, pp 625-635.

- A straight forward and computationally efficient method was presented by including the area import/export constraints in the concept of unit commitment.
- The savings resulting from a unified unit commitment and economy interchange of power could be analyzed on a daily, monthly and annual basis.
- A comprehensive computer program was developed utilizing all the concepts and was tested on Texas Municipal power system

2.[65] F.N.Lee and Q.Feng, "Multi area unit commitment", IEEE Transactions on Power Systems, Vol 7, May 1992, pp 591-599.

- A thermal unit commitment method for interconnected multiarea power systems has been presented. The method is a natural extension of the commitment utilization factor (CUF)-based single-area unit commitment method.
- CUF is extended to reflect the impact of multiarea transmission interconnection

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constraints on the utilization efficiency of committing a candidate unit at a given priority position.

- The multiarea CUF is used in conjunction with the average full load cost. (AFLC) to efficiently determine the optimal or a near-optimal multiarea priority commitment order.
- This priority order is then used to generate the multiarea unit commitment schedule. The excellent quality of the results of the CUF-based multiarea method is consistent with that of the previously reported single-area method

2.1.2 Merits and demerits of Priority List Method

The Merits and Demerits of Priority List Method are summarized and given below.

Merits

1)The Priority List Method is used to find the solution for unit commitment that is feasible with respect to all relevant inequality constraints. It handles functional inequality constraints also efficiently.

2) Priority List Method are better fitted to highly constrained problems.

3) Priority List Method can accommodate non linearities easily compared to other methods.

4)Compact explicit Priority List Methods are very efficient, reliable, accurate and fast.

5)This is true when the optimal step in the gradient direction is computed automatically through quadratic developments.

Demerits

1) Priority List Method suffers from the difficulty of handling all the inequality constraints usually encountered in the problem of unit commitment.

2) During the problem solving process, the direction of the priority has to be changed often and this leads to a very slow convergences.

3) Priority List Method basically exhibit slow convergence characteristics near the optimal solution.

4) These methods are difficult to solve in the presence of inequality constraints.

2.2 Dynamic Programming Method

This method is applicable to a wide class of problems and through this method the optimum combination of units to use without calculating the cost of all possible combinations can be found. The essence of dynamic programming is that the problem of finding the optimum outputs of the various units for a given load is replaced by the problem of finding the optimum outputs of the various units for all the loads between the minimum and maximum capacity of the units[2].

2.2.1 Significant Contributions

1. [12]. Walter L.Snyder and H.David Powell and John C.Rayburn, “Dynamic Programming approach to unit commitment”, IEEE Transactions on Power Systems, Vol., PWRS-2, No 2, May 1987, pp 339-348.

- A dynamic programming algorithm to solve the problem of unit commitment was developed.
- The algorithm effectively incorporated a number of special features and effectively dealt with the control of problem size.
- It also took into consideration the practical aspects and design techniques

2. [41] Frad N.Lee, “Short term thermal unit commitment-A new method”, IEEE Transactions on Power Systems, Vol. 3, No 2, May 1988, pp 421-428.

- A new method for short term thermal unit has been developed
- It employed a 20 unit mid western utility system, the EPRI 174 unit synthetic utility system and EPRI 155 synthetic utility system.
- It was observed that the proposed algorithm produced the same unit commitment schedule as a frequency used DP-STC algorithm in 15 seconds of computation time when tested on a 20 unit system.
- It was observed that the overall time of the computational process was drastically reduced with the employing of the new algorithm.

3.[42] S.K.Tong and S.M.Shahidehpour, “Hydrothermal unit commitment with probabilistic constraints using segmentation method”, IEEE Transactions on Power Systems, Vol.5, No 1, Feb 1990, pp 276-282.

- Hydrothermal unit commitment has been studied based on a formulation which employs the unit commitment as a reliability constraint.
- This approach provides a rational modeling of the problem by considering the outages of thermal units and the uncertainty of the demand.
- For hydrothermal coordination, an expected incremental cost grid of thermal generation is constructed for different levels of hydro generating capacity by introducing a new algorithm.
- The global optimization has been executed in an iterative loop which consists of thermal unit commitment and hydrothermal coordination.

4. [44]C.Wang and S.H.Shahidehpour, “Effects of ramp-rate limits on unit commitment and economic dispatch”, IEEE Transactions on Power Systems, Vol 8, No 3, Aug 1993, pp 1341-1350.

- Proposed an algorithm to consider the ramp characteristics in starting up and shutting down

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the generating units as well as increasing and decreasing the power generation.

- The use of ramp-rate constraints to simulate the unit state and generation changes was found to be effective approach in the view of theoretical development of industrial process.
- Since implementing ramp-rate constraints was a dynamic process, dynamic programming was found to be a proper tool to solve the problem.
- A dynamic dispatch procedure was adopted to obtain a suitable power allocation which incorporated the unit generating capability information given by unit commitment and unit ramping constraints as well as economic constraints.

5.[39] C.K.Pang, G.B.Sheble and F.Albuyeh, "Evaluation of dynamic programming based methods and multiple area representation for thermal unit commitments", IEEE transactions on Power Apparatus and Systems, Vol., PAS-100, No 3, Mar 1981, pp 1212-1218.

- Compared the performance of 4 unit commitment methods, three of which were based on the dynamic programming approach.
- Also presented the modeling of inter areas flow constraints by linear flow network, so that it recognizes any existing transmission limitations.
- Results demonstrated the importance of multiple area representation in unit commitment and also its effect on schedule costs and assured the determination of realizable schedules

6. [40] P.P.J.Van den Bosch and G.Honderd, "A solution of unit commitment problem via decomposition and dynamic programming", IEEE transactions on Power Apparatus and Systems, Vol., PAS-104, No 7, July 1985, pp 1684-1690.

- Proposed the decomposition and dynamic programming as techniques for solving the unit commitment problem
- It was shown that a unit commitment problem with 100 units and 24 periods could be solved in about 3 minutes.

2.2.2 Merits and demerits of Dynamic Programming Method

The merits and demerits of dynamic programming method can be summarized as follows:

Merits:

1. The method has the ability to converge fast.
2. It can handle inequality constraints very well.
3. In this method, binding inequality constraints are to be identified, which helps in fast convergence.
4. The Dynamic programming approach is a flexible formulation that can be used to develop different unit commitment algorithms to the requirements of different applications.
5. With this method efficient and robust solutions can be obtained for problems of any practical size.
6. Solution time varies approximately in proportion to network size and is relatively independent of the number of controls or inequality constraints.
7. There is no need of user supplied tuning and scaling factors for the optimization process.

Demerits:

1. The penalty near the limit is very small by which the optimal solution will tend to the variable to float over the limit.
2. Dynamic programming has a drawback of the convergence characteristics that are sensitive to the initial conditions and they may even fail to converge due to inappropriate initial conditions.

2.3 Lagrange Relaxation Method

It derived its name from the well known mathematical technique of using lagrange multipliers for solving constrained optimization problems, but is really a decomposition technique for the solution of large scale mathematical programming problems. The lagrangian relaxation methodology uses a different kind of decomposition and generates easy subproblems for deciding commitment and generation schedules for single units over the planning horizon independent of commitment of other units [16].

