

Unit Commitment in Power System: A Review

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Abstract: This study reveals to the basic studies of the problem a generating utility faces in order to decide which of its thermal units to start-up and to shutdown over a period of time to meet the forecasted load demand. It gives a review and general backgrounds of research and developments in the field of unit commitment problem based on many published articles and web-sites. Here, it is attempted to perform a comprehensive survey of research done in the area of unit commitment using various methodologies and techniques. This may be a helpful tool for the researchers, scientists or investigators working in the area of unit commitment.

Key words: Unit Commitment Problem (UCP), Dynamic Programming (DP), Lagrangian Relaxation (LR), techniques, investigators, India

INTRODUCTION

In the present contentious era of the power system operation, one of the most challenging jobs is to decide which electricity generation units should run in each period so as to satisfy a predictably varying demand for electricity. The problem is interesting because in a typical electrical system, there are a variety of units available for generating electricity and each unit has its own characteristics. Such type of decisions and actions are made under the section unit commitment.

Unit Commitment Problem (UCP) adverts to the task of finding an optimal schedule and a production level for each generating unit over a given period of time. The unit commitment decision indicates which generating units are to be in use at each point in time over a scheduling horizon (Muckstadt and Koenig, 1977; Takriti *et al.*, 1995). An important criterion in power system operation is to meet the load demand at least possible fuel cost using an amalgamate of different power plants. Furthermore, in order to supply high quality electric power to customers in a fastened and economical manner, thermal unit commitment is considered to be one of the best available options. The planning of the committed generating units generally for a time period of 1 or 2 days to 2 weeks split down in a periods of 1 h. The committed units should satisfy the forecasted system load and reserve requirements at minimal operating cost, subject to a large set of other system, technological and environmental constraints (Viana *et al.*, 2001). Also, the available and committed generating units should be able to supply the peak demands as well as the seasonal demands. At one

extreme, a nuclear power unit can provide electricity at a very low incremental cost for each additional megawatt hour of energy but it has both a high cost of starting up again once it has been shut down and it takes awhile to bring it back up to full power. A typical nuclear unit may be shut down only in the Spring or Autumn when there is very little heating or air-conditioning demand so demand is lowest. At the other extreme, a gas turbine generator can be started up in a few minutes. However, its incremental cost per megawatt hour is much more expensive (Wood and Wollenberg, 1996). Similarly, the limited amount of hydro-electric energy stored in the dams and the system reservoirs may not prove to be sufficient to respond to high demands. Therefore, costly thermal generating-units are often used to make up for the supply shortage (Sen and Kothari, 1998). Since, generators cannot instantly turn on and produce power, unit commitment must be planned in advance so that enough generation is always available to handle system demand with an adequate reserve margin in the event that generators or transmission lines go out or load demand increases. The start up and shut down processes are considered in the post-processing step performed after the UC calculation (Park *et al.*, 2000a, b). In case of the worse load forecast, the deviation of the conventional UC solution can be overcome with the lower load level and the more hourly reserve requirements (Park *et al.*, 2000a, b). Several conventional methods are available to solve the UCP. But all these methods need the exact mathematical model of the system and there may be a chance of bog down at the local optimum (Kadam *et al.*, 2009).

PRIORITY LIST METHOD

The simplest unit commitment solution is to list all combinations of units on and off as well as the corresponding total cost to create a rank list and then make the decision according to the rank table. This method is called the priority list (Ivey, 1999). The generation of initial solution is important, particularly for the UC problem. The initial solution is usually generated at random. However, this technique is difficult to get a feasible solution for the UC problem with many constraints, resulting in the quality of solution obtained being unsatisfactory (Senjyu *et al.*, 2003; Srinivasan and Chazelas, 2004; Mori and Matsuzaki, 2001). The priority list method is an efficient method to overcome this problem. This method is simple and requires short computing time and small computer memory (Tingfan and Ting, 2008). However, the UC solution obtained from the priority list method may not be the optimal schedule because start-up cost and ramp rate constraints are not included in determining the priority commitment order and AFLC does not adequately reflect the operating cost of generating units when they do not operate at the full load (Tseng, 1996; Lee, 1989; Lee and Feng, 1992).

