Wind-Thermal Integrated Power System Scheduling Problem Using Cuckoo Search Algorithm

K. Chandrasekaran, Department of Electrical and Electronics Engineering, National Institute of Technology, Tiruchirappalli, India
Sishaj P. Simon, Department of Electrical and Electronics Engineering, National Institute of Technology, Tiruchirappalli, India

ABSTRACT

A new nature inspired metaheuristic algorithm known as the cuckoo search algorithm (CSA) is presented in this paper, to solve the unit commitment problem (UCP) for hybrid power system. The utilization of wind energy sources is increasing throughout the world. It is therefore important to develop the protocol for the integration of wind generation system with conventional thermal unit generation system. High wind penetration can lead to high-risk level in power system reliability. In order to maintain the system reliability, wind power dispatch is usually restricted and energy storage is considered for smoothing out the fluctuations. On solving UCP, the proposed binary coded CSA finds the ON/OFF status of the generating units while the economic dispatch problem (EDP) is solved using the real coded CSA. The proposed methodology is tested and validated on 3, 4, 9, 12, 38 and 100 unit systems for 24 hour scheduling horizon. The effectiveness of the proposed technique is demonstrated by comparing its performance with the other methods reported in the literature.

Keywords: Cuckoo Search Algorithm (CSA), Economic Dispatch Problem (EDP), Energy Storage, Hybrid Power System, Levy Flight Mechanism, Unit Commitment Problem (UCP)

1. INTRODUCTION

The unit commitment problem plays a major role in the economic operation of power system. The objective of UCP is to find an optimal status and dispatching of the generating units, so that the operating cost of the whole scheduling period can be minimized while satisfying the system and unit constraints. The past decade has seen a significant growth in wind power which is alternative to the conventional fuel-based resources. Because of the intermittent nature of the wind, wind power production cannot be controlled to the same extent as conventional generation, and this complicates the task of power system balancing. However, cost savings can be realized from the reduction of thermal plant commitment if part of the wind power can be counted toward “firm” energy resource. To aid in the system integration of wind power in to the thermal power system, management of reserve and reliability of the system must be investigated. An efficient wind power forecast techniques would allow the power industries
to utilize wind power and save some money. However, there must be a balance between these cost savings and the potential impact on system reliability.

Mathematically, the UC is a large-scale, non-convex, non-linear, mixed-integer optimization problem. The best solution to UCP can be obtained by complete enumeration, but the requirement of the excessive computational resource is impossible in practice. Several solution methods have been proposed to solve the UCP (Padhy, 2004), such as priority list (PL) (Happ et al., 1971; Baldwin et al., 1960), dynamic programming (DP) (Pang et al., 1981; Snyder et al., 1987), Lagrangian relaxation (LR) (Virmani et al., 1989; Aoki et al., 1989; Lee, 1989), genetic algorithm (GA) (Kazarlis et al., 1996; Rudolf & Bayreithner, 1999; Yang et al., 1997; Swarup & Yamashiro, 2002; Arroyo & Conejo, 2002; Damousis, 2004), particle swarm optimization (PSO) (Xiong et al., 2008; Papadakis & Erlich, 2008; Bajpai & Conejo, 2007; Saber, 2006a; Gaing, 2003; Ting et al., 2006), ant colony optimization (ACO) (Simon et al., 2006; Damousis et al., 2012), bacterial foraging (BF) (Javad et al., 2011) and artificial bee colony algorithm (ABC) (Chandrasekaran et al., 2012) are used. The PL method is fast but produces suboptimal solution which leads to higher operation costs. The DP method has the advantage of being able to solve problems of a variety of sizes. But it may lead to more mathematical complexity and increase in computation time, if the constraints are taken into consideration. The LR method is capable of solving large-scale UCPs within short execution times. It has the advantage of being easily modifiable to model characteristics of specific utilities and can be considered unit constraints relatively easy but it suffers from numerical convergence and the solution quality due to the dual nature of the algorithm is poor. Technique like GA, EP, SA, PSO, ACO, ABC and BF are able to obtain near optimal solution, for a large power system the computational time is quiet high. Though many techniques are developed to solve UCP, no technique has been accepted as the best so far. In this context, an attempt is made to solve UCP using a newly developed cuckoo search algorithm.

2. PROPOSED WORK

In this paper a new conceptual model is proposed to integrate the wind and energy storage battery with the thermal generation in the UCP. Due to the stochastic nature noticed during the integration of wind power and energy storage, the system becomes highly non-linear. Therefore newly developed heuristic cuckoo search algorithm (CSA) (Yang & Deb, 2009; Yang & Deb, 2010) is suitably implemented in the scheduling of generators. Two strategies based on spinning reserve allocation in UCP (deterministic criterion and probabilistic criterion) are carried out. Also this paper proposes the implementation of CSA to solve the UCP. Here, binary coded CSA is proposed to solve the UCP and the real-coded CSA is used to solve the EDP.

3. PROBLEM FORMULATION

Generally the UCP is solved with minimizing the total fuel cost. The fuel cost minimization problem is formulated as:

Minimize

\[
F_c = \sum_{i=1}^{H} \sum_{j=1}^{N} F_e(P_{i,j}) + \sum_{k=1}^{H} SC_k = \sum_{i=1}^{H} \sum_{j=1}^{N} \left( a_{i,j} P_{i,j} + b_{i,j} P_{i,j}^2 + c_{i,j} P_{i,j}^3 \right) I_{i,j} + \sum_{k=1}^{H} SC_k
\]

(1)

3.1. Problem Constraints

3.1.1. Power Balance Constraint

The sum of the total generated power and inverter output at each hour must be equal to the
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