2.3.1 Significant Contributions

1. [17] Sudhir Virmani, Kal Imhof and Shishir Mukherjee, "Implementation of a lagrangian relaxation based unit commitment problem", IEEE Transactions on Power Systems, Vol. 4, No 4, Oct 1989, pp 1373-1380.

- Has provided an understanding of the practical aspect of the lagrangian relaxation methodology for solving the thermal unit commitment problem.
- It has been showed that the method involves decomposition of the problem into a sequence of master problems and sub problems whose solution converges to an ϵ-optimal solution to the original problems.
- The major purpose of the paper was to provide a mathematical formulation of the unit commitment problem related to lagrangian methodology as a solution technique and also to provide a detailed account of the practical computational steps needed to apply the technique.

2.[16] Fulin Zhuang and F.D.Galiana, "Towards a rigorous and practical unit commitment by Lagrangian Relaxation", IEEE Transactions on Power Systems, Vol 3, No 2, May 1988, pp 763-773

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- Lagrangian relaxation method based on Wolf's algorithm specialized to solve the economic dispatch problem is implemented.
- Penalty factors or the selection of the gradient step size are not essential.
- The method was developed purely for research purposes; therefore, the model used is limited and employs the classical economic dispatch with voltage, real, and reactive power as constraints.
- The CPU time is less as convergence is very fast.
- It increases with system size.
- Validated on 5-, 14-, 30-, 57- and 118-bus systems

3. [18]N.Jimenez Redondo and A.J.Conejo, "Short term hydro-thermal coordination by lagrangian relaxation: solution of the dual problem", IEEE Transactions on Power Systems, Vol 14, No 1, Feb 1999, pp 89-95.

- Real-time solutions with dependable & satisfactory results are achieved by employing structured, sparsity programmed matrix solution techniques
- Contingency constrained economic dispatch requirements are met by the lagrangian relaxation algorithm which is one of the original works for economic dispatch.
- The method is able to deal with practical components of a power system and the optimization schedule is included in the power flow with no area interchange.
- Easily applicable to other optimization schedules and was validated on a practical 247-bus system.

4. [19]Samer Takriti and John R.Birge, " Using Integer programming to refine lagrangian based unit commitment solutions", IEEE Transactions on Power Systems, Vol 15, no 1, Feb 2000, pp 151-156.

- Solved a unit commitment problem, having an infeasible initial starting point, by lagrange relaxation technique.
- Four objective functions namely, fuel cost, active and reactive losses, have been considered in the solution of Lagrangian method. This is evident from: Lagrange method required an execution time of five minutes to solve up to 2000 buses on large mainframe computers.
- A feasible solution from an infeasible starting point was obtained by formation of a sequence of lagrange multipliers that converge to the optimal solution of the original nonlinear problem.
- Unit commitment solutions based on the above methods, for four different systems with a range of 350-,1100- ,1600- and 1900- buses, are evaluated and the observations are:
- The augmented Lagrangian solves a sequence of subproblems with a changed objective. It is based wholly on the first derivative information. By this method a viable solution can be obtained in the presence of power flow divergence.
- Development of the economic dispatch problem by this method is much more complex than the classical economic dispatch problem.

5. [62] Q.Zhai, X.Guan and J.Cui, "unit commitment with identical units:sucessive subproblem solving method based on lagrangian relaxation", IEEE transactions on Power Systems., Vol 17, Nov 2002, pp 1250-1257.

- It has been shown that when the Lagrangian relaxation based methods are applied to solve power system unit commitment, the identical solutions to the subproblems associated with identical units may cause the dual solution to be far away from the optimal solution and serious solution oscillations.
- As a result, the quality of the feasible solution obtained may be very unsatisfactory. This issue has been long recognized as an inherent disadvantage of Lagrangian relaxation based methods.
- In this paper, the homogeneous solution issue is identified and analyzed through a simple example. Based on this analysis, a successive subproblem solving method is developed. The new method combines the concepts of augmented Lagrangian relaxation and surrogate subgradient to produce a good search direction at the high level.
- The low level subproblems including those corresponding to the identical units are solved successively so that the commitments of the identical units may not be homogeneous in the dual solution.
- Compared with the standard Lagrangian relaxation method, the new method can obtain better dual solutions and avoid the solution oscillations. Numerical testing shows the new method is efficient and the quality of the feasible solution is greatly improved.

6. [43]Slobodan Ruzic and Nikola Rajakovic, "A new approach for solving extended unit commitment problem", IEEE Transactions on Power Systems, Vol 6, No 1, Feb 1991, pp 269-277.

- Presents an original approach for solving extended unit commitment.
- The unit ramp rates have been incorporated into a dual optimization algorithm, giving a

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possibility of application of feasible direction method for primal problem solution.

- The mathematical model developed in this paper also included the transmission capacity limits, regulation reserve requirements of pre specified group of units, transmission losses and fuel constraints.

2.3.2 Merits and demerits of Lagrange Relaxation method

The merits and demerits of lagrange relaxation method can be summarized as follows:

Merits:

1) The method is well suited to infeasible or divergent starting points.

2) Unit commitment in ill conditioned and divergent systems can be solved in most cases.

3) The Lagrange relaxation method does not require the use of penalty factors or the determination of gradient step size which can cause convergence difficulties. In this way convergence is very fast.

4) The method can solve both the load flow and economic dispatch problems.

5) During the optimization phase all intermediate results feasible and the algorithm indicates whether or not a feasible solution is possible.

6) The accuracy of lagrange relaxation method is much higher compared to other established methods.

Demerits

1. The main problems of using the lagarangian relaxation in unit commitment are:

a) difficult in obtaining the convergence of approximating programming cycle

b) Difficulties in obtaining solution of lagrangian programming in large dimension of approximating unit commitment problems.

c) Complexity and reliability of Lagrangian relaxation

2. Lagrangian relaxation based techniques have some disadvantages associated with the piecewise quadratic cost approximations.

2.4 Branch And Bound Method

The branch and bound procedure consists of repeated application of the following steps. First that portion of the solution space in which the optimal solution is known to lie is partitioned into subsets. Second, if all of the elements in a subset violate the constraints of the minimization problem, then that subset is eliminated from further consideration. Third, an upper bound on the minimum value of the objective function is computed. Finally lower bounds are computed on the value of objective function when the decision variables are constrained to lie in each subset still under consideration. A subset is then fathomed if its lower bound exceeds the upper bound of the minimization problem, since the optimal decision variable cannot lie in that subset. Convergence takes place when only one subset of decision variables remain and the upper and lower bounds are equal for that subset.

2.4.1 Significant Contributions

1. [22] Arthur I.Cohen and Miki Yoshimura, "A Branch and Bound Algorithm for unit commitment", IEEE transactions on Power Apparatus and Systems, Vol., PAS-102, No 2, Feb 1983, pp 444-450.

This algorithm differs from the other techniques such that:

- It assumes no priority ordering
- It allows time-dependent start up costs
- It can directly take into account stochastic demand and unit outages.