Researchers proposed a methodological priority list method which is simple and more efficient than conventional priority list method and incorporates more intelligent strategy with priority list as the backbone. The solutions obtained by Methodology Priority List Method are deterministic (Tingfang and Ting, 2008; Tseng, 1996; Lee, 1989; Ting *et al.*, 2006; Rajan and Mohan, 2004; Zhuang and Galiana, 1988). The simplicity of the MPL and fast calculation of ED leads to a methodological and competent method in comparison with conventional method (Pang *et al.*, 1981a). Burns and Gibson (1975) proposed a dynamic priority list that varies with the system demand.

DYNAMIC PROGRAMMING METHOD

The Dynamic Programming algorithm (DP) has proven to be one of the successful approaches to unit commitment. Due to the enumerative nature of the method, dynamic programming suffers from a long processing time that expands exponentially with the size of the problem and soon reaches a level that is practically impossible to compute. Therefore, in practice many heuristic strategies have been introduced to limit the dynamic search for a large system (Ouyang and Shahidehpour, 1991). Ouyang and Shahidehpour (1991) proposed the DP-TC algorithm and employed various

heuristic strategies in the paper. Finally, experimental results are presented which support the methodology by utilizing a much smaller execution time while preserving the quality of the optimization. According to Bosch and Honderd (1985), a large scale scheduling problem is decomposed into a series of overlapping sub-problems and each sub-problem is solved by dynamic programming. One of the algorithm proposed by Pang and Chen (1976) and Pang *et al.* (1981b) known as DP-SC uses a strict priority list search sequence to reduce the possible combinations at every stage. Another method by the researchers employs a fixed search window to truncate the priority list in which only the truncated combinations are evaluated. This method known as DP-TC performs much better than DP-SC as an optimizer; however it requires a much longer processing time.

LAGRANGIAN RELAXATION

LR has been successfully applied to the complex UC problem including various hard constraints (e.g., ramp rate constraints minimum up and down time etc.) (Bavafa *et al.*, 2009). However, ramping constraints in UC problem required enlarging state spaces dramatically for dynamic programming to solve each unit sub-problem (Peterson and Brammer, 1995). The total number of states was the sum of number of down states, number of ramp up states, number of up states and number of ramp down states (Wang and Shahidehpour, 1994).

Bavafa *et al.* (2009) proposed a hybrid Lagrangian Relaxation with Evolutionary Programming and Quadratic Programming (LREQP) for ramp Rate Constrained Unit commitment (RUC) problem. Researchers proposed that Lagrangian Relaxation (LR) is one of the most successful approaches (Svoboda *et al.*, 1997; Abdul-Rahman *et al.*, 1996; Guan *et al.*, 2003; Cohen and Sherkat, 1987). One of the most obvious advantages of the Lagrangian Relaxation Method is its quantitative measure of the solution quality since the cost of the dual function is a lower bound on the cost of the primal problem. For UC problems, the duality gap, the relative difference between the feasible cost and the dual cost is rather small, often with (1-2%).

This accuracy was considered sufficient for industrial applications before the emergence of wholesale competitive energy markets (Ferreira *et al.*, 1989; Guan *et al.*, 1997; Shaw, 1995; Baldick, 1995). Poommalee and Damrongkulkamjorn (2008) obtained the Unit Commitment considering Security-Constrained Optimal Power Flow (UC-SCOPF) by using Lagrangian Relaxation with Genetic Algorithm (LRGA).

