Renewable and Sustainable Energy Reviews 29 (2014) 911–923

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Mixed integer programming of multi-objective security-constrained hydro/thermal unit commitment

Mohammad Reza Norouzi [a], Abdollah Ahmadi [b,*], Ali Esmaeel Nezhad [b], Amir Ghaedi [c]

[a] Department of Electrical Engineering, Islamic Azad University, Lamerd Branch, Lamerd, Iran
[b] Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Fars 79681-15356, Iran
[c] Department of Electrical Engineering, Islamic Azad University, Dariun Branch, Shiraz, Iran

ARTICLE INFO

Article history:
Received 5 June 2013
Received in revised form
1 September 2013
Accepted 8 September 2013
Available online 8 October 2013

Keywords:
Security-constrained unit commitment
Mixed integer linear programming
Multi-objective optimization
Augmented ε-constraint method
Hydro units

ABSTRACT

This paper proposes a method for short term security-constrained unit commitment (SCUC) for hydro and thermal generation units. The SCUC problem is modeled as a multi-objective problem to concurrently minimize the ISO's cost as well as minimizing the emissions caused by thermal units. The non-linearity of valve loading effects is linearized in the presented problem. In order to model the SCUC problem more realistically, this paper considers the dynamic ramp rate of thermal units instead of the fixed rate. Moreover, multi-performance curves pertaining to hydro units are developed and the proposed SCUC problem includes the prohibited operating zones (POZs). Besides, the model of SCUC is transformed into mixed integer linear programming (MILP) instead of using mixed integer non-linear programming (MINLP) which has the capability to be solved efficiently using optimization software even for real size power systems. Pareto optimal solutions are generated by employing lexicographic optimization as well as hybrid augmented-weighted ε-constraint technique. Furthermore, a Fuzzy decision maker is utilized in this paper to determine the most preferred solution among Pareto optimal solutions derived through solving the proposed multi-objective SCUC problem. Eventually, the proposed model is implemented on modified IEEE 118-bus system comprising 54 thermal units and 8 hydro units. The simulation results reveal that the solutions obtained from the proposed technique in comparison with other methods established recently are superior in terms of total cost and emission output.

Contents

* Corresponding author. Tel.: +98 917 1688909; fax: +98 761 3333272.
E-mail addresses: ahmadi.abdollah.janah@gmail.com, ahmadi_janah@yahoomail.com (A. Ahmadi).