This method is based on the assumption that units with non zero start up cost will cycle at most once in a 24 hour period.

It incorporated time-dependent minimum up and down constraints and it does not require a priority ordering of the units.

This method can be extended to allow for a probabilistic reserve constraint.

2.[46]. G.S.lauer, N.R.Sandell,N.R.Bertsekas and T.A.Posbergh, "Solution of large scale optimal unit commitment problems," IEEE Transactions of power systems, Vol., PAS 101, Jan 1982, pp 79-96

- Solved the unit commitment problem, using a Branch and bound technique.
- Equality and inequality constraints were included in the linear programming problem Irrespective of the size of the problem, 20-60 iterations were required to attain the solution
- Using this algorithm, both linear and nonlinear optimization problems with large numbers of constraints, were solved.
- The algorithm was employed to solve, a large problem comprising 880 variables and 3680 constraints, and the sparsity of the constraint matrix was taken in to account.
- This method was validated on up to 118 buses with 3680 constraints and it was realized that the dual affine algorithm is only suitable for a problem with inequality constraints.
- With the problem modified to a primal problem with only inequality constraints, Adler's method was employed to get initial feasible points
- The advantage of the branch and bound method over the other methods was recognized.

2.4.2 Merits and Demerits of Branch and bound method

Merits

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1. The branch and bound method is one of the most efficient algorithms. Maintains good accuracy while achieving great advantages in speed of convergence of as much as 12:1 in some cases when compared with other known linear programming techniques.
2. The branch and bound method can solve a large scale linear programming problem by moving through all the branches, rather than the boundary as in the simplex method, of the feasible region to find an optimal solution.
3. The branch and bound method is preferably adapted to UC due to its reliability, speed and accuracy.
4. It provides user interaction in the selection of constraints.

Demerits

1. Limitation due to starting and terminating conditions
2. Infeasible solution if step size is chosen improperly.

2.5 Integer And Mixed Integer Method

Integer programming optimizes integer function of integer variables. A modification of standard integer programming that allows non-integer function is known as mixed-integer programming (MIP). MIP treats the objective and constraint functions as continuous and the variables as integers

1.[23] T.S.Dillon, K.W.Edwin, H.D.Kochs and R.J.Taud, "Integer Programming approach to the problem of optimal unit commitment with probabilistic reserve determination", IEEE transactions on Power Apparatus and Systems, Vol., PAS-97, No 6, Nov 1978, pp 2154-2166.

- A method for determining the unit commitment schedule for hydro-thermal systems using extensions and modifications of the Branch and Bound method for Inteler Programming has been developed.
- Significant features of the method include its computational practicability for realistic systems and proper representation of reserves associated with different risk levels.
- Contracts relating to power interchange have also been adequately modeled for such an approach.

2.[24] Samer Takriti and John R.Birge, " Using Integer programming to refine lagrangian based unit commitment solutions", IEEE Transactions on Power Systems, Vol 15, no 1, Feb 2000, pp 151-156.

- A technique for refining the unit commitment obtained from solving the Lagrangian has been developed.
- Their model was a computer program with nonlinear constraints. It has been shown that it can be solved to optimality using the branch-and-bound technique.
- Numerical results indicated a significant improvement in the quality of the solution obtained

3. INTELLIGENT METHODOLOGIES

Intelligent methods mainly include Simulated annealing, Genetic Algorithm, Ant colony, Particle Swarm Optimization, fuzzy logic and neural networks.

The drawbacks of conventional methods can be summarized as three major problems:

- Firstly, they may not be able to provide optimal solution and usually getting stuck at a local optimal.
- Secondly, all these methods are based on assumption of continuity and differentiability of objective function which is not actually allowed in a practical system.

3.1 Simulated Annealing

The motivation for Simulated Annealing algorithm comes from the analogy between the physical annealing of solids and combinatorial optimization problems. Physical annealing refers to the process of finding low energy states of a solid by initially melting the substance and then lowering the temperature slowly, spending a long time at temperatures close to the freezing point. The recent interest began with the work of Kirkpatrick (1983) and Cerny (1985). They showed how a model for simulating the annealing of solids, as proposed by Metropolis et al. (1953) could be used for optimization problems, where the objective function to be minimized corresponded to the energy of states of the solid. The Simulated annealing method resembles the cooling process of molten metals through annealing. At high temperature, the atoms in the molten metal can move freely with respect to each other, but as the temperature is reduced, the movement of the atoms gets restricted. The atoms start to get ordered and finally form crystals having the minimum possible energy.

1.[66] F.Zhuang and F.D.Galiana, "Unit commitment by Simulated Annealing", IEEE Transactions on Power Systems, Vol.5, No 1 Feb 1990, pp 311-318.

- A general optimization method, known as simulated annealing, has been applied to generation unit commitment.

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- By exploiting the resemblance between a minimization process and the cooling of a molten metal, simulated annealing generates feasible solutions randomly and moves among these solutions using a strategy leading to a global minimum with high probabilities.
- The method assumed no specific problem structures and was found to be highly flexible in handling unit commitment constraints. A concise introduction to the method has been given. Numerical results on test systems of up to 100 units have been reported

2. [67] U.D.Annakage, T.Numnonda and N.C.Pahalawatha, "Unit commitment by parallel simulated annealing", IEE Proc., Generation, Transmission and Distribution, Vol 142, No 6, Nov 1995, pp 595-600.

- The application of parallel simulated annealing for unit commitment problem has been investigated. Two parallel simulated annealing concepts, speculative computation and serial subset, are applied to a unit commitment problem of ten thermal generators.
- A combined scheme where speculative computation is used in the initial phase and the serial subset is used in the final phase has also been presented.
- The parallel simulated annealing schemes are tested with an example problem and the results show that the parallel schemes can considerably speed up the computation of simulated annealing

3. [68]A.H.Mantawy, Y.L.Abdel magid and Shokri Z.Selim, " A simulated Annealing Algorithm for unit Commitment", IEEE Transactions on Power Systems, Vol 13, No 1,Feb 1998, pp 197-204.

- This paper presents a simulated annealing algorithm (SAA) to solve the unit commitment problem (UCP).
- New rules for randomly generating feasible solutions are introduced. The problem has two subproblems: a combinatorial optimization problem; and a nonlinear programming problem. The former is solved using the SAA while the latter problem is solved via a quadratic programming routine.
- Numerical results showed an improvement in the solutions costs compared to previously obtained results

4. [69] C.Christober Asir Rajan and M.R.Mohan, "An evolutionary programming based simulated annealing method for solving the unit commitment problem", Electrical Power and Energy systems 29 , 2007, pp 540-550.