GENETIC ALGORITHMS

Genetic Algorithms (GA) whose search is based on natural evolution are promising techniques for solving the difficult UC problem. GA can inherently deal with inequality constraints imposed on the control variables such as power limits, ramping rate and spinning reserve constraints (Li, 2000). Liao and Tsao (2002) presented a new approach, the hybrid genetic algorithm/fuzzy system and Tabu search for short-term thermal generating unit commitment. He discussed four improvement plans for the GA. The four improvements include:

- The improvement about regulate scale of fitness function
- The improvement in the selection items and reproduction strategy
- The crossover ratio and mutation ratio are from the fixed value change to be determined using Fuzzy System Method
- Importing the best local search method into the algorithm

Maojun and Tiaosheng (2001) proposed a gene complementary genetic algorithm for unit commitment and constructed three kinds of genetic operators. The results of experiment show that the algorithm proposed in this research is available for the UCP. Jalilzadeh and Pirhayati (2009) presented an Improved Genetic Algorithm (IGA) for UCP with lowest cost. A modified approach to the solution of unit commitment problem using genetic algorithms is proposed in this research. Improvement in cost and quality of solution is obtained. In order to obtain a near optimal solution in low computational time and storage requirements with respect to all specified constraints. Ademovic *et al.* (2010) presented a genetic algorithm using real-coded chromosomes in opposite to the more commonly used binary coded scheme.

SIMULATED ANNEALING

Simulated Annealing (SA) is a recent optimization technique proposed by Kirkpatrick *et al.* (1983) which simulate the annealing of metals. Annealing refers to the slow procedure of gradually cooling a metal until it reaches its freezing point where the energy of the system has acquired the globally minimal value (Zhuang and Galiana, 1990). Simopoulos and Contaxis (2004) proposed some new rules concerning the cooling schedule and the random generation of the initial solution of the system. The results obtained in system studies show the effectiveness of the proposed model and indicate the

need for further research in this area. Simopoulos *et al.* (2005) presented an enhanced SA algorithm for the solution of the short-term UC problem. The algorithm uses a simple cooling schedule while an effective approach for the random generation of the initial solution is implemented. Viana *et al.* (2001) proposed a resolution approach based on simulated annealing. The interest of developing code with modular programming languages like C++ has also been enlightened. Two coding schemes (a binary and an integer one) were presented and a particular attention was given to neighborhood structures and searching strategies (Viana *et al.*, 2001). Christopher and Rajan (2004) presented a new approach to solve the short term unit commitment problem using an evolutionary programming based simulated annealing method with cooling and banking constraints. The objective of this research was to find the generation scheduling such that the total operating cost can be minimized when subjected to a variety of constraints.

PARTICLE SWARM OPTIMIZATION

Sriyanyong and Song (2005) proposed Particle Swarm Optimization (PSO) combined with Lagrange Relaxation Method (LR) for solving UCP. The proposed approach employs PSO algorithm for optimal settings of lagrangian multipliers. The feasibility of the proposed method is demonstrated for four and ten unit systems, respectively. Xiong *et al.* (2008) presented a new strategy to produce particle which all of them are feasible solution enhanced the convergence speed and applied multi particle swarm to parallel arithmetic, escaped the local optimum solution. The simulation results show that the presented method is more efficient than genetic algorithm which could obtain the global optimum solution more probably. Jeong *et al.* (2009) presented a new binary particle swarm optimization based approach for solving the UC problems. To enhance the performance of the conventional BPSO, this research proposes a Quantum-inspired BPSO (QBPSO) which is based on the concept and principles of quantum computing such as a quantum bit and superposition of states. Ge (2010) proposed a new approach to solve Ramp rate constrained Unit Commitment (RUC) problem by improving the method of PSO, namely Improved Priority List and Enhanced Particle Swarm Optimization (IPL-EPSSO). The IPL-EPSSO proposed in this research is a combination of Improved Priority List (IPL) and Enhanced Particle Swarm Optimization (EPSSO) which decomposes UC problem into two sub-optimization problems and solves them, respectively (Ge, 2010).