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.09.020

1. Introduction

In vertically integrated power systems, the goal of implementing unit commitment (UC) is optimizing energy sources in a way that the load demand is supplied with the least cost. Besides, if security criteria are included in the UC, then it is known as security-constrained unit commitment (SCUC). If the UC is performed by each of the generation companies (GENCOs) to optimize energy sources in a way that the GENCO's profit becomes maximized, it is called Price-Based Unit Commitment (PBUC) [1]. A MILP framework for the UC problem relating to thermal units is proposed in Ref. [2] in which fewer number of binary variables and constraints are needed compared to the models reviewed before leading to remarkable less computational burden. On the basis of the SCUC model presented in Ref. [3], an efficient AC corrective/preventive contingency dispatch comprising 24-h time period is proposed. A SCUC model considering energy and ancillary services auction is proposed in Ref. [4] which is applicable to reserve requirements optimization in electricity market framework by ISO. Ref. [5] has suggested a model having the capability to solve the coordinated generation and transmission maintenance scheduling with SCUC in which the scheduling period is weeks to months and decomposition of the optimization problem is performed using Lagrangian relaxation method. In Ref. [6], the intermittent and volatile wind power generation is included in the SCUC problem while Benders decomposition is employed to solve the problem. The problem of determining optimal response of a thermal unit along with a hydro GENCO to a spot electricity market is investigated in Refs. [7,8] in which the profit of the unit through participating in spot market to sell both energy and spinning reserve is set as the objective function to be maximized. The problem of short- hydrothermal scheduling is addressed in Ref. [9] utilizing Modified Differential Evolution (MDE) algorithm. Ref. [10] has proposed mid-term risk-constrained hydro-thermal scheduling problem in a stochastic framework for a GENCO that its objective is assigned to maximize payoffs as well as minimizing financial risks during its mid-term scheduling of thermal, cascaded hydro in addition to pumped-storage units. The act of determining the PBUC status for power generation companies is performed in Ref. [10] through solving self-scheduling problem prior to giving their bids to a day-ahead market. The proposed model is formulated as a deterministic optimization problem to maximize the profit exploiting 0/1 MILP technique. Ref. [11] has employed Improved Particle Swarm Optimization (IPSO) algorithm to solve the short-term hydrothermal scheduling problem in order to obtain the optimal power generation. The GENCO's arbitrage problem is taken into consideration in Ref. [12] utilizing stochastic PBUC while modeling the associated risks. The requirements of short term hydro-thermal scheduling (SHTS) problem are not met anymore after passage of the clean air act amendments in 1990 [13] and the emission issues must be unavoidably taken into account. Ref. [14] was one of the foremost work trying to solve the UC problem while emissions minimization had been taken into consideration as another objective function and the proposed problem was solved employing weighting method to make the two-objective problem a single-objective optimization problem. Unsupported efficient solutions cannot be generated by weighting method in multi-objective integer problems as well as MIP ones. The results derived from weighting method are highly dependent on the scaling of objective functions. Thus, objective functions should be scaled to a common scale prior to the weighted sum formation [15]. Multi-objective evolutionary algorithm is applied to the environmental/economic dispatch (EED) problem in Ref. [16] to simultaneously minimize the fuel cost as well as minimizing the emissions. Unlike weighting method needing large number of optimization problems to be solved, the suggested approach in Ref. [16] requires only a single run to trace the Pareto optimal front. Ref. [17] solves the stochastic multi-objective generation scheduling problem employing weight age pattern search methods while operating cost, NO_x and the risk caused by the variance of active as well as reactive power mismatch are set to be minimized concurrently and the proposed model is implemented on IEEE 11-bus system. The problem of minimizing cost, SO_2, CO_2, and NO_x is addressed in Ref. [18] using Non-Inferior Surface estimation method. The electric power dispatch is done in Ref. [19] employing a fuzzified multi-objective particle swarm optimization (MOPSO) algorithm while economic and environmental issues are all taken into consideration and the results derived from this technique is compared with those obtained from weighted sum method and evolutionary multi-objective optimization algorithms. Ref. [20] presents an interactive Fuzzy satisfying approach on the basis of evolutionary programming (EP) technique while the decision maker (DM) is supposed to have Fuzzy targets for each objective function; afterwards the corresponding Pareto optimal solution for the decision maker targets is generated by implementing the Fuzzy satisfying method based on the EP technique. A stochastic multi-objective framework is presented in Ref. [21] utilizing Fuzzy decision making wherein the tradeoff relation between conflicting objective functions is simulated by weighting method. ε-constraint is another multi-objective technique utilized in Ref. [22] to produce non-dominated solutions for thermal power dispatch with operating cost and emissions as objective functions that are assumed to be minimized; After that, the most preferred solution is determined for the proposed multi-objective problem by surrogate worth trade-off approach. In Refs. [23,24], the economic/emission load dispatch problem is formulated in the multi-objective framework and solved employing Hopfield neural networks and non-dominated sorting genetic algorithm (NSGA), respectively. Ref. [25] suggests MOPSO algorithm to solve the stochastic economic/emission load dispatch problem. The NSGA is utilized in Ref. [26] to generate the Pareto optimal front and the most compromise solution is selected by multi-attribute decision making method. The ε-constraint is applied to the multi-objective problem with objective functions of GENCO's profit to be minimized and emissions to be minimized in a day-ahead joint