Review of Metaheuristic Optimization Methods for Unit Commitment in Power System Operation and Planning

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Abstract : Unit commitment (UC) is considered one of the essential activities in power system planning and operation. The complexity and non-linearity nature of the UC problem make metaheuristic optimizations techniques more relevant for their solutions. Apart from minimizing the operational cost, the increased public awareness regarding the harmful effects of atmospheric pollutants on the environment and other environmental regulations have led researchers to focus on environmental effect as another unit commitment objective function. This paper reviews some published research papers based on metaheuristic techniques considering their single and multi-objective functions. However, the practical, technical and economic importance of the unit commitment problem is proven by the enormous amount of the available literature for attaining their solutions.

Keywords : **Cost of Production, Hybrid Optimization, Metaheuristic Technique, Optimization, Unit Commitment.**

I. INTRODUCTION

Unit commitment (UC) problem is an important optimizing task for scheduling the on/off states of generating units with objective function usually of minimizing cost [1, 2]. The increased public awareness regarding the harmful effects of atmospheric pollutants on the environment, as well as the tightening of environmental regulations has led to another objective function of UC in minimizing the environmental effect. The carbon emissions produced by fossil-fueled thermal power plants need also to be minimized. It is necessary to consider these emissions as another objective [3]. A small improvement in the optimization like 0.5% would bring millions of dollars cost reduction per year for a large utility grid [4]. The unit commitment problem is considered as one of the key aspects in power system operation [5]. UC is a traditional mixed-integer non-convex problem and remains a key optimization task in power system scheduling [4]. The UC problem (UCP) consists of deciding which power generator units must be committed or decommitted in order to satisfy demand over a planning horizon. A short-term planning is generally split into periods of one hour each in [6, 7] with varying loads and generations under different generational, environmental and technical constraints [7]. The production levels at which units operate (pre-dispatch) must also be determined, and the committed units must generally satisfy the forecasted system load and reserve requirements, as well as a large set of technological constraints [8]. Therefore, UC plays a major role in the operation planning of power systems [6] including environmental concerns [3].

II. PREVIOUS RESEARCHES

Since increasing the number of generating units makes it difficult to solve in practice, many approaches have been introduced to solve the UC problem [1]. For the purpose of this writeup, metaheuristic optimization approach is reviewed. The approach of dealing with UC problems include the Binary Whale Optimization Algorithm (BWOA) [9], Binary Grey Wolf Optimizer (BGWO) algorithm [10], Grey Wolf Optimization (GWO) Algorithm [11], a Quantum Inspired Binary Grey Wolf Optimizer (QI-BGWO) [12], HYBRID-BAT search algorithm 10-unit system [13], an improved version of the Binary Quantum-Inspired Gravitational Search Algorithm (BQIGSA) and proposes a new approach to solve the UC problem based on the improved BQIGSA, called QGSA-UC. [1], a Hybrid Particle Swarm Optimization Approach With Small Population size (HPSO-SP) in [2], ‘‘local branching’’ and an hybridization of Particle Swarm Optimization (PSO) with a Mixed Integer Programming Solver [8], Binary Coded Modified Moth Flame Optimization Algorithm (BMMFOA) [5], Particle Swarm Optimization and Tabu Search algorithm [14], using Lagrangian Relaxation (LR) and PSO [15], deterministic method named Cut-And-Branch [6], Combination of proposed Weighted-Improved Crazy Particle Swarm Optimization with a Pseudo Code Based Algorithm and scenario analysis method [16], Genetic Algorithm (GA) or Dynamic Programming (DP) to solve UC and then Shuffled BAT (BAT) technique as an evolutionary based approach to solve the constrained Economic Load Dispatch (ELD) problem [17], an improved real-coded genetic algorithm and an enhanced Mixed Integer Linear Programming (MILP) [18], combinations of three algorithms including Charged Search System (CSS), PSO and Ants Colony Search (ACS) [19] and hybrid metaheuristic DEEPSO, which is combination of Differential Evolution (DE), Evolutionary Programming (EP) and PSO [20] metaheuristic approach combined with a non-dominated sorting known as Biased Random Key Genetic Algorithm [3, 21].

III. OVERVIEW OF UC ADVANCES USING METAHEURISTIC OPTIMIZATION

This section will present the review of research work with a metaheuristic technique and also hybrid optimization algorithms as used in solving unit commitment (UC) problem. These optimization algorithms provide solution methods for different types of single and multiple objective functions of the UC problem. Computing the production schedule is an essential problem in power system management today. The practical, technical and economic importance of the unit commitment problem is proven by the enormous amount of the available literature for attaining the solution in the past few decades. Unit commitment problem should be solved based on considering the ever-changing demands of the operational environments that are caused by technical and methodological advancements in the power system industry [22].

Metaheuristic technique

A metaheuristic approach known as the Binary Whale Optimization Algorithm (BWOA) is proposed to solve complex, constrained, non-convex, binary- nature Profit-Based Unit Commitment (PBUC) optimization problems of a price-taking generation company (GenCo) in the electricity market have been extensively discussed. To simulate the binary-nature PBUC problem, the continuous, real-value whale position/location is mapped into binary search space through various transfer functions. The effectiveness of the BWOA approaches is examined in test systems with different market mechanisms, i.e. an energy-only market, and energy and reserve market participation with different reserve payment methods. The simulation results are presented, discussed and compared with other existing approaches [9].