TABU SEARCH METHOD

The Tabu Search (TS) algorithm is mainly used for solving combinatorial optimization problems. It is an iterative search algorithm, characterized by the use of a flexible memory. It is able to eliminate local minima and to search areas beyond a local minimum. The TS Method is also mainly used to solve simplified OPF problems such as unit commitment and reactive optimization problems. Rajan *et al.* (2002) proposed new Neural Based Tabu Search (NBTS) based algorithm for the unit commitment problem. The objective of this research was to find the generation scheduling such that the total operating cost can be minimized when subjected to a variety of constraints. The results show an improvement in the quality of obtained solutions compared with previous results. The successful implementation presented in this research highlights the importance of NBTS approach as a powerful tool for solving difficult combinatorial optimization problems. Rajan *et al.* (2003) developed an improved version of NBTS approach. They were able to find good UC schedules and their hypothesis was moved beyond doubt by the case study under consideration. It was shown that the results obtained from the proposed method were far superior to those obtained from conventional methods. Borghetti *et al.* (2001) suggested that to explore all of the feasible solution space, the meta-heuristic algorithm should occasionally accept the worse solution than the current one because the exploration of their neighborhood may lead to a better region and a better result. Once there is no better solution in the neighborhood of the current one, the Tabu search is terminated. There is no guarantee that the Tabu search will yield the global optimal result especially with large systems.

FUZZY LOGIC ALGORITHM

Saneifard *et al.* (2007) proposed that fuzzy logic is a mathematical theory which encompasses the idea of vagueness when defining a concept or a meaning. In this research, no attempt has been made to determine the optimality or the degree of optimality that can be obtained using fuzzy logic. The primary objective has been the demonstration that if the process of unit commitment can be described linguistically then such linguistic descriptions can be translated to a solution that yields similar results compared to dynamic programming. Kadam *et al.* (2009) described the application of fuzzy logic algorithm for determining short term commitment of thermal units in electrical power generation. The results obtained from fuzzy logic based approach were compared

with the priority list method solution to unit commitment problem. The comparison fuzzy logic based approach were powerful tools for solving such highly non-linear, multi constrained optimization problems in electrical power systems. This study attempts to find the best schedule from a set of good feasible commitment decisions.

Wang *et al.* (2011) used the fuzzy variable to more accurately describe the future power load while the fuzzy value at risk is employed as a technique to evaluate the power demand and reserve for each period. To handle the improved unit commitment problem, they proposed a Local Convergence Averse binary Particle Swarm Optimization (LCA-PSO) which overperforms existing algorithms (Wang *et al.*, 2011).

EVOLUTIONARY PROGRAMMING

Chen and Wang (2002) presented a conjunctive co-evolutionary algorithm for unit commitment. The proposed algorithm is a denotation of the conventional evolutionary programming which appears to have considerable potential for formulating and solving more complex problems by precisely modeling the convolution of cooperating species. Christober and Rajan (2004) used Evolutionary Programming (EP) method in conjunction with the Tabu search method. As indicated in the research, the EP algorithm has also proved to be an efficient tool for solving the important economic dispatch problem for units with non smooth fuel cost functions. Such functions may be included in the proposed EP search for practical problem solving. The main advantage of the proposed algorithm is speed. The EPTS approach avoids entrapping in local optimum solutions. Also, disadvantages of huge memory sizes required by the SA method are eliminated (Rajan and Mohan, 2004). Rajan (2006) presented a new approach to solve the short-term unit commitment problem using an evolutionary programming based Tabu search method with cooling and banking constraints. The objective of this research was to find the generation scheduling such that the total operating cost could be minimized when subjected to a variety of constraints (Christober and Rajan, 2004).

CONCLUSION

This study shows an introductory concept of various methodologies used to solve unit commitment problem in power system along with literature review of research on unit commitment problem. The research may help the new researchers expeditiously with a brief idea of power system unit commitment and various research studied may give a quick approach to the new researchers.

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