- A new approach to solve the short-term unit commitment problem using an evolutionary programming based simulated annealing method has been proposed.
- The main objective was to find the generation scheduling such that the total operating cost can be minimized, when subjected to a variety of constraints. Evolutionary programming, which happens to be a global optimisation technique for solving unit commitment Problem, operates on a system, which is designed to encode each unit's operating schedule with regard to its minimum up/down time.
- In this, the unit commitment schedule is coded as a string of symbols. An initial population of parent solutions is generated at random. Here, each schedule is formed by committing all the units according to their initial status ("flat start").
- The Neyveli Thermal Power Station (NTPS) Unit-II in India demonstrates the effectiveness of the proposed approach; extensive studies have also been performed for different power systems consists of 10, 26, 34 generating units.
- Numerical results are shown comparing the cost solutions and computation time obtained by using the Evolutionary Programming method and other conventional methods like Dynamic Programming, Lagrangian Relaxation and Simulated Annealing and Tabu Search in reaching proper unit commitment.

5. [70] K.P.Wong and Y.W.Wong, "Short term hydrothermal scheduling part I: simulated annealing approach", Proc., Inst., Elect, Eng., Gen, Transm, Dist., Vol 141, 1994, pp 497-501.

- The paper developed a short-term hydrothermal scheduling algorithm based on the simulated annealing technique. In the algorithm, the power balance constraint, total water discharge constraint, reservoir volume limits and constraints on the operation limits of the hydrothermal generator and the thermal generator were fully accounted for.
- The relative operation capacities of the hydroplant and the thermal plant were also considered.
- A relaxation method for checking the limits was proposed and included in the algorithm. The performance of the algorithm was demonstrated through a test example

6.[71]A. Viana, , J.P. de Sousa, M.Matos, "Simulated annealing for the unit commitment

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problem", Power Tech Proceedings, 2001 IEEE Porto , 2001, Vol 2, pp 1-4.

- Due to their efficiency and their interesting design and implementation features, metaheuristics have been used for a long time with success, in dealing with combinatorial problems.
- They have been applied to the unit commitment problem with rather interesting results that justify further research in the area.
- In this paper a simulated annealing approach to the unit commitment problem has been presented. Two coding schemes have been compared, new neighborhood structures have been presented and some searching strategies have been discussed.
- Preliminary computational experience, performed on some test instances, shows that this approach is flexible, effective and able to handle variations on the problem structure

7. [72]D.N.Simopoulos,S.D.Kavatza, C.D.Vournas, "Reliability Constrained Unit Commitment Using Simulated Annealing", IEEE Transactions in Power systems, Issue 4, Nov 2006, pp 1699 – 1706.

- This paper proposed a new method for the incorporation of the unit unavailability and the uncertainty of the load forecast in the solution of the short-term unit commitment problem.
- The above parameters were taken into account in order to assess the required spinning reserve capacity at each hour of the dispatch period, so as to maintain an acceptable reliability level.
- The unit commitment problem has been solved by a simulated annealing algorithm resulting in near-optimal unit commitment solutions. The evaluation of the required spinning reserve capacity is performed by implementing reliability constraints, based on the expected unserved energy and loss of load probability indexes.
- In this way, the required spinning reserve capacity is effectively scheduled according to the desired reliability level. Numerical simulations have proven the efficiency of the proposed method

8. [73]Suzannah Yin Wa Wong, "An enhanced simulated annealing approach to unit commitment", International Journal of Electrical Power & Energy Systems, Vol 20, Issue 5, June 1998, pp 359-368.

- Owing to the inability of simulated annealing (SA) to generate solutions that always satisfy all the constraints, the performance of a pure SA-approach established by previous researchers in solving the unit commitment (UC) problem was not so promising.
- The SA technique is, however, easy to implement, requires little expert knowledge and is not memory intensive. Hence, this work attempted to develop an enhanced SA-approach for solving the UC problem by adopting mechanisms to ensure that the candidate solutions produced are feasible and satisfy all the constraints.
- The performance of the enhanced SA-based algorithm was demonstrated through two real-life UC problems in power systems. The results of the two studies were also compared with previous reported UC solution methods.

3.1.1 Merits and Demerits of Simulated Annealing

The following are the merits and demerits of simulated annealing

Merits

- Simulated annealing can deal effectively with arbitrary systems and cost functions
- It statistically guarantees finding an optimal solution
- It is relatively easy to code, even for complex problems
- It generally gives a good solution

Demerits

- If a large value of initial temperature (T) is considered, it takes a number of iterations for convergence and if a small value of T is considered, the search might not be adequate before converging to a true optimum
- Considering a large value of 'n' increases the computational time
- The choice of initial temperature and 'n' remains a trail and error process in Simulated Annealing

3.2 Binary Coded Genetic Algorithm Method

It is observed that Genetic Algorithm (GA) is an appropriate method to solve this problem, which eliminates the above drawbacks. GAs differs from other optimization and search procedures in four ways:

1. GAs work with a coding of the parameter set, not the parameters themselves. Therefore GAs can easily handle the integer or discrete variables.
2. GAs search within a population of points, not a single point. Therefore GAs can provide a globally optimal solution.
3. GAs use only objective function information, not derivatives or other auxiliary knowledge. Therefore GAs can deal with non-smooth, non-continuous and

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non-differentiable functions which are actually exist in a practical optimization problem.

4. GAs use probabilistic transition rules, not deterministic rules. We use GA because the features of GA are different from other search techniques in several aspects, such as:

- The algorithm is a multipath that searches many peaks in parallel and hence reducing the possibility of local minimum trapping.
- GA works with a coding of parameters instead of the parameters themselves. The coding of parameter will help the genetic operator to evolve the current state into the next state with minimum computations.
- GA evaluates the fitness of each string to guide its search instead of the optimization function.

1. [47].Shyh Jier Huang and Ching-Lien Huang, "Application of genetic based neural network to thermal unit commitment", IEEE Transactions on Power Systems, Vol 12, No 2, May 1997, pp 654-660.

- Solved unit commitment problems using Genetic Algorithm method. Its merits are, the non restriction of any convexity limitations on the generator cost function and effective coding of Gas to work on parallel machines.
- GA is superior to Dynamic programming, as per the performance observed in Economic dispatch problem.
- The run time of the second GA solution (EGA method) proportionately increases with size of the system.

2. [48] A.H.Mantawy, Y.L.Abdel magid and Shokri Z.Selim, "A new genetic –tabu search algorithm for unit commitment problem", Electric Power Systems Research 49 (1999), pp 71-78.

- Solved Large Scale unit commitment by combined approach of Genetic Algorithm and tabu search.
- Designed new encoding technique where in, the chromosome has only an encoding normalized incremental cost.
- The approach gives good performance and discards operational and insecure violations.
- The dynamical hierarchy of the coding procedure designed in this approach, enables to code numerous control variables in a practical system within a suitable string length.
- There is no correlation between total number of bits in the chromosome and number of units.
- This method obtains better optimal fuel cost of the normal case and global optimal point compared to gradient based conventional method.

3. [49]A.H.Mantawy, Y.L.Abdel magid and Shokri Z.Selim, "Integrating genetic algorithms, tabu search and simulated annealing for unit commitment problem", IEEE Transactions on Power Systems, Vol 14, No 3, Aug 1999, pp 829-836.