The environmental concerns are having a significant impact on the operation of power systems. The traditional UCP, which minimizes the total production costs is inadequate when environmental emissions need to be considered in the operation of power plants. The article proposes a metaheuristic approach combined with a non-dominated sorting procedure to find solutions for the multi-objective UCP [21]. Thus, Table 3.1 summarize some methods used in solving UC problem with their optimization techniques, objectives and contributions.

Table 3.1 Some metaheuristic methods used for solving UC problem

Reference	Optimization method	Objectives	Contribution
[9]	Binary Whale Optimization (BWO) Algorithm	Minimizing cost	Optimizing Profit-based UC (PBUC).
[12]	Quantum Inspired Binary Grey Wolf Optimizer (QI-BGWO)	UC problem	Solving UC problem using Meta-heuristic framework
[3]	Biased Random Key Genetic Algorithm	Multi-objective UC: Economic and Environmental Criteria	Addresses UC problems using multi-objective optimization
[10]	Binary Grey Wolf Optimizer (BGWO)	Cost minimization.	Optimal commitment schedule of thermal units
[1]	Binary Quantum-Inspired Gravitational Search Algorithm (BQIGSA)	Minimizing fuel cost	Solving UC problem by (BQIGSA)
[23]	Ant Lion Optimizer (ALO)	Minimizing the total operating cost, TOC of the overall power system scheduling period	Ant Lion Optimizer (ALO) for solving UC Problem
[24]	Improved Ant Colony Search Algorithm (ACA)	Minimizing system operating cost	Optimal UC by ACA
[25]	Harmony Search (HS) Algorithm	Minimizing system operating cost	Optimal UC by HS
[26]	Particle Swarm Optimization (PSO)	Minimizing cost, cost- emission	Determination of dynamic solution to UC Problem
[27]	Improved version of Shuffled Frog Leaping Algorithm (ISFLA)	Minimize the total operating cost through a generation scheduling	An Improved Shuffled Frog Leaping Algorithm (ISFLA) Approach for solving UC Problem
[28]	Shuffled Frog Leaping Algorithm (SFLA)	UC Problem	Optimizing UC Using SFLA.
[21]	Biased Random Key Genetic Algorithm	Multi-objective UC: Economic and Environmental Criteria	Metaheuristic approach combined with a non-dominated sorting procedure to find solutions for the multi-objective UC problem.

Hybrid Optimization Algorithm (HOA)

A novel parallel-series hybrid metaheuristic optimization method is proposed. The noble approach combines a hybrid topology binary particle swarm optimization, the self-adaptive differential evolution algorithm and a lambda iteration method, to simultaneously and intelligently determine the binary on/off status of each thermal unit, the generation power of online units, as well as the demand side management of plug-in electric vehicles. The proposed parallel-series hybrid method is first assessed on a

10-unit benchmark, and then on a case where renewable generation and smart PEV management are integrated. Numerical results confirm the superiority of the proposed new algorithm in comparison with some popular metaheuristic approaches [4]. Thus, Table 3.2 depicts some techniques used in solving UC problem using hybrid algorithm optimization.

Table 3.2 Some published work using Metaheuristic Hybrid Algorithm techniques for solving UC problems

Reference	Optimization method	Objectives	Contribution
[29]	Hybrid: Binary Successive Approach (BSA) and Civilized Swarm Optimization (CSO)	Maximizing profit-based unit commitment (PBUC) problem.	Profit based UC using hybrid optimization technique
[30]	Hybrid: Particle Swarm Optimization (PSO), Tabu Search (TS), and Lagrangian Relaxation (LR).	Reducing the production cost	Development of a proper UC scheduling of the production units
[4]	Hybrid topology: Binary Particle Swarm Optimization (BPSO), the Self-adaptive Differential Evolution algorithm (SDEA) and a Lambda Iteration Method (LIM)	Economic cost of power generations: fossil fuel cost, start-up cost	A novel hybrid metaheuristic method for solving a hybrid UC problem
[19]	Charged search system (CSS), particle swarm optimization (PSO), and ants colony Search (ACS)	Minimizing operating cost	Analysis and comparison of UC optimization.
[13]	Hybrid BAT-GA Optimisation	Minimizing fuel cost	Optimisation of Security Constrained UC Problem for 10-unit System
[2]	Hybrid Particle Swarm Optimization approach with Small Population size (HPSO-SP)	Minimizing the total fuel cost of thermal units	optimal short-term hydro-thermal UC.
[16]	Combination of weighted -improved crazy particle swarm optimization, pseudo code-based algorithm, scenario analysis method	Minimizing total thermal unit fuel cost subject to various constraints.	Clustering based UC with wind power uncertainty
[15]	Lagrangian Relaxation (LR) and Particle Swarm Optimization (PSO)	Reduce startup cost	Optimization of UC using LR and PSO.
[31]	Cuckoo Search Algorithm (CSO) and Levy Flights Algorithm (LFA).	Minimizing system operating cost	Optimization of UC using CSO and LFA.
[32]	Immune - Tabu Hybrid Algorithm	Thermal unit commitment (TUC)	Hybrid algorithm for thermal UC.

IV. CONCLUSION AND FUTURE SCOPE

This paper presents an appraisal of some published articles based on metaheuristic technique for solving UC problems in power system operation and planning. The optimization approaches used by researchers in this write-up have been briefly identified to provide the foundation for assessing the UC optimization approaches. However, various single and multiple objectives of UC problems that include profit-based UC, minimizing total operational cost, thermal UC problem reduction, economic and environmental criteria multi-objective functions were recorded from various articles. However, the practical, technical and financial importance of the UC problem is proven by the enormous amount of the available literature for attaining the solution in the past few decades; and more metaheuristic methods for solving UC problems are expected to evolve.

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