- Provided solution to optimal power flow problem of large distribution system using simple genetic algorithm-tabu search and simulated annealing.
- The objective includes fuel cost minimization and retaining the power outputs of generators, in their safe limits.
- Constraints are bifurcated in to active and passive to reduce the CPU time.
- Active constraints are incorporated in Genetic Algorithm to derive the optimal solution, as they only have direct access to the cost function.
- Using simple genetic operations namely, proportionate reproduction, simple mutation and one point cross over in binary codes, results indicate that a simple GA-tabu search-SA will give good result.
- With more number of constraints typical to a large scale system, GA takes longer CPU time to converge.

4. [50]K. A. Juste, H. Kitu, E. Tunaka and J. Hasegawa, "An Evolutionary Programming Solution to the Unit Commitment Problem", IEEE Transactions on Power Systems, Vol. 14, No. 4, Nov 1999, pp 1452-1459.

- Improved Genetic Algorithm integrated with Multiplier Updating (IGA – MU) is employed to solve complicated problem of Power unit commitments having valve point effects and multiple fuels.
- An effective search to actively explore solutions is achieved by IGA coupled with an improved evolutionary direction operator. The MU is used to deal the equality and inequality constraints of the unit commitment problem.
- The method has several important advantages namely, easy concept; simple implementation, more useful than earlier approaches, better performance, compared to CGA – MU (Conventional Genetic Algorithm with Multiplier Updating), robustness of algorithm, adaptable to large scale systems; automatic tuning of the randomly assigned penalty to a proper value, and the condition for only a small population in the accurate and practical unit commitment problem.

5. [51] A Rudolf and R Baryrleithner, "A genetic algorithm for solving unit commitment problem of

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a hydro-thermal power system", IEEE Transactions on Power Systems, Vol 14, No 4, Nov 1999, pp 1460-1468.

- A GA method was employed to solve the complex problem of unit commitment.
- Probabilities of GA operations such as cross over and mutation were taken as the normal values. Algorithms for GAbased UC was created and analysed.
- Results show that the GA has quicker convergence and smaller generation costs in comparison to other methods.
- The GA based UC demonstrated better performance in respect of convergence, consistency in different runs and lower cost of generation in comparison to simple other methods.

6. [52] K.S.Swarup and S.Yamashiro, "Unit Commitment solution methodology using genetic algorithm", IEEE Transactions on Power Systems, Vol 17, No 1, Feb 2002, pp 87-91.

- Genetic Algorithm was used to solve unit commitment problem.
- The method uses the Genetic Algorithm (GA) to get a close to global solution for solving the problem of UC to decide the optimal global solution.
- The method was validated on the standard IEEE system and the results show that the approach provided a good solution as compared to the previous methods.

7. [60] G.B.Sheble, "Unit commitment by genetic algorithm with penalty methods and a comparison of Lagrangian search and genetic algorithm-economic dispatch example", Electric Power Energy Systems., Vol 18, No 6, Feb 1996, pp 339-346.

- Genetic algorithm has been applied to the unit commitment scheduling problem and to the economic dispatch of generating units.
- The first half of the paper applies the genetic algorithm to the unit commitment scheduling problem, which is the problem of determining the optimal set of generating units within a power system, to be used during the next one to seven days.
- The first half of the paper presents an explanation of the genetic-based unit commitment algorithm, the implementation of this algorithm and a discussion of the problems encountered when using this algorithm with penalty methods for unit commitment scheduling.
- The second half of the paper applies a genetic algorithm to solve the economic dispatch problem. Using the economic dispatch problem as a basic for comparison, several approaches to implementing a refined genetic algorithm are explored. The results are verified for a sample problem using a classical Lagrangian search technique.

8. [61] H.Yang, P.Yang and C.Huang, "A parallel genetic algorithm approach to solving unit commitment problem: implementation on the transputer networks", IEEE Transactions on Power Systems., Vol 12, May 1997, pp 661-668

- Through a constraint handling technique, this paper proposes a parallel genetic algorithm (GA) approach to solving the thermal unit commitment (UC) problem.
- The developed algorithm is implemented on an eight-processor transputer network, processors of which are arranged in master-slave and dual-direction ring structures, respectively.
- The proposed approach has been tested on a 38-unit thermal power system over a 24-hour period. Speed-up and efficiency for each topology with different number of processor are compared to those of the sequential GA approach.
- The proposed topology of dual-direction ring is shown to be well amenable to parallel implementation of the GA for the UC problem

9. [63] X.Ma, A.A.El-keib, R.E.Smith and H.Ma, "A genetic algorithm based approach to thermal unit commitment of electric power systems", Electric Power systems Research, Vol 34, 1995, pp 29-36.

- A new approach based on genetic algorithms to solve the thermal unit commitment problem of electric power systems has been presented.
- Genetic algorithms (GAs) are general search techniques based on the biological metaphor and are very suitable for solving combinatorial optimization problems. Because of its nonconvex and combinatorial nature, the unit commitment problem is difficult to solve by conventional programming methods.
- However, it is well suited for the application of the GAs. A key to the success of the implementation of the proposed algorithm is a newly developed knowledge-augmented mutation-like operator, named here the forced mutation.
- It was found to improve, significantly, the efficiency of the GA in solving the unit commitment problem. Two different coding schemes were devised and tested. In addition, the effects of GAs' control variables on convergence were extensively studied. The

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approach was tested on a ten-unit system. Test results clearly reveal the robustness and promise of the proposed approach.

3.2.1 Merits and Demerits of Genetic Algorithm

The Merits and Demerits of Genetic Algorithm are summarized and given below.

Merits

1. GAs can handle the Integer or discrete variables.
2. GAs can provide a globally optimum solution as it can avoid the trap of local optima.
3. GAs can deal with the non-smooth, non continuous, non-convex and non differentiable functions which actually exist in practical optimisation problems.
4. GAs has the potential to find solutions in many different areas of the search space simultaneously, there by multiple objectives can be achieved in single run.
5. GAs are adaptable to change, ability to generate large number of solutions and rapid convergence.
6. GAs can be easily coded to work on parallel computers.

Demerits

1. GAs are stochastic algorithms and the solution they provide to the UC problem is not guaranteed to be optimum.
2. The execution time and the quality of the solution, deteriorate with the increase of the chromosome length, i.e., the UC problem size.
3. If the size of the power system is increasing, the GA approach can produce more in feasible springs which may lead to wastage of computational efforts.

3.3 Ant Colony Optimization Method

This algorithm is a member of ant colony algorithm family, in swarm intelligence methods, and it constitutes some meta heuristic optimizations. Initially proposed by Marco Dorigo in 1992, the first algorithm was aiming to search for an optimal path in a graph, based on the behavior of ants seeking a path between their colony and a source of food. The original idea has since diversified to solve a wider class of numerical problems, and as a result, several problems have emerged, drawing on various aspects of the behavior of ants.

1. [74]Shyh-Jier Huang, "Enhancement of hydroelectric generation scheduling using ant colony system based optimization approaches", IEEE Transactions on Power Systems, Vol 16, No 3, Sep 2001, pp 296-301.

- In this paper, an ant colony system (ACS) based optimization approach been proposed for the enhancement of hydroelectric generation scheduling.
- To apply the method to solve this problem, the search space of multi-stage scheduling is first determined. Through a collection of cooperative agents called ants, the near-optimal solution to the scheduling problem is effectively achieved.
- In the algorithm, the state transition rule, local pheromone-updating rule, and global pheromone-updating rule are all added to facilitate the computation. Because this method can operate the population of agents simultaneously, the process stagnation can be better prevented.
- The optimization capability can be thus significantly enhanced. The proposed approach has been tested on Taiwan Power System (Taipower) through the utility data. Test results demonstrated the feasibility and effectiveness of the method for the application considered

2. [75] N.S.Sisworahardjo and A.A.El-Keib, "Unit Commitment using the ant colony search algorithm", Proc., of 2002 Large Engineering systems Conference on Power Engineering, pp 2-6.

- The paper presented an ant colony search algorithm (ACSA)-based approach to solve the unit commitment (UC) problem. This ACSA algorithm is a relatively new meta-heuristic for solving hard combinatorial optimization problems.
- It is a population-based approach that uses exploitation of positive feedback, distributed computation as well as a constructive greedy heuristic. Positive feedback is for fast discovery of good solutions, distributed computation avoids early convergence, and the greedy heuristic helps find adequate solutions in the early stages of the search process.
- The ACSA was inspired from natural behavior of the ant colonies on how they find the food source and bring them back to their nest by building the unique trail formation.
- The proposed approach determines the search space of multi-stage scheduling followed by considering the unit transition related constraints during the process of state transition.
- The paper described the proposed approach and presents test results on a 10-unit test system that demonstrated its effectiveness in solving the UC problem.

3. [76] Sishaj P.Simon, Narayana Prasad Padhy and R.S.Anand, " An Ant Colony System approach for

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unit commitment problem", Electric power Systems Research 28 (2006), pp 315-323.

- Ant colony system (ACS) model is more suitable for solving combinatorial optimization problem, so ACS has been applied to the hard combinatorial Unit commitment problem (UCP).
- Here, a parallel can be drawn of ants finding the shortest path from source (nest) to its destination (food) and solving UCP to obtain the minimum cost path (MCP) for scheduling of thermal units for the demand forecasted.
- Multi-stage decisions give ant search a competitive edge over other conventional approaches like dynamic programming (DP) and branch and bound (BB) integer programming techniques. Before the artificial ants starts finding the MCP, all possible combination of states satisfying the load demand with spinning reserve constraint are selected for complete scheduling period which is called as the ant search space (ASS).
- Then the artificial ants are allowed to explore the MCP in this search space. The proposed model has been demonstrated on a practical ten unit system and a brief study has been performed with respect to generation cost, solution time and parameter settings on a numerical example with four unit system.

4.[77] Ahmed Yousuf Saber and Abdulaziz Mohammad Alshareef, "Scalable unit commitment by memory-bounded ant colony optimization with A Local Search", Electrical Power and Energy Systems 30, 2008, pp 403-414.

- Ant colony optimization (ACO) has been successfully applied in optimization problems. Performance of the basic ACO for small problems with moderate dimension and searching space has also been satisfactory.
- As the searching space grows exponentially in the large-scale unit commitment problem, the basic ACO is not applicable for the vast size of pheromone matrix of ACO in practical time and physical computer-memory limit.
- However, memory-bounded methods prune the least-promising nodes to fit the system in computer memory.
- Therefore, the paper proposed memory-bounded ant colony optimization (MACO) in this paper for the scalable (no restriction for system size) unit commitment problem. This MACO intelligently solves the limitation of computer memory, and does not permit the system to grow beyond a bound on memory.
- In the memory-bounded ACO implementation, a heuristic is introduced to increase local searching ability and probabilistic nearest neighbor method is applied to estimate pheromone intensity for the forgotten value. Finally, the benchmark data sets and existing methods are used to show the effectiveness of the proposed method.

5. [78]Nascimento, F.R.; Silva, I.C.; Oliveira, E.J.; Dias, B.H.; Marcato, A.L.M, "Thermal Unit Commitment using improved ant colony optimization algorithm via Lagrange multipliers", PowerTech, 2011, pp 1-5

- This article proposes the use of Lagrange multipliers associated with discrete variables of the Thermal Unit Commitment problem as a source of information for the ant colony algorithm.
- To achieve this, the discrete variables that are inherent to the problem are mitigated through a sigmoid function. By doing so, the non-linear optimization issue is solved through the use of the primal-dual interior-point method, generating Lagrange multipliers associated to the ON/OFF decision variables as subproducts which are used to draw up a list of priorities, where part of the colony will make use of this information in the search for solutions.
- The results obtained show that the information taken into consideration significantly improves the efficiency of the colony search process.

6. [79] K.Vaisakh and L.R.Srinivas, "Evolving ant colony optimization based unit commitment", International Journal of Applied soft computing, Vol 11, Issue 2, Mar 2011

- Ant colony optimization (ACO) was inspired by the observation of natural behavior of real ants' pheromone trail formation and foraging. Ant colony optimization is more suitable for combinatorial optimization problems.
- ACO is successfully applied to the traveling salesman problem. Multistage decision making of ACO gives an edge over other conventional methods.
- This paper proposed evolving ant colony optimization (EACO) method for solving unit commitment (UC) problem. The EACO employs genetic algorithm (GA) for finding optimal set of ACO parameters, while ACO solves the UC problem.
- Problem formulation took into consideration the minimum up and down time constraints, startup cost, spinning reserve, and generation limit constraints. The feasibility of the proposed approach was demonstrated on two

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different systems. The test results were encouraging and compared with those obtained by other methods.

7. [80] K. Rajangam, V. P. Arunachalam R. Subramanian, "Ant colony search algorithm to solve unit commitment problem", International Journal of current computer science and Technology, Vol 1, No 6, 2011

- The paper presents an ACSA based approach to solve the unit commitment problem. This ACSA algorithm is a relatively new meta-heuristic for solving hard combinatorial optimization problems. It is a population-based approach that uses exploitation of positive feedback, distributed computation as well as constructive greedy heuristic.
- Problem formulation takes into consideration of the minimum up and down time constraints, start up cost, shut-down cost, spinning reserve, ramp rate constraints and generation limit constraints.
- The feasibility of this proposed approach is demonstrated for 4 and 10 unit systems. The test results are encouraging and are compared with those obtained by other methods.

3.3.1 Merits and Demerits of Ant Colony Optimization method

The Merits and Demerits of ant colony optimization method are summarized and given below.

Merits:

1) There is an inherent parallelism in the case of ant colony optimization

2) The presence of positive feedback accounts for rapid discovery of good solution

3) It is highly efficient for solving problems like traveling salesman problem and other complicated problems

4) Can be employed in dynamic applications since it easily adapts to changes such as new distance etc

Demerits

1)The analysis of ant colony optimization theoretically is highly difficult

2) The probability distribution changes by iteration by iteration only

3) Research in the case of ant colony optimization is experimental rather than theoretical

4) Time taken by the algorithm to converge is uncertain even though it definitely converges.

3.4 Particle Swarm Optimization Method

Particle swarm optimization (PSO) is a population based stochastic optimization technique inspired by social behavior of bird flocking or fish schooling. In PSO, the search for an optimal solution is conducted using a population of particles, each of which represents a candidate solution to the optimization problem. Particles change their position by flying round a multidimensional space by following current optimal particles until a relatively unchanged position has been achieved or until computational limitations are exceeded. Each particle adjusts its trajectory towards its own previous best position and towards the global best position attained till then. PSO is easy to implement and provides fast convergence for many optimization problems and has gained lot of attention in power system applications recently.

1. [53] Nasser Sadati, Mahdi Hajian and Majid Zamani, "Unit Commitment Using Particle Swarm-Based-Simulated Annealing Optimization Approach", Proc., of the IEEE Swarm Intelligence Symposium, April 2007, pp 297-302

- Provided capable and dependable evolutionary based method, the Particle swarm optimization (PSO) along with simulated annealing, to solve problem of unit commitment.
- For optimal position of UC problem control variables, PSO-SA algorithm is used.
- Presumptions forced on the optimized objective functions are considerably removed by this optimization technique in solving unit commitment problem,
- Validation was done for the objective functions such as fuel cost minimization,.
- Observations prove that this method is better than the conventional methods and Genetic Algorithms in respect of efficacy and robustness.

2. [55] Tomonobu Senjyu, Shantanu Chakraborty, Ahmed Yousuf Saber, Hirofumi Toyama, Atsushi Yona and Toshihisa Funabashi, "Thermal Generation Scheduling Strategy Using Binary Clustered Particle Swarm Optimization Algorithm", 2nd IEEE International Conference on Power and Energy (PECON 08), Dec, 2008, pp 872-877.

- Solved the complex unit commitment problem using an improved particle swarm optimization.
- Improved the performance of the conventional PSO by adopting this approach which uses the binary clustered type of particle swarm optimization.
- The global searching ability and getaway from local minimum is enhanced by uniting, the chaotic sequences with the linearly decreasing inertia weights.
- Further, the diversity of the population is enlarged by adding the velocity updation
- The global searching capability as well as preventing the solution from entrapment in local optima, by the above approaches.

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3.[56]Xiaohui Yuan, Hao Nie, Anjun Su, Liang Wang and Yanbin Yuan, "An improved binary particle swarm optimization for unit commitment problem", Expert Systems with Applications, 36, 2009, pp 8049-8055.

- Length of Chromosome is reduced and hence the size of population is reduced.
- Number of generations is reduced. This makes the computational effort simple and effective.
- The problem of use of real numbers in the production of population has been avoided. This makes the unit commitment as another simple GA search problem.
- Blind search is avoided.
- The process begins with no insignificant population.
- System nonlinearities are somewhat considered as the initial chromosome is obtained from the mathematical programming of nonlinear equations.

4.[59].Jong-Bae Park, Yun-Won Jeong, Joong-Rin Shin and kwang Y. Lee, An Improved particle Swarm Optimisation for Nonconvex Economic Dispatch Problems, IEEE Transactions Power Systems, vol.25, No 1, pp 156-166, Feb 2010.

- Solved the non convex economic dispatch problems using an improved particle swarm optimization.
- Improved the performance of the conventional PSO by adopting this approach which uses the chaotic sequences and the crossover operation.
- The global searching ability and getaway from local minimum is enhanced by uniting, the chaotic sequences with the linearly decreasing inertia weights.
- Further, the diversity of the population is enlarged by adding the crossover operation.
- The global searching capability as well as preventing the solution from entrapment in local optima, by the above approaches.

3.4.1 Merits and Demerits of PSO Method

Merits

1. PSO is one of the modern heuristic algorithms capable to solve large-scale non convex optimisation problems like unit commitment.
2. The main advantages of PSO algorithms are: simple concept, easy implementation, relative robustness to control parameters and computational efficiency.
3. The prominent merit of PSO is its fast convergence speed.
4. PSO algorithm can be realized simply for less parameter adjusting.
5. PSO can easily deal with non differentiable and non convex objective functions.
6. PSO has the flexibility to control the balance between the global and local exploration of the search space.

Demerits

1. The candidate solutions in PSO are coded as a set of real numbers. But, most of the control variables such as load changes and generation capacities change in discrete manner. Real coding of these variables represents a limitation of PSO methods as simple round-off calculations may lead to significant errors.
2. Slow convergence in refined search stage (weak local search ability).

4. NEED FOR ALTERNATE TECHNIQUES

An exhaustive literature survey is carried out for the existing UC methodologies and observations are presented. With the knowledge gained, need for alternative UC methodologies are discussed in detail, in this paper. The objective of this work is to explore the necessity for alternative approaches for UC solution that can overcome the disadvantages and retain advantages of the existing methodologies.

Limitations of mathematical methods

Limited capabilities in handling large-scale power system problems. They become too slow if the variables are large in number.

They are not guaranteed to converge to global optimum of the general non convex problems like UC.

The methods may satisfy necessary conditions but not all the sufficient conditions. Also they are weak in handling qualitative constraints.

Inconsistency in the final results due to approximations made while Linearizing some of the nonlinear objective functions and constraints.

Consideration of certain equality or inequality constraints makes difficulty in obtaining the solution.

The process may converge slowly due to the requirement for the satisfaction of large number of constraints.

Some mathematical models are too complex to deal with.

These methods are difficult to apply for the problems with discrete variables such as load variations and variations in generations.

Limitations of Evolutionary Algorithms

The following limitations may be observed in GA approach:

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The solution deteriorates with the increase of chromosome length. Hence to limit its size, limitations are imposed in consideration of number of control variables.
GA method tends to fail with the more difficult problems and needs good problem knowledge to be tuned.
Careless representation in any of the schemes that are used in the formation of chromosomes shall nullify the effectiveness of mutation and crossover operators.
The use is restricted for small problems such as those handling less variables, constraints etc.
GA is a stochastic approach where the solution is not guaranteed to be the optimum.
Higher computational time and conventional methods rather than GA method are well suited for finding a best solution of well behaved convex optimization problems of only few variables.

Necessity of Alternative Methodologies

The major necessities to go for alternate methodologies can be seen as follows:

- Improvements in Speed and good accurate solution.
- Need for consideration of large varieties of constraints.
- Need for avoiding the blind search, encountering with infeasible strings, and wastage of computational effort.
- Need for consideration of System nonlinearities.
- Need for reduction in population size, number of populations in order to make the computational effort simple and effective.
- Need for incorporating a local search method within an evolutionary algorithm that can overcome most of the obstacles that arise as a result of finite population size.
- Need for identification and selection of proper control parameters that influence exploitation of chromosomes and extraction of global optimum solution.
- Need for reducing time for searching for a global optimum solution and memory needed to process the population.
- Need for improvements in coding and decoding of Chromosome that minimizes the population size.
- By integrating objective functions, other than cost objective function, it can be said economical conditions can be studied together with system security constraints and other system requirements.

4.1. Fuzzy Logic

The real world is complex and complexity in the world generally arises from uncertainty. Electric power systems are large, complex, geographically widely distributed systems and influenced by unexpected events. These facts make it difficult to effectively deal with many power system problems through strict mathematical approaches alone. The salient feature of Fuzzy concept is that it provides a model free description of control system and does not require any model identification. In the last few years the applications of artificial intelligent techniques have been opening doors to convert human experience into a form understandable by computers. Advanced control based on artificial intelligent techniques is called intelligent control. Fuzzy logic is a technique to apply human-like thinking into a control system. A fuzzy system can be designed to emulate human deductive thinking that is, the process people use to infer conclusions from what they know.

1. [34] S.Saneifard, N.R.Prasad and Howard A Smolleck, "A fuzzy logic approach to unit commitment", IEEE Transactions on Power Systems, Vol 12, No 2, May 1997, pp 988-995.

- The application of fuzzy logic to the unit commitment problem is demonstrated.
- This method allows a qualitative description of the behavior of a power system, the system's characteristics, and response without the need for exact mathematical formulations.
- It is demonstrated, through a numerical example, that a fuzzy-logic-based approach achieves a logical and feasible economical cost of operation of the power system, which is the major objective of unit commitment

2. [35]N.P.Padhy, "Unit Commitment using hybrid models: a comparative study for dynamic programming expert system, fuzzy system and genetic algorithms", Electrical Power and Energy systems 23 (2000), pp 827-836.

- Hybrid models for solving unit commitment problem have been proposed.
- To incorporate the changes due to the addition of new constraints automatically, an expert system (ES) has been proposed.
- The ES combines both schedules of units to be committed based on any classical or traditional algorithms and the knowledge of experienced power system operators. A solution database, i.e. information contained in the previous schedule is used to facilitate the current solution process. The proposed ES receives the input, i.e. the unit commitment solutions from a fuzzy-neural network.

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- Due to the mathematical complexity of traditional techniques for solving unit commitment problem and also to facilitate comparison genetic algorithm, a non-traditional optimization technique has also been proposed.
- To demonstrate the effectiveness of the models proposed, extensive studies have been performed for different power systems consisting of 10, 26 and 34 generating units.
- The generation cost obtained and the computational time required by the proposed model has been compared with the existing traditional techniques such as dynamic programming (DP), ES, fuzzy system (FS) and genetic algorithms (GA).

3. [57] T.Aruldoss Albert Victoire and A.Ebenezer Jeyakumar, "A tabu search based hybrid optimization approach for a fuzzy modeled unit commitment problem", Electric power Systems Research 76 (2006) pp 413-425.

- A solution model for the unit commitment problem (UCP) using fuzzy logic to address uncertainties in the problem has been presented.
- Hybrid tabu search (TS), particle swarm optimization (PSO) and sequential quadratic programming (SQP) technique (hybrid TS–PSO–SQP) is used to schedule the generating units based on the fuzzy logic decisions.
- The fitness function for the hybrid TS–PSO–SQP is formulated by combining the objective function of UCP and a penalty calculated from the fuzzy logic decisions.
- The non-linear programming sub-problem of the UCP is solved using the hybrid PSO–SQP technique. Simulation results on a practical Neyveli Thermal Power Station system (NTPS) in India and several example systems validate, the presented UCP model is reasonable by ensuring quality solution with sufficient level of spinning reserve throughout the scheduling horizon for secure operation of the system.

4. [58] Ahmed Yousuf saber, T.Senjyu, Atsushi Yona, N.Urasaki and Toshihisa Funabashi, "Fuzzy unit commitment solution-A novel twofold simulated annealing approach", Electric Power systems Research 77 (2007), 1699-1712.

- A twofold simulated annealing (twofold-SA) method for the optimization of fuzzy unit commitment formulation has been proposed.
- In this technique, simulated annealing (SA) and fuzzy logic are combined to obtain SA acceptance probabilities from fuzzy membership degrees. Fuzzy load is calculated from error statistics and an initial solution is generated by a priority list method.
- The initial solution is decomposed into hourly-schedules and each hourly-schedule is modified by decomposed-SA using a bit flipping operator.
- A new solution consists of these hourly-schedules of entire scheduling period after repair, as unit-wise constraints may not be fulfilled at the time of an individual hourly-schedule modification.
- This helps to detect and modify promising schedules of appropriate hours. In coupling-SA, this new solution is accepted for the next iteration if its cost is less than that of current solution. The proposed method is tested using standard reported data sets. Numerical results show an improvement in solution cost and time compared to the results obtained from other existing methods.

5. [64] N.P.Padhy, V.R.Ramachandran and S.R.Paranjothi, "Fuzzy Decision system for unit commitment risk analysis", International Journal of Power Energy systems., Vol 19, No 2, 1999, pp 180-185.

- In this paper, a possibilistic approach has been applied in analyzing the effect of load uncertainties on unit commitment risk analysis rather than the probabilistic approach using the usual Markov model.
- The risk analysis, which is the analysis of the risk of having insufficient committed capacity to compensate for unit failures and/or load variations, plays an important role in running an electric utility economically.
- Key factors such as load demand and reserve margin are treated as fuzzy variables. A fuzzy decision system has been developed to determine the risk associated with a given load curve and also to select the units to be on or off based on fuzzy variables.

5. CONCLUSIONS

Because of the nature of the problem, in recent times artificial intelligent approach has found to be more attracting the researchers to solve the unit commitment problem. This survey has explored the advantages and disadvantages in evolutionary algorithms like Genetic algorithms, particle swarm optimization along with exploring the conventional techniques of solving unit commitment problem. With reference to UC, this survey provides basic up gradations required for solving UC solution methodologies. In this survey various popular

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techniques in unit commitment, covering both Conventional as well as Intelligent methodologies have been covered. To begin with, the conventional Mathematical methods of solving the unit commitment have been discussed. Generally the objective function is taken as minimization of total production cost of scheduled generating units, as it reflects current economic dispatch practice and importantly cost related aspect is always ranked high among operational requirements in Power Systems. The objectives of UC have been mentioned, which include reduction of the costs of meeting the load demand for a power system while up keeping the security of the system without exceeding the generator limits.

In addition, the challenges before UC which remain to be answered are explained. It is to be mentioned, in the previous research work, attempt is made to meet the challenge of coping up with response time requirements, for on line use. The conventional methods include Priority List Method, Dynamic Programming Method, Lagrange Relaxation Method, Branch and Bound Method, Integer and Mixed Integer method. Among these methods, the Lagrange relaxation method is found to be the most efficient algorithm. It maintains good accuracy while achieving the speed of convergence in some cases when compared to other known linear programming methods. The method can solve large scale linear programming provided user interaction in the selection of constraints. The Intelligent methods covered are Simulated annealing, GA, Ant colony, PSO and Fuzzy logic methods. These methods are suitable in solving multiple objective problems as they are versatile in handling qualitative constraints. The advantages of the intelligent methods include learning ability, fast convergence and their suitability for non linear modeling. Among these two methods, fuzzy logic method has better advantages such as handling both integer and discrete variables, providing globally optimum solutions dealing with non smooth, non continuous, non convex and non differentiable functions normally found in practical optimization problems. Further fuzzy logic technique is adaptable to change, have ability to generate large number of solutions and provide rapid convergence